

**Dynamic Connectedness, Optimal Hedging Strategy and Co-
movement amongst Energy, Gold, Technology, Green Bonds and
APEC Equity Markets: Global Crisis Implications**

Thesis Submitted for the Award of the Degree of

DOCTOR OF PHILOSOPHY

in

Commerce

By

Pankaj Kumar

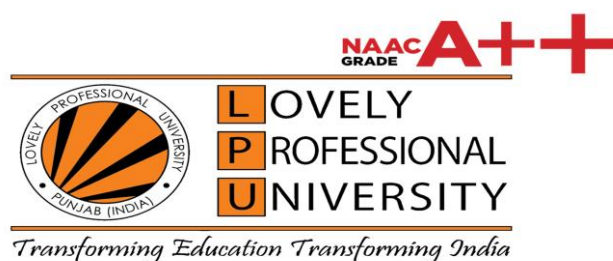
Registration Number: 42200061

Supervised By

Dr. Rupinder Katoch - 34530

(Professor)

Department of Commerce at Mittal School of Business

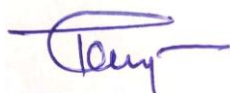


LOVELY PROFESSIONAL UNIVERSITY, PUNJAB

2026

DECLARATION

I, Pankaj Kumar, hereby declare that the thesis entitled " Dynamic Connectedness, Optimal Hedging Strategy and Co-movement amongst Energy, Gold, Technology, Green Bonds and APEC Equity Markets: Global Crisis Implications" submitted to the Lovely Professional University for the award of Degree of Doctor of Philosophy in Commerce, is an original research work carried out by me at Mittal School of Business in the Lovely Professional University during the period of 2022-25 under the supervision of Dr. Rupinder Katoch (Professor), Mittal School of Business, Lovely Professional University. Any extract to this research in part or as a whole has not been included, incorporated or added to any other work or similar title by any scholar in any other university.



(Signature of Scholar)

Name of the scholar: Pankaj Kumar

Registration No. 42200061

Department of Commerce

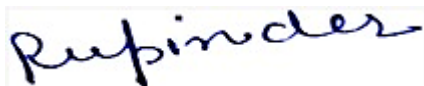
Mittal School of Business

Lovely Professional University,

Punjab, India

CERTIFICATE TO WHOM IT MAY CONCERN

I certify that Pankaj Kumar has prepared his thesis entitled " Dynamic Connectedness, Optimal Hedging Strategy and Co-movement amongst Energy, Gold, Technology, Green Bonds and APEC Equity Markets: Global Crisis Implications " for the award of PhD degree from Lovely Professional University under my guidance. He has carried out his work at Mittal School of Business, Lovely Professional University. Dr. Rupinder Katoch Professor (Finance) Mittal School of Business Lovely Professional University Phagwara, India.



Dr. Rupinder Katoch (34530),

Professor (Finance),

Department of Commerce

Mittal School of Business

Lovely Professional University,

Punjab, India

ACKNOWLEDGEMENT

I began my research journey with the blessings and guidance of my family, for which I am eternally grateful. I am deeply thankful to the Almighty for providing me with the strength and wisdom to overcome the challenges encountered along the way.

My heartfelt gratitude goes to my father, Mr. Sukh Ram; my mother, Mrs. Anita Devi; my beloved wife, Mrs. Rishu; my children, Yashita and Dakshit; and my entire family for their unconditional love, support, and encouragement. Their faith in me, sacrifices, and constant motivation have been the foundation of my success.

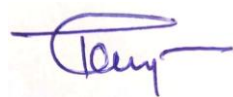
I would like to express my deepest appreciation to my research guide, Dr. Rupinder Katoch, whose expertise, mentorship, and guidance have been instrumental in the completion of this thesis. Her continuous support and insightful feedback have enriched my research and pushed me to strive for excellence. Her dedication to my growth as a scholar has been inspiring.

I am also grateful to my colleagues, whose constructive feedback and thoughtful discussions have enhanced my work. Their encouragement has been a constant source of strength and inspiration.

I wish to extend my sincere thanks to the various departments of Lovely Professional University, including the Central Library, Departmental Library, Administrative Section, and Academic Section, for their prompt assistance and support throughout the course of my research.

Lastly, I express my heartfelt thanks to all my friends, seniors, and well-wishers who have contributed in various ways to the successful completion of this thesis. Though I may not be able to mention everyone by name, I am thankful to all who have helped me along the way.

Pankaj Kumar



Date: 10.08.2026

ABSTRACT

This study investigates the dynamic interconnectedness, multivariate portfolios, and time–frequency co-movement between equity markets of 19 APEC countries and six major global asset classes—Green Bonds, Clean Energy, Crude Oil, Natural Gas, Gold, and Technology—over the period January 2015 to December 2024. Using a time-varying parameter vector autoregression (TVP-VAR) framework, the Total Connectedness Index (TCI) reveals substantial variation in global financial integration, with peaks above 80% during crisis episodes such as the 2024 Iran–Israel conflict, and troughs below 40% during the 2020 COVID-19 period. Crude oil emerged as the dominant net transmitter of volatility (NET = +13.92%), while Green Bonds (NET = –21.47%) and Gold (NET = –19.38%) acted as persistent receivers, indicating their susceptibility to external shocks. In contrast, Clean Energy (NET = –0.77%) and Natural Gas (NET = +1.18%) displayed near-neutral NET spillovers, highlighting their role as stable diversifiers across market regimes.

Portfolio optimization using Minimum Variance (MVP), Minimum Correlation (MCP), and Minimum Connectedness (MCoP) frameworks demonstrates varying effectiveness. The MVP showed the highest Sharpe Ratio (0.0306). In the MVP, Green Bond (42% weight) has a positive hedge effectiveness (HE = 0.59) and assists in mitigating risk, which leads to the highest Sharpe ratio and stability. Clean Energy (0.02%) has a very low allocation in the MVP, but a high hedge effectiveness (HE = 0.98), which means that it is a good risk-reducing asset even though it is low weighted. Technology (0.05%) also has a positive contribution with high hedge effectiveness (HE = 0.96) and provides significant diversification benefits. Conversely, the MCP and MCOP have a smaller allocation and negative hedge effectiveness of Green Bond, which results in a reduced risk reduction and increased volatility. Bivariate hedge analysis confirmed the positive hedging efficiency of Natural Gas, Crude Oil, Technology, Green Bonds and Gold across multiple markets.

Wavelet coherence analysis further uncovers time–frequency leadership patterns, confirming that Clean Energy and Gold consistently lead equity markets across various crises. Clean Energy exhibited widespread medium- and long-term coherence during climate and geopolitical events, particularly in Australia, China, and Vietnam. Gold acted as a leading indicator in most APEC markets during COVID-19 and war periods. Green Bonds led markets in countries such as Malaysia and New Zealand, reflecting their increasing

financialization during ESG transitions. Technology and Natural Gas displayed strategic medium-term leadership in APEC economies.

Overall, the integrated evidence supports a hybrid and dynamically adjusted asset allocation strategy. Assets with near-zero NET spillover and high hedge effectiveness—especially Clean Energy and Natural Gas—offer forward-looking diversification during volatile regimes. The results have critical implications for investors and policymakers in navigating geopolitical and energy-driven risks, advocating for adaptive portfolio structures and the use of multi-asset early warning indicators for enhanced financial resilience.

Contents

DECLARATION	II
CERTIFICATE TO WHOM IT MAY CONCERN	III
ACKNOWLEDGEMENT	IV
ABSTRACT	V
1. INTRODUCTION.....	2
1.1 AN OVERVIEW OF APEC ECONOMIES	3
1.2 ENERGY MARKETS	7
1.3 TECHNOLOGY	13
1.4 GREEN BONDS	16
1.5 GOLD	19
1.6. APEC ENERGY INVESTMENTS	21
1.7 APEC TECHNOLOGICAL DEVELOPMENTS	24
1.7 BASIC THEORIES ON FINANCIAL MARKET	28
1.7.1 EFFICIENT CAPITAL MARKET THEORY	29
1.7.2 THE EMH CATEGORIZES MARKET EFFICIENCY INTO THREE TYPES:.....	29
1.7.3 CAPITAL ASSET PRICING MODEL (CAPM)	30
1.7.4 THEORY OF INTERNATIONAL PORTFOLIO DIVERSIFICATION	31
1.8 TRENDS IN APEC STOCK EXCHANGES, TECHNOLOGY, GREEN FINANCE, AND GOLD PRICES	32
1.8.1 MALAYSIA INDEX	34
1.8.2 VIETNAM INDEX	35
1.8.3 SOUTH KOREA INDEX	36
1.8.4 JAPAN INDEX.....	36
1.8.5 U.S. INDEX	37
1.8.6 RUSSIA INDEX	37
1.8.7 THAILAND INDEX	38
1.8.8 INDONESIA INDEX	39
1.8.9 TAIWAN INDEX.....	39
1.8.10 NEW ZEALAND INDEX	40
1.8.11 PERU INDEX	41
1.8.12 CANADA INDEX.....	42
1.8.13 PHILIPPINES INDEX	43
1.8.14 GOLD INDEX.....	44
1.8.15 TECHNOLOGY INDEX (PRICE TREND).....	45
1.8.16 GREEN BOND INDEX (PRICE TREND).....	45
1.8.17 CLEAN ENERGY INDEX (PRICE TREND).....	46
1.9 CRISIS AND APEC'S RESPONSES: NAVIGATING THROUGH GLOBAL CHALLENGES	48
1.9.1 OIL CRISIS (2015-2016):.....	48
1.9.2 CLIMATE CRISIS (2017):	51
1.8.3. MEAN TEMPERATURES AND EXTREME HEAT DAYS	54
1.10 GREEN CREDIT MARKETS: FUNDING THE LOW-CARBON TRANSITION	59

1.10.1 GREEN LOANS AND GREEN BONDS.....	59
1.10.2 GREEN CREDIT AND FINANCIAL RISKS	60
1.10.3 ENCOURAGING THE GREEN CREDIT MARKETS.....	60
1.11 CONCLUSION: FUTURE OF CLIMATE-RESILIENT FINANCIAL MARKETS IN APEC.....	61
1.12 COVID-19 PANDEMIC (2020-2021):.....	62
1.13 RUSSIA-UKRAINE WAR (2022-2023):	65
1.14 IRAN-ISRAEL CONFLICT (2024):	67
1.15 SECTORAL INSIGHTS	70
1.16 SIGNIFICANCE OF STUDY	72
1.17 PROBLEM STATEMENT	72
1.17.1 RESEARCH GAP	73
1.18 CHAPTER PLAN	74
2. REVIEW OF LITERATURE	77
2.1 LITERATURE REVIEW ON DYNAMIC CONNECTEDNESS AMONG FINANCIAL MARKETS.....	77
2.1.1 DYNAMIC CONNECTEDNESS BETWEEN ENERGY AND EQUITY MARKET.....	78
2.1.2 DYNAMIC CONNECTEDNESS BETWEEN GREEN BONDS AND EQUITY MARKET	80
2.1.3 DYNAMIC CONNECTEDNESS AMONG TECHNOLOGY AND EQUITY MARKET	82
2.1.4 DYNAMIC CONNECTEDNESS BETWEEN GOLD AND EQUITY MARKET	83
2.1.5 DYNAMIC CONNECTEDNESS OF APEC EQUITY MARKETS.....	84
2.1.6 THE SPILLOVER OVER APEC EQUITY MARKETS: THE INFLUENCES OF REGIONAL INTEGRATION, GLOBAL EVENTS, AND INNOVATIONS IN FINANCES	86
2.2 BEST HEDGING STRATEGY	87
2.2.1 GREEN BOND SPILLOVER AS A HEDGE AGAINST EQUITY MARKET RISK.....	89
2.2.2 BEST HEDGING STRATEGY BETWEEN ENERGY AND EQUITY MARKETS.....	92
2.2.3 BEST HEDGING STRATEGY BETWEEN GREEN BONDS AND EQUITY MARKET	93
2.2.4 BEST HEDGING STRATEGY BETWEEN TECHNOLOGY AND EQUITY MARKET	95
2.2.5 BEST HEDGING STRATEGY BETWEEN GOLD AND EQUITY MARKET	96
2.2.6 BEST HEDGING STRATEGY BETWEEN APEC EQUITY MARKETS.....	97
2.3 CO-MOVEMENT.....	98
2.3.1. CO-MOVEMENT BETWEEN ENERGY AND EQUITY MARKET.....	100
2.3.2 GREEN BONDS AND EQUITY MARKET CO-MOVEMENT.....	102
2.3.3 TECHNOLOGY AND EQUITY MARKET CO-MOVEMENT	103
2.3.4 CO-MOVEMENT AMONG GOLD AND EQUITY MARKET	104
2.3.5 CO-MOVEMENT OF APEC EQUITY MARKETS.....	105
2.4 BIBLIOMETRIC ANALYSIS OF EQUITY AND ENERGY MARKETS SPILL OVERS	106
2.4.1 DATA COLLECTION	106
2.4.2 RESULTS OF THE DESCRIPTIVE ANALYSIS AND DISCUSSION	108
2.5 RESULTS OF NETWORK ANALYSIS AND DISCUSSION	127
2.5.1 ANALYSIS OF KEYWORD CO-OCCURRENCE NETWORK.....	127
2.6 BIBLIOMETRIC REVIEW: GREEN BONDS AND EQUITY MARKET SPILLOVERS.....	132
2.6.1 DATA COLLECTION	132
2.6.2 AVERAGE NUMBER CITATION PER YEAR.....	134
2.6.3 TOP 20 GLOBAL MOST CITED ARTICLES	136
2.6.4 TOP 20 GLOBALLY COLLABORATED COUNTRIES	140
2.6.5 TOP-20 MOST FREQUENT KEYWORDS	142
2.6.6 FACTORIAL ANALYSIS OVERVIEW:	146
2.7 BIBLIOMETRIC REVIEW: TECHNOLOGY MARKETS AND EQUITY MARKET SPILLOVERS	149
2.7.1 DATA COLLECTION	149

2.7.2 TOP 15 GLOBALLY MOST CITED ARTICLE	151
2.7.3 YEARLY FREQUENCY OF TOPICS (KEYWORDS)	155
2.7.4 MOST RELEVANT KEYWORDS/ MOST FREQUENT WORDS	156
2.7.5 KEYWORDS OCCURRENCE NETWORK CLUSTER	160
2.7.6 FACTORIAL ANALYSIS	161
2.8 CONCLUSION	164
3. RESEARCH METHODOLOGY	167
3.1 RESEARCH GAP.....	168
3.2 RESEARCH QUESTIONS??	169
3.3 NEED OF THE STUDY	169
3.4 RESEARCH OBJECTIVES	169
3.5 RESEARCH DESIGN AND DATA	170
3.5.1 ROBUSTNESS CHECKS:.....	173
3.6 EMPIRICAL MODELS	173
3.6.1 TVP-VAR BASED CONNECTEDNESS APPROACH	177
3.6.2 PORTFOLIO BACK-TESTING	179
3.6.3 HEDGING EFFECTIVENESS	181
3.6.4 WAVELET THEORY	182
3.7 MODEL ASSUMPTIONS AND LIMITATIONS.....	192
3.7.1 TVP-VAR CONNECTEDNESS FRAMEWORK	192
3.7.2 WAVELET COHERENCE ANALYSIS	193
3.7.3 PORTFOLIO OPTIMIZATION MODELS (MVP, MCP, MCoP)	193
3.7.4 DATA LIMITATIONS	193
4 RESULT ANALYSIS AND INTERPRETATION	196
4.1 OVERVIEW OF DESCRIPTIVE STATISTICS	196
4.2 CONNECTEDNESS ANALYSIS	201
4.2.1 DYNAMIC CONNECTEDNESS	202
4.2.2 DYNAMIC TOTAL CONNECTEDNESS	209
4.3 PORTFOLIOS	214
4.3.1 MINIMUM VARIANCE PORTFOLIO	217
4.3.2 MINIMUM CORRELATION PORTFOLIO	219
4.3.3 MINIMUM CONNECTEDNESS PORTFOLIO	221
4.4 PORTFOLIO ANALYSIS	222
4.4.1 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF CLEAN ENERGY WITH APEC	223
4.4.2 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF GREEN BOND/APEC	225
4.4.3 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF TECHNOLOGY/APEC	226
4.4.4 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF NATURAL GAS/APEC	226
4.4.5 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF CRUDE OIL/APEC	227
4.4.6 OPTIMAL BIVARIATE PORTFOLIO WEIGHTS OF GOLD/APEC	228
4.4.7 SHARPE RATIO	228
4.5 WAVELET ANALYSIS	230
4.5.1 WAVELET COHERENCE.....	230
4.5.2 PARTIAL WAVELET COHERENCE	265
4.5.3 WAVELET CORRELATION.....	289

5 SUMMARY, CONCLUSION AND SUGGESTIONS.....	321
5.1 STUDY OVERVIEW.....	321
5.1.1 CONNECTEDNESS APPROACH TVP-VAR	322
5.1.2 WAVELET ANALYSIS OF TIME-FREQUENCY CO-MOVEMENT	323
5.1.3 PORTFOLIO OPTIMIZATION MODELS: MVP, MCP AND MCoP	323
5.2 MAIN FINDINGS BY OBJECTIVES.....	324
5.2.1 DESCRIPTION OF DESCRIPTIVE STATISTICS AND IMPLICATIONS.....	324
5.2.2 OBJECTIVE 1: DYNAMIC CONNECTEDNESS.....	325
5.2.3 OBJECTIVE 2: OPTIMAL HEDGING AND PORTFOLIO ALLOCATION.....	327
5.2.4 OBJECTIVE 3: WAVELET COHERENCE	330
5.3 POLICY IMPLICATIONS AND INVESTOR ADVICE BASED ON OPTIMAL PORTFOLIO STRATEGIES AND RELATED FINDINGS.....	339
5.3.1 IMPLICATIONS FOR INSTITUTIONAL INVESTORS AND PORTFOLIO MANAGERS	339
5.3.2 IMPLICATIONS FOR REGULATORY BODIES AND POLICYMAKERS	340
5.3.3 IMPLICATIONS FOR SUSTAINABLE FINANCE AND ESG POLICY	340
5.4 THEORETICAL CONTRIBUTIONS OF THE STUDY	341
5.4.1 THEORETICAL CONTRIBUTION 1 (TC-1) EXTENSION OF TVP-VAR CONNECTEDNESS TO A MULTI-ASSET, MULTI-CRISIS APEC FRAMEWORK.....	341
5.4.2 THEORETICAL CONTRIBUTION 2 (TC-2) FIRST INTEGRATION OF GREEN BONDS INTO THE MINIMUM CONNECTEDNESS PORTFOLIO FOR APEC CRISIS-PERIOD ANALYSIS.....	342
5.4.3 THEORETICAL CONTRIBUTION 3 (TC-3) FREQUENCY-DOMAIN EXTENSION OF INTERNATIONAL PORTFOLIO DIVERSIFICATION THEORY TO 19 APEC MARKETS	342
5.5 LIMITATIONS.....	342
5.6 FUTURE RESEARCH DIRECTIONS	343
REFERENCES:.....	344

LIST OF TABLES

Table No.	Table Title	Page No.
Chapter 1 Tables (Introduction)		
1.1	APEC (Asia-Pacific Economic Cooperation) region has witnessed substantial economic	4
1.2	Changes in temperature related variables in baseline scenario of APEC countries.	55
Chapter 2 Tables (Review of Literature)		
2.1	Top 20 most relevant journals	110
2.2	Top 20 most productive scholars.	111
2.3	Institutions with more than 10 publications	111
2.4	Top 20 contributing countries.	112
2.5	Top 20 frequent keywords in the Dynamic Connectedness, Optimal Hedging Strategy and Co-movement research.	113
2.6	Top 50 article globally cited	114
2.7	Words cluster	128
2.8	Average citation per year	133
2.9	Top 20 global most cited articles	135
2.10	Top 20 Globally Collaborated Countries	140
2.11	Top-20 Most Frequent Keywords	142
2.12	Top 15 Globally Most Cited Article	151
2.13	Yearly Frequency of Topics (Keywords)	155
2.14	Most Relevant Keywords/ Most Frequent Words	156
Chapter 3 Tables (Research Methodology)		
3.1	List of variables APEC Countries and Green Bonds, Energy, Commodity and technology	171
3.2	Events Covered in this this study	171
3.3	Objective-wise Methodology (Models for achieving objectives)	175
Chapter 4 Tables (Result Analysis and Interpretation)		
4.1	Summary Statistics	197
4.2	Dynamic Connectedness	205

4.3	Investor Takeaways from Connectedness	207
4.3.1	Consolidated Summary of Key Empirical Findings	212
4.4	Dynamic Multivariate Portfolio Weights: Results are based on the time varying variance-covariance retrieved from the TVP-VAR (0.99,0.99) with one lag.	216
4.5	Minimum Correlation Portfolio	219
4.6	Minimum Connectedness Portfolio	220
4.7	Optimal bivariate portfolio weights of Clean Energy/APEC	223
4.8	Optimal bivariate portfolio weights of Green Bond/APEC	224
4.9	Optimal bivariate portfolio weights of Technology/APEC	225
4.10	Optimal bivariate portfolio weights of Natural Gas/APEC	226
4.11	Optimal bivariate portfolio weights of Crude Oil/APEC	227
4.12	Optimal bivariate portfolio weights of Gold/APEC	227
4.13	Sharpe Ratio	228
4.14	Summary Table Wavelet coherence between Gold and APEC	238
4.15	Summary Table Wavelet coherence between Natural Gas and APEC	243
4.16	Summary Table Wavelet coherence between Green Bonds and APEC	248
4.17	Summary Table Wavelet coherence between Technology and APEC	253
4.18	Summary Table Wavelet coherence between Clean Energy and APEC	258
4.19	Summary Table Wavelet coherence between Crude Oil and APEC	263
4.20	Summary of the results of the APEC Stock Market and Clean Energy	292
4.21	Summary of the wavelet correlation with APEC Stock Market and Crude Oil.	297
4.22	Summary of the wavelet correlation with APEC Stock Market and Green Bond.	302
4.23	Summary of the wavelet correlation with APEC Stock Market and Gold.	307

4.24	Summary of the wavelet correlation with APEC Stock Market and Natural Gas.	312
4.25	Summary of the wavelet correlation with APEC Stock Market and Technology.	318
Chapter 5 Tables (Summary, Conclusion and Suggestions)		
5.1	Comparative Portfolio Performance and Suitability	329
5.2	Gold as a Leading Indicator for APEC Equity Markets During Global Crises	331
5.3	Natural Gas Leading APEC Equity Market Movements by Crisis	332
5.4	Green Bonds Leading APEC Equity Index Movements Across Global Shock Periods	333
5.5	Technology Sector as a Predictor of APEC Equity Market Dynamics During Crisis Episodes	334
5.6	Clean Energy as a Structural Lead Asset for APEC Equity Markets Across Major Crises	335

LIST OF FIGURES

Figure No.	Figure Title	Page No.
Chapter 1 Figures (Introduction)		
1.1	Global energy investment in clean energy and in fossil fuels, 2015-2023	12
1.2	Increase in annual clean energy investment in selected countries and regions, 2019-2023.	12
1.3	Green Bonds market divided in regions	16
1.4	The global green bonds market was valued at \$582.6 billion in 2023, and is projected to reach \$1,555.1 billion by 2033, growing at a CAGR of 10.1% from 2024 to 2033.	16
1.5	Additional annual investment in the energy system needed per year as % of GDP compared to baseline	24
1.6	Malaysia FBMKLCI Index price trends 2015 to 2024.	32
1.7	Vietnam IDFPVNPD Index price trends 2015 to 2024.	32
1.8	South Korea KR30 Index price trends 2015 to 2024.	32
1.9	Japan SPJ500 Index price trends 2015 to 2024.	32
1.10	U.S. USSPX Index price trends 2015 to 2024.	33
1.11	Russia IMOEX Index price trends 2015 to 2024.	33
1.12	Thailand SBBCTLU Index price trends 2015 to 2024.	33
1.13	Indonesia SBBCIDU Index price trends 2015 to 2024.	33
1.14	Taiwan SBBCTAU Index price trends 2015 to 2024.	33
1.15	New Zealand SBPCNZU Index price trends 2015 to 2024.	33
1.16	Peru SBPCPEU Index price trends 2015 to 2024.	33
1.17	Canada SBBCCAU Index price trends 2015 to 2024.	33
1.18	Philippines SBBCPHU Index price trends 2015 to 2024.	34
1.19	Gold S&P SPGSGC Index price trends 2015 to 2024.	34
1.20	Technology Dow Jones Global Technology Index W1TEC Index	34

	price trends 2015 to 2024.	
1.21	Green Bonds S&P SPGRBND Index price trends 2015 to 2024.	34
1.22	Clean Energy S&P SPGTCSUP Index price trends 2015 to 2024.	34
1.23	Oil price trends 2011 to 2016	34
1.24	Country Level Temperature Change, Baseline	54
Chapter 2 Figures (Review Of Literature)		
2.1	Year-wise annual production of energy-equity market nexus research	107
2.2	Top 10 most relevant journals	109
2.3	keyword co-occurrence network analysis	130
2.4	Top 10 most relevant words	141
2.5	Words Cloud	144
2.6	Tree map of words	145
2.7	keyword co-occurrence network analysis	146
2.8	Factorial Analysis overall structure of the data keywords clusters	147
2.9	(Hierarchical Clustering), hierarchical relationships diagram	148
2.10	Word cloud network	158
2.11	Keywords occurrence Network Cluster	160
2.12	The network visualization of co-citation cluster	161
2.13	Factorial Analysis overall structure of the data keywords clusters	164
2.14	(Hierarchical Clustering), hierarchical relationships diagram	164
Chapter 3 Figures (Research Methodology)		
3.1	Bird Eye view of Research Methodology	168
3.2	APEC Member Economies.	170
3.3	Empirical Framework Graphical re-presentation of Study Methodology and Variables and Major Crisis (Events)	174
3.4	Graphical re-presentation of models used in the study on R studio.	176
Chapter 4 Figures (Result Analysis and Interpretation)		
4.1	Graphical Presentation of standardized time series data	198
4.2	Graphical Presentation of Log returns	199
4.3	Unconditional Correlations	201

4.4	Network of Connectedness	208
4.5	Dynamic Total Connectedness: Results are based on a TVPVAR (0.99,0.99) model with lag length of order 1 (BIC) and a 20-step-ahead forecast.	208
4.6	FROM Spillover, (2016-2024)	210
4.7	TO Spillover, (2016-2024)	211
4.8	NET Spillover, (2016-2024)	212
4.9	Time-Varying Portfolio Weights of TVP-VAR(0.99, 0.99) with MVP, MCP, and MCoP Strategies	215
4.10	Wavelet Coherence between Gold and APEC	234
4.11	Wavelet Coherence between Natural Gas and APEC	239
4.12	Wavelet Coherence between Green Bonds and APEC	244
4.13	Wavelet Coherence between Technology and APEC	249
4.14	Wavelet Coherence between Clean Energy and APEC	254
4.15	Wavelet Coherence between Crude Oil and APEC	259
4.16	PWC between Crude Oil and APEC	266
4.17	PWC between Natural Gas and APEC	271
4.18	PWC between Technology and APEC	275
4.19	PWC between Green Bonds and APEC	279
4.20	PWC between Clean Energy and APEC	283
4.21	PWC between Gold and APEC	286
4.22	Wavelet correlation between the APEC stock markets and clean energy	289
4.23	Wavelet correlation countrywide relationship with crude oil	294
4.24	Wavelet correlation countrywide relationship with green bonds	299
4.25	Wavelet correlation countrywide relationship with gold	304
4.26	Wavelet correlation countrywide relationship with Natural Gas	309
4.27	Wavelet correlation Stock Market countrywide relationship with Technology stocks	314

Chapter 1

This chapter provides an in-depth explanation of the dynamic growth climate in the APEC economies that have become potential global investment destinations due to sustainable finance, technological development, and strong economic performance. It discusses the fast growth of the green bonds market and the growing stream of climate finance, which is the focus of financing clean energy and environmentally friendly projects in the region. The chapter also looks at the changing global and APEC energy markets whereby more investments are being done in renewable energy which is an indication of a move towards low-carbon economies. The industries are changing due to technological changes, especially in the areas of AI, digital infrastructure, and supply chain innovation, which are the economic change drivers in APEC. In addition to this, the chapter also examines the new regulatory and ethical issues, and also examines the pricing trends in APEC stock markets, energy commodities, gold, and green finance and technology indices. Overall, the chapter is an indication of the sustainability, innovation, and economic resilience that characterizes the strategic significance of the APEC region in the global economy.

1. Introduction

The global markets have been linked as economic activities become more interdependent. Financial liberalization has become a major trend and this has resulted in unprecedented integration of international financial systems (Fang & Ju, 2024). The liberalization of capital, financial regulatory reforms, and the development of information technology have greatly increased the interconnectedness of international financial markets, and a literature on financial market spillover effects has emerged (Jones & Knaack, 2019). The type of financial market connectedness is something that one should be aware of especially when it comes to inter-market information flows and risk transmission since extreme movements in returns or

abnormal risk behavior is usually associated with the occurrence and transmission of financial crises. In this respect, financial market connectedness offers useful information on systemic risk, which is not limited to the weaknesses of individual markets (Henriques & Sadorsky, 2024). Thus, effective monitoring of financial markets and enhancement of economic integration requires a good understanding of this interconnectedness. APEC initiative has played a significant role in promoting economic cooperation in the Asia-Pacific region, especially in promoting international trade and regional connectivity (Noor, 2012). As economic integration among member economies has progressed, especially following the Global Financial Crisis (GFC), APEC economies have become increasingly interconnected not only within the region but also with the rest of the global dynamics (APEC, 2023). This is characterized by increased sensitivity and responsiveness to global forces like energy price volatility, technological innovation, climate change effects and changes in sustainable finance, which are all redefining policy agendas and economic policies in the Pacific Rim.

1.1 An Overview of APEC Economies

Asia-Pacific Economic Cooperation (APEC) is a large inter-governmental organization that consists of 21 member economies along the Pacific Rim that was formed in 1989 to achieve free trade and economic cooperation in the Asia-Pacific region (APEC, 2024). The organization began with twelve founding economies Australia, Brunei Darussalam, Canada, Indonesia, Japan, South Korea, Malaysia, New Zealand, the Philippines, Singapore, Thailand, and the United States. Over time, membership expanded to include China, Hong Kong, Taiwan, Mexico, Papua New Guinea, Chile, Peru, Russia, and Vietnam, bringing the total to twenty-one member economies. The concept of APEC was to react to the growing economic interdependence of the economics within the Asia-Pacific and to liberalize the markets to the agricultural and raw material export past Europe which had already been accomplished by the success of the post-ministerial conferences of the ASEAN. One of the most potent multi-lateral groups in the world based in Singapore, consisting of both the developing and developed economies, is to enhance inclusive and sustainable economic growth through the formation of APEC (OECD, 2005). This has enabled it to be flexible as it makes a difference to global economic governance by its own uniquely in that it is voluntary and non-binding in nature of cooperation.

The milestones in institutional development by APEC have been the adoption of the Bogor Goals in 1994 that sought to have the goal of achieving free and open trade and investment

by 2020 and 2010 by the developed and the developing members respectively (ERIA, 2023). Over the years, APEC has become more than a trade and investment organization to a great generator of innovation, sustainability and inclusive development. It also plays host to APEC Economic Leaders Meeting once a year, where the heads of member governments or their representatives meet, and goes to a different host economy with every meeting often involving a cultural exchange. APEC also established the APEC Business Advisory Council (ABAC), wherein the views of the business sector are sought and it collaborates with other global partners such as the Joint Organisations Data Initiative (JODI) to improve the transparency of energy data. APEC can be said to be one of the most significant contributors to economic policy of the most dynamic region of the world which actively contributes to such spheres as digital economy, climate change, and green finance.

In the present time, the APEC region has close to 40 percent world population, nearly 50 percent world trade and approximately 60 percent world GDP (Fang & Ju, 2024). In 2023, more than 60 percent of U.S. exports of goods (\$1.6 trillion) were to members of the APEC, and seven of the top ten United States trading partners are members of the APEC (Magazzino et al., 2022). These exports support almost seven million American jobs. As of 2022, APEC economies had contributed 1.5 trillion dollars of investments in America where 2.3 million American had been employed (Kurihara, 2003).

Table 1.1 APEC (Asia-Pacific Economic Cooperation) region has witnessed substantial economic

	2019	2020	2021	2022	2023
Total Population (in thousands)	25,334.8	25,649.2	25,685.4	26,014.4	26,638.5
Population Growth Rate (annual %)	1.5	1.2	0.1	1.3	2.4
GDP, Constant 2015 USD (in millions)	1,494,773.4	1,489,770.6	1,521,232.0	1,586,172.6	1,634,027.2
GDP Growth Rate (annual %)	2.2	-0.3	2.1	4.3	3.0
Consumer Prices (annual %)	1.6	0.8	2.9	6.6	5.6
Unemployment Rate, Total (% of total labor force)	5.2	6.5	5.1	3.7	3.7

Value Added, Agriculture (% of GDP)	2.1	2.0	2.3	2.7	2.6
Value Added, Industry (% of GDP)	25.3	25.4	25.4	27.5	27.7
Value Added, Services (% of GDP)	66.0	66.3	65.7	63.3	63.6
Exports of Merchandise Goods (in current USD millions)	271,005 .0	250,823 .0	344,864 .0	412,683 .0	371,278 .0
Exports of Commercial Services (in current USD millions)	69,874. 0	48,840. 0	44,020. 0	50,954. 0	73,068. 0
Imports of Merchandise Goods (in current USD millions)	221,564 .0	211,824 .0	261,165 .0	309,189 .0	287,406 .0
Imports of Commercial Services (in current USD millions)	70,503. 0	39,061. 0	40,184. 0	65,242. 0	82,436. 0
Internet Subscriptions, Broadband (per 100 inhabitants)	34.5	35.3	35.8	36.6	36.4

Source: www.apec.org

Table-1.1 indicates that the APEC (Asia-Pacific Economic Cooperation) region has experienced significant economic activity and growth in the last few years, which provides an attractive environment to investors. By 2023, the total population of APEC economies was about 2.97 billion people, and the population growth rate was stable at about 0.3 percent per year (APEC Secretariat, 2024). This population increase means an increase in the number of consumers, which leads to the demand of goods and services in the region. The APEC region has been found to be strong in its economic growth even during the tough times. The region was hit by a contraction in 2020 due to the global pandemic but rebounded in 2021 with a 6.1 percent growth. Subsequently, the growth was stabilized at 2.4 percent in 2022 and is projected to increase further at 3.3 percent in 2023. This slow recovery and expansion is a sign of a healthy economic environment and APEC is a good investment destination (Wiegand et al., 2024). The GDP of the region in 2023, expressed in constant 2015 USD, was about USD 56.6 trillion, which means that the economic activity was steadily increasing. This performance provides a good basis to future returns on investments and the different markets in the APEC economies have a lot of potentials to expand in the long run. The APEC economies remain in the world trade. The region exported merchandise goods to the tune of

USD 11.7 trillion in 2023, indicating the significance of the region in the global supply chain (A. San Andres et al., 2024). Although there are some fluctuations, this degree of export activity indicates the good trade relations and market demand of products of APEC economies, including industrial goods and services.

On the same note, the export of commercial services was about USD 2.7 trillion in 2023, which indicates an increase in the areas of technology, finance, and tourism, which are the main factors that attract investment opportunities (Press Information Bureau & Ministry of Commerce and Industry, 2025). This trade expansion can be of benefit to investors especially in areas where APEC economies have competitive advantages. The APEC economies are characterized by a wide range of sectoral contributions to GDP, with services being the leading sector, contributing approximately 64.9 percent of GDP in 2021 (Asia-Pacific Economic Cooperation, 2022). The industry sector came next at 28.1 percent and the agriculture sector added 3.7 percent to the GDP of the region (APEC, 2020). This economic diversification offers stability and opportunity to investors, who can invest in various industries depending on their interests, either in services (e.g., fintech, tech services) or industry (e.g., manufacturing, construction). The industries that are likely to grow in the next few years are technology and AI-driven industries, which are supported by a tech-savvy consumer base and government policies that encourage innovation.

The unemployment rate in the area has been relatively low, with a steady recovery after the COVID-19 pandemic, with the rate being around 3.9% in 2023 (U.S. Bureau of Labour Statistics, 2025). The labour market in the region is competitive, and the presence of a skilled workforce, especially in such areas as AI, IT, and digital technologies, can provide investors with access to talent pools in industries that are likely to grow in the future (Wang et al., 2024). Also, the young labor force in most of the APEC countries is a major growth driver of innovation and consumer demand, which makes APEC a favorable region to invest in technology and services.

Digital infrastructure is also growing at a high rate in the region. Broadband internet subscriptions per 100 inhabitants increased steadily, reaching 34.3 in 2023, indicating a growing adoption of digital technologies by the population (ITU , 2023; Trading Economics, 2025). This is a good indicator to investors in technology-related industries such as e-commerce, cloud computing, and digital services because it offers a good environment to companies that deal with internet-based products and services. The increase in broadband

penetration is an indication of the growing digital economy, with consumers being more connected, which presents a huge market of digital innovations, online platforms, and service providers (Yoo & Yi, 2022).

The APEC economies are well positioned in the key trade routes in the world and have well developed importation and exportation infrastructure. The region remains a center of both goods and services, with imports of merchandise goods and commercial services amounting to approximately USD 11.8 trillion and USD 2.7 trillion, respectively, in 2023 (The Economic Times, 2024). This trade flow is a great opportunity to investors in the logistics, warehousing and transportation industries, and also in technology-based logistics solutions to streamline the flow of goods.

There has been an increasing interest in APEC economies to create business-friendly environments through the adoption of favourable policies, such as digital trade agreements, stronger intellectual property protections, and regulatory reforms to promote innovation in fields like AI, fintech, and green technologies (Jones, 2023; Giulazian, 2021). The signing of Free Trade Agreements (FTA) and Digital Economy Agreements (DEA) of APEC countries shows how critical the cross-border collaboration and regulatory alleviation is strengthens the investment climate in the region (APEC, 2023).

Thus the APEC economies, which have a wide range of markets which are growing at a fast rate, strong trade connection and low rates of unemployment present a lively investment climate. It is an ambitious region, focused on innovation and the digital development and its population is expanding and diversifying its share in terms of GDP, so it is an excellent investment territory in almost all respects (Garcia & Landeros, 2020; Cugno et al., 2021). The opportunities that are offered by the development of AI technologies, online connectivity and diversification of industries in the APEC economies are numerous to the investors seeking exposure to the emerging economies with high rates of growth potential.

1.2 Energy markets

The energy market is examined in this study specifically because of its documented role as the dominant net transmitter of volatility ($NET = +13.92\%$) across APEC markets, making it the primary shock initiator in the multi-asset connectedness network investigated here. The reason behind the slow population growth has been owing to the world economic growth which has led to rise in demand of energy. It is within recent years that the effect of energy

consumption on the environment has been felt and most threatening has been air pollution and carbon emission since 1970 (Dincer, 2000). These enhanced environmental awareness have instituted two significant trends in energy industry. On the one hand, the establishment of emissions trading markets, the best-known of which is the Emissions Trading Scheme (ETS) of the European Union that is to limit the amount of carbon emissions through the mechanism of the market (Perthuis and Trotignon, 2014; Edenhofer, 2014). Second, there are more studies on renewable and clean energy sources that are available and can be realized as an alternative to the conventional fossil fuel (Jacobsson and Johnson, 2000). Such trends suggest greater shift towards sustainable energy practices on environmental concerns.

This has seen economists in the past few years calling on policy makers to action on sustainable energy sectors so as to curtail the negative effects of the air pollution as well as curtail the economic hazards of the fluctuation of oil prices (Bakhsh et al., 2024). Such suggestions rely on the existing population growth in the world and the growing demand of the fossil fuel. To a great extent, supply and demand shape the market of a commodity like oil that is sold on the global market. As a result, the rising demand of oil by the emerging economies and the possible limitation of oil supply are likely to increase the oil prices. This situation provides a powerful motivation to investors to find alternatives, which will speed up the transition to renewable energy sources (Durand-Lasserve & Pierru, 2021). The future of oil markets is still complicated, particularly in the near to medium term, since the nations that consume the most oil do not always have the biggest reserves of crude oil. Reports by Reuters attribute the fears of future oil shortages to the forecasts that the world oil demand will reach its peak by 2040, in line with the Hubbert Peak Theory (T. H. Jones & Willms, 2018). Previous estimates in 2004 indicated that the world oil production may reach its peak between 2016 and 2040, which underscores the uncertainty of long-term oil supply (Gallagher, 2010; Bardi, 2018).

To address these issues, most industrialized countries that are members of the International Atomic Energy Agency (IAEA) have developed strategic plans to increase their utilization of renewable energy sources (Kenn, 2020). In the last ten years, several studies have been conducted on the correlation between financial and economic factors and the development of renewable energy sectors. The economic shocks like pandemics, geopolitical tensions, and terrorist attacks- have led to unprecedented fluctuations in oil prices, which, in turn, have affected the investment trends in renewable energy in both developed and developing economies (Hoang et al., 2021; Magazzino et al., 2021; Horky et al., 2022). In addition, the

technological changes and capital market dynamics are critical in facilitating or discouraging investments in renewable energy. Such changing dynamics can motivate oil-exporting nations to lessen their reliance on oil income by investing in renewable energy. This change may be caused by the falling demand in the developing economies as well as the pressure on the oil prices. In most cases, it is believed that an increase in the price of fossil fuels will be beneficial to the alternative energy firms since an increase in the price of oil will increase the demand of renewable energy solutions (Ang et al., 2022; G. Wang et al., 2024). Nevertheless, empirical evidence on this relationship is scarce and there is still a lot of uncertainty regarding the sensitivity of the financial performance of renewable energy firms to changes in oil prices. Nevertheless, the incentive to transit to renewable sources of energy caused by the long-term price increase in oil could be called an important incentive (Maji et al., 2019; Christophers, 2021; Dorigoni & Anzalone, 2024).

Energy market plays an important role in the running of the economies, industries, transport and households in an international scale (FAO, 2000). It entails the production, distribution, and marketing of the sources of the energy such as oil, natural gas, coal and the renewables and the forces of supply and demand in world are some of the major forces that push in the price of energy. Energy markets are highly volatile and dynamic and they respond to several factors like geopolitical occurrences, changes in technology, government policies and climatic conditions (Tabash et al., 2024; Kuzemko et al., 2024). The price of energy is erratic and exposes or offers opportunity to the industries that use it as a resource. Other market trading mechanisms are the spot, future contracts and energy equity investment (Kim et al., 2024; Mensi et al., 2024).

The most significant energy commodity that is traded in the world and used in industrial applications, electricity generation, and transportation is crude oil, natural gas, coal, gasoline, and heating oil (Ahmad & Zhang, 2020). Crude oil is the most traded energy commodity that can be described as extremely sensitive to geopolitical tensions, OPEC decisions, and overall economic activity, and consequently, it is volatile as well as liquid (Zhang et al., 2023; Gong et al., 2020). Natural gas that is largely utilized in electricity and heating has the prices that depend on weather, storage and seasonal demand. Although currently, coal faces a consumption decline in some parts of the world due to environmental concerns, it retains its relevance in the developing ecosystems, and its trade is ongoing (Chen et al., 2023). One of the by-products of crude oil is gasoline and it is influenced by travelling trend and fuel efficiency. Similarly, heating oil, which is also a source of residential and commercial

heating, when used in the colder regions and, also experiences seasonal increase and decrease in the price and it is typically associated with the cost of crude oil (Devold & ABB Oil and Gas, 2013). The most traded energy commodity across the globe is crude oil, and transportation, plastics, and chemicals are major components of the commodity (Li et al., 2021). It is liquid and volatile since its price is highly sensitive to geopolitical issues, the policy of OPEC production, and economic cycles in general (Ikevuje et al., 2024). Natural gas on the other part is considered to be a clean power source and efficient in heating. It is frequently regionally priced and can vary with seasonal demand e.g. heating in winter or cooling in summer. Coal is a reliable and abundant source of energy, but its use is falling as the world turns to clean energy, though it is still a major source of energy in developing economies (Pouresmaieli et al., 2023).

Energy cost is subject to a number of interdependent factors with the most significant ones being the forces of supply and demand. A supply shock can cause sudden price volatility and this may be caused by geopolitical tensions, natural disasters, and dramatic changes in economic activity (Mac Kinnon et al., 2017). As an example, OPEC resolutions are very crucial in the process of setting the prices of crude oil in the global market because this body manipulates the production quotas to determine the supply. On the same note, geopolitical tensions like the conflict of oil-producing regions or sanctions on the key energy exporters may cause a substantial influence on the energy supply and consequently, the volatility of the market. Weather conditions also matter, cold winters imply a higher heating load and hot summers a higher electricity load to cool the air. The production and transportation of energy may be disrupted by natural disasters (hurricanes), which lead to a sharp shift in prices in the area. Market trends and long-term pricing are also affected by government policies on subsidies, renewable energy mandates, or carbon taxation, especially as countries move to cleaner energy sources (Mrabet et al., 2024; Z. Zhang et al., 2022).

Energy trading is associated with a number of risks, which are mainly caused by price fluctuations, geopolitical risks, and regulatory risks. The market is very sensitive and therefore the prices can change drastically hence energy trading is risky. Geopolitical shocks, like wars in major energy-producing areas, can lead to sudden shifts in energy prices. Regulatory risks are also important; e.g. changes in energy policies, e.g. the elimination of fossil fuel subsidies or the imposition of more stringent emissions standards, can cause sudden market fluctuations. In addition, weather effects, including extreme weather events or sudden seasonal variations, may interfere with energy production and consumption patterns,

increasing market volatility. Leverage is another risk that is often employed in energy trading to maximize the possible profits but also exposes the trader to the risk of significant losses in case the market moves contrary to the expectations.

The energy market is made up of a wide range of players, which include producers (oil and gas companies), refiners, utility providers, institutional investors, and speculators. These players trade to hedge risk, ensure energy supply or to make money out of market movements. Central banks, trading firms, and government agencies are also important, especially in terms of regulation and stabilization (Singh et al., 2024; Almeida et al., 2024). Retail traders may trade in energy markets via online platforms where they can trade futures contracts, ETFs or commodity-oriented funds, whereas institutional investors may trade over-the-counter (OTC) and long-term contracts with producers to trade bulk energy (Cludius et al., 2022; Gregersen & Ørmen, 2024).

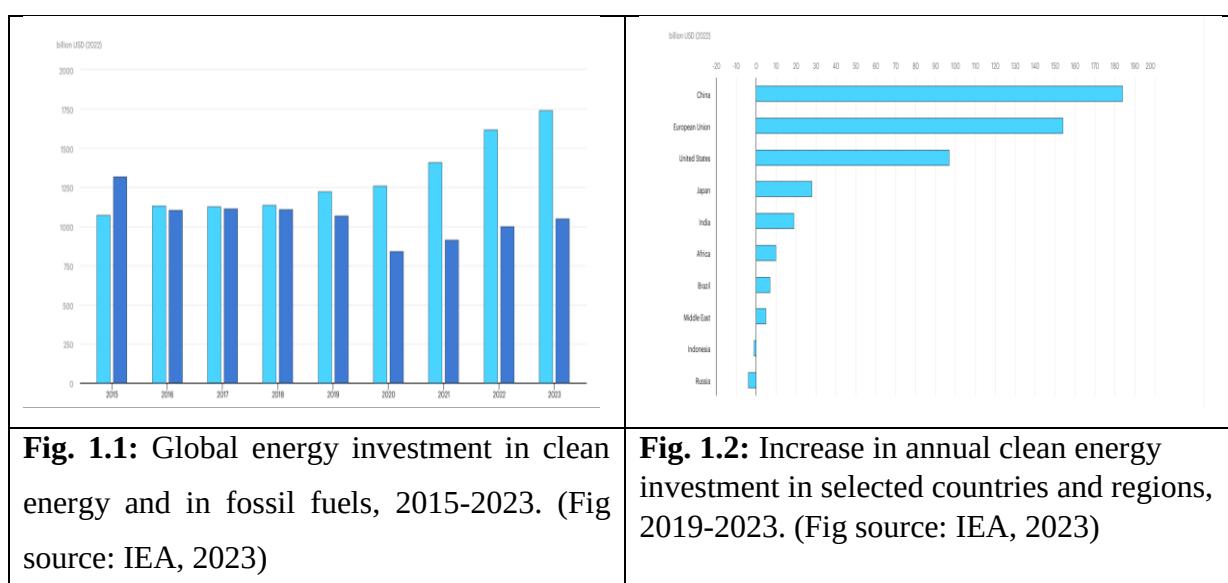
The main commodity exchanges where energy commodities are traded include NYMEX (New York Mercantile Exchange), ICE (Intercontinental Exchange), and MCX (Multi Commodity Exchange of India). Trading in futures contracts and options on crude oil, natural gas, and other energy products is possible on these platforms. These markets are available to retail investors through online trading platforms, providing them with an opportunity to trade in commodity futures and exchange-traded funds (ETFs). Large-scale trading is usually done by institutional traders who enter into OTC transactions and long-term contracts with energy producers (Rajesh & Nandini, 2023).

Energy stocks offer an investment in a vital industry that supports the world economy. Energy firms, both fossil-based and renewable energy, tend to produce consistent cash flows and dividends, which makes them appealing to long-term investors who want to grow and receive income. In addition, energy stocks provide inflation hedging and diversification opportunities, particularly as the world shifts to cleaner energy. The current transition to renewables (solar, wind, and electric vehicles (EVs)) has led to investment in clean energy technologies, which has opened up new opportunities to investors. It is estimated that USD 2.8 trillion will be invested in the energy sector in 2023, of which more than USD 1.7 trillion will be spent on clean energy projects, such as renewable power, nuclear energy, grid enhancements, and storage technology (IEA, 2023). Since 2021, investment in clean energy has increased dramatically due to a combination of high fossil fuel prices, robust government policy support (such as the US Inflation Reduction Act), and a more convergent set of climate

and energy security objectives. It is projected that solar power will have the highest investment in the energy sector with more than USD 380 billion being invested in solar energy in 2023 alone. Electric vehicle (EV) investment has also been on the rise, with the world sales of electric cars projected to grow by more than a third in 2023 (Gehlmann et al., 2024).

Nevertheless, there are still difficulties. The spending on fossil fuels still comprises a large part of the energy expenditure. As an example, it is estimated that USD 950 billion will be invested in fossil fuel supply in 2023, and a significant part of it will be spent on upstream oil and gas production (IEA, 2023). Although clean energy investment is increasing at a high rate, there is a fear of geographical imbalances in investment where most of the clean energy investments are in advanced economies and China (Krishnamurthy & Krishnamurthy, 2025). The developing nations, especially in Africa and some regions in Asia, are not keeping up with the investment in clean energy, mainly because of financial limitations, regulatory issues, and the lack of access to funds (Raihan et al., 2024).

In general, the energy market is one of the most active and important spheres of the world economy. The current shift towards cleaner energy sources, as well as the volatility of fossil fuel prices, is still defining investment opportunities in the sector (Farghali et al., 2023). With governments and industries adjusting to a new energy environment, energy commodities will continue to be in demand, which offers great opportunities to traders, investors, and energy producers (Lv, 2023). Nevertheless, the market is a complicated environment that needs to be approached with caution and consideration of geopolitical events, regulatory changes, and technological innovations that still influence energy prices and investment patterns.



1.3 Technology

The technology sector is included in this study as a major asset class whose digital ecosystem and global supply-chain linkages position it as a medium-term leader in APEC equity market co-movement, particularly during the COVID-19 period and the Russia-Ukraine War. The Fourth Industrial Revolution has led to a significant transformation in the way the world produces goods, shifting it away from traditional methods to new and technology-based methods (Moavenzadeh, 2015; Lin et al., 2017; Yang and Gu, 2021). The era is characterized by the increasing popularity of such advanced technologies as automation, artificial intelligence, the Internet of Things, and machine learning. The COVID-19 pandemic also accelerated the shift to online platforms and automation in various sectors. Consequently, not only has the business operation been significantly changed, but the character and orientation of global investment strategies have also been significantly altered (Filippi et al., 2023; Khan et al., 2024). Over the past few years, alternative asset classes and new investment opportunities as well as flexible risk management strategies have gained prominence (Huynh et al., 2020). These new or non-traditional assets have to be considered by the modern portfolio managers because they provide good portfolio diversification options.

Portfolio diversification has become a key issue as the financial markets continue to integrate (Attia et al., 2023). The current financial crisis and volatility have highlighted the importance of investors to take into account different options to reduce the risks and maximize the returns. In this regard, artificial intelligence (AI), robotics, and blockchain stock have been gaining much limelight as a promising portfolio diversifier against such concerns (Soori et al., 2023). Such technological industries have not only been found to be dynamic but have evolved to become as attractive in the levels they possess in terms of growth potential that gives an investor a chance of hedging against the traditional volatility of the market.

The emergence of the Fourth Industrial Revolution (FIR) where the creation and increase in the AI run robotics, blockchain, and other forms of digital technologies have witnessed the place of new asset classes to change the investment horizon. The firms dealing with AI and robotics are increasingly becoming a good portfolio diversification investment. Such industries are not only growing within the traditional manufacturing sector but also in other sectors such as autonomous cars, trading algorithms, customer service automation and even medical diagnostics. This popularity speaks of their increased significance and their capacity to offer high-growth opportunities to investors. The AI and robotics technology stocks are

getting more and more popular due to the potential high returns which can be exploited as a hedge against more volatile or traditional asset classes in a diversified portfolio.

Diversification strategies can also be made possible by the introduction of blockchain technology. Blockchain, which was synonymous with cryptocurrencies, has turned out to be a core financial disruptor, with a decentralized model of transactions, financial systems, and even contracts. Blockchain does not limit itself to cryptocurrencies, and it touches upon such areas as supply chain management, cybersecurity, financial transactions, and even the verification of digital identity (Rivera et al., 2024). This versatility and the possibility of mass use make companies related to blockchain an attractive alternative investment, which also diversifies the portfolio (Sergio & Wedemeier, 2025). Blockchain and other technologies have gained popularity as well as a form of digital gold, which provides protection against risks in the traditional financial markets (Gad et al., 2022; Hoque et al., 2024).

Also, financial technology (fintech) stocks have become another successful component of diversified portfolios. The financial sector digitization can be accessed by investors with the help of fintech companies that innovate in online banking, lending, payment processing, and insurtech through the usage of AI and blockchain (Missaoui et al., 2025; Rafiuddin et al., 2023). Such companies will have good growth patterns since they are going through the transition to digital and mobile-first financial services. Consequently, fintech shares have been in the spotlight as the method of diversifying out of more conventional, slower-growing financial investments (Abakah et al., 2024).

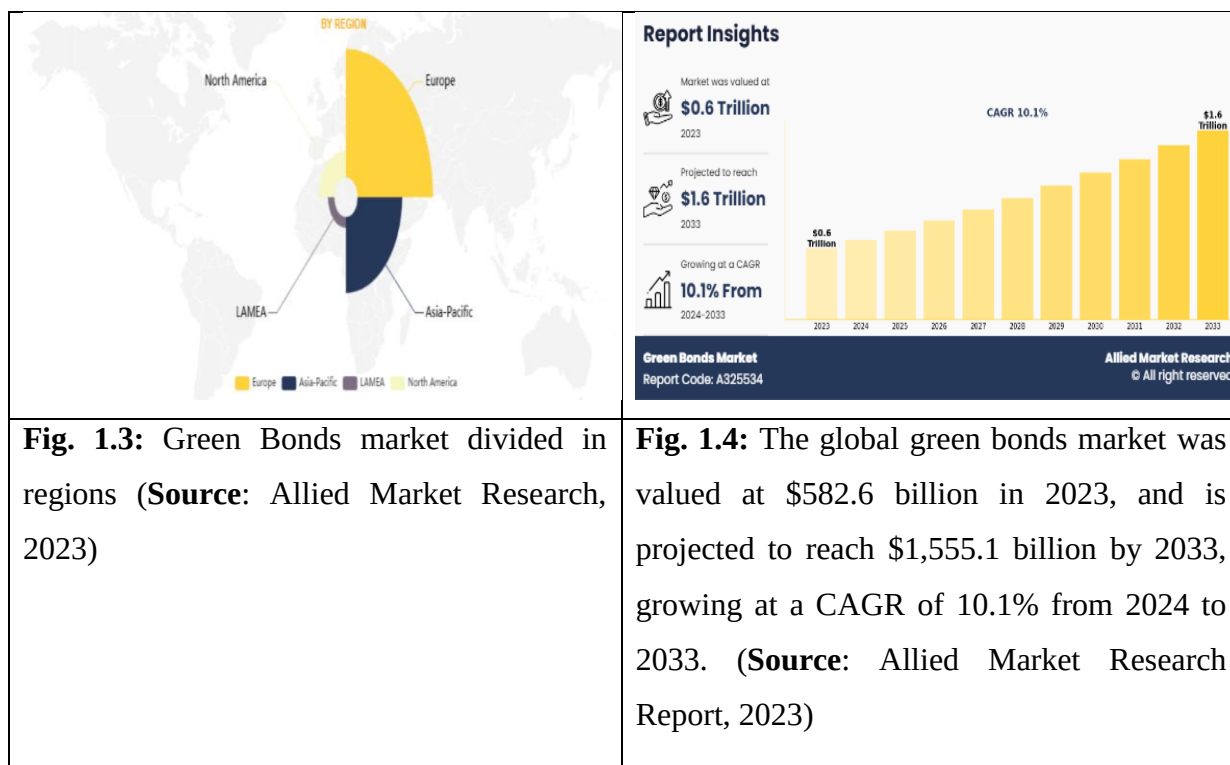
The growing globalization and financial integration of markets also auger well with the prospects of diversification using technology stocks. With the increased integration of the economy, the significance of the spillover effect and the correlation between various asset classes is increasing. The technological stocks, particularly in the fast-growing industry such as AI and blockchain, can provide protection and opportunities not present in conventional assets. This especially holds during market volatility where asset class correlations tend to increase and diversified portfolios are important in risk reduction. The investment strategy that incorporates the utilization of technology-related assets can therefore provide an avenue of attaining a wider market exposure especially during the stressful or volatile times.

A good enough reason to add AI, robotics, and blockchain companies to portfolios is the possibility of the companies to contribute to growth in various sectors of the economy (Gomez-Martinez and Medrano-Garcia, 2024). Not only do they reduce risk, but they also

offer the potential of high returns since their industries grow and develop (Hossain et al., 2024). Investors are also realizing that through the combination of these technology stocks, they can make their portfolios more robust, adapt to the current digital transformation, and diversify against the traditional market risks (Nafiu et al., 2025). These sectors will continue to grow, and therefore, their contribution to the portfolio diversification will be more significant, and they will become an inevitable component of international investment strategies (Farid et al., 2021; Ozdemir and Tas, 2024).

The Dow Jones Global Technology Index is the market-capitalization-weighted index that covers the performance of the top technology companies in the developed and emerging markets. The index is a broad index of companies involved in technology and includes companies dealing with software, hardware, semiconductors, IT services, telecommunications equipment and digital infrastructure. The index reflects the international and dynamic character of the technology sector by including companies across sub-sectors and geographies. The index is managed by S&P Dow Jones Indices and its constituents are chosen on the basis of market size, liquidity and sector classification. It frequently features some of the most powerful tech companies in the world like Apple, Microsoft, and Samsung emphasizing its emphasis on industry leaders that advance technological development and global connectivity. The Dow Jones Global Technology Index is an important index in the current rapidly changing digital economy that investors, fund managers, and analysts use to gain exposure to the technology sector (Wall Street, 2024). It does not only monitor the financial performance of tech equities but also provides information about the overall economic changes, such as the increasing significance of digital platforms, mobile communication, and information technology infrastructure. Since technology companies often have a different performance pattern than more traditional industries such as energy or finance, the index is also applied as a strategic portfolio diversification tool.

Thus, the emergence of technology in the financial sector has greatly interfered with the conventional practices, and it has been central in the development of the Fourth Industrial Revolution. This revolution has redefined different sectors in the financial services industry such as insurance, investment management, fundraising, and peer-to-peer lending (Guild, 2017). An increasing number of studies point to the relationship between FinTech innovation and sustainable development, indicating that technological innovation in the financial sector has a positive impact on the overall economic growth (Shin & Choi, 2019; Sadigov et al., 2020; Khiewngamdee et al., 2019; Romdhane et al., 2020).



1.4 Green Bonds

Green bonds are included in this study because of their rapidly growing market size and their unique role as net receivers of volatility ($NET = -21.47\%$), which positions them as potential stabilizers in diversified APEC portfolios during crisis-driven market turbulence. The green bonds market has expanded exponentially, and it is now a significant component of the sustainable finance market. The global market size of green bonds was estimated at 582.6 billion in 2023 and is projected to rise to 1,555.1 billion by 2033, at a CAGR of 10.1% between 2024 and 2033 (Sumant, 2023). This growth can be attributed to the increasing demand in funding climate-related and environmentally sustainable initiatives as governments, corporations, and financial institutions prioritize sustainability and match their investments to international climate goals. Green bonds are debt securities that are issued to raise money to finance or refinance projects that have a positive environmental impact such as renewable energy, clean energy, energy efficient transportation, sustainable water management and greenhouse gas emission reduction. They are treated like regular bonds but are specifically invested in projects that promote environmental sustainability and climate action providing investors with a transparent and sustainable way to invest in climate action. These projects are in line with the United Nations Sustainable Development Goals (SDGs), and they are renewable energy, energy efficiency, waste management, and sustainable water

management. Green bonds also help shift to a low-carbon, green economy by funding green projects (Fan & Shahbaz, 2023; Sanderson, 2018). These are also helping governments and businesses meet their commitments made in international agreements such as the Paris Climate Agreement that mandates massive investment into sustainable energy and climate adaptation. Green bond is a serious gap filler to achieve the climate goals globally and the world is estimated to require about 2.5 trillion dollars per year to achieve SDGs and about 1 trillion dollars of this sum shall be expended on green energy initiatives (Alamgir & Cheng, 2023; Ahmed et al., 2023).

As illustrated by the fig-4, the market of green bonds is divided into regions, with four biggest market being Europe, with a dominant share of 51.87 percent in 2023. The issuance of green bonds in the region has been increasing tremendously and so far, the amount raised in green bonds exceeds USD 750 billion (Demska et al., 2025). Europe is reported to be ahead in the market because of its robust policy frameworks, sustainability and the rising use of green strategies to cut emissions and enhance energy efficiency. In the meantime, the Asia Pacific will be the most rapidly developing market of green bonds, with China constituting 44 percent of the region in 2023 (Griffith Asia Institute, 2024). The higher interest in sustainable investments in Asia, as well as the higher governmental support, can make the region the potential region of green bonds issuance in the nearest future.

Further than the increasing market in the mature markets, the need of investing in sustainable investments has been able to form a great force in the green bonds market. The interest in Environmental, Social and Governance (ESG) factors is growing over the last several years, and investors are getting more involved in them (Vu et al., 2024). The main cause of this change is the increasing understanding of the issues of climate change, environmental erosion, and social responsibility, and this makes investors desiring to find opportunities whose profits are not limited to financial gains but also have to meet their values. Pension funds, asset managers and insurance companies are also institutional investors, and they are increasingly integrating the application of ESG criteria into their investment strategy. The need to invest in projects that would lead to environmental sustainability, e.g. renewable energy, green infrastructure, and energy efficient technologies would motivate such investors.

This has seen the increase in popularity of green bonds. These highly bankable securities offer a chance to fund environmentally sound projects and allow the investors to diversify

their portfolio and respond to global risks facing the world like climate change. This demand has been increased by the emergence of the unprecedented individual investors that give more emphasis on sustainability especially the millennials. Such investors are likely to invest in investment products that contribute to social and environmental benefits, which has subsequently contributed to the growth of the market of green bonds. With the increase of such population, the probability of the continuation of the demand of green bond increase is quite possible (Pašiušienė et al., 2023). Moreover, the return on green bonds has been seen to perform well financially, and this also gives it more advantage over others. In the future the green bonds market is likely to be a part of the world market financial environment as more people realize the possibilities of the sustainable investment (Sreelakshmi et al., 2025).

The market of green bonds is also being transformed by technological changes. The blockchain technology is improving the transparency and the fact that the money being raised is handled accordingly (Javaid et al., 2022). With data analytics, investors can quantify the effect of their investment, and this is presenting them with superior methods of monitoring the environmental worth of projects in which they invest. Nonetheless, despite the growth trend, the market is not doing well. These are regional regulatory differences, inconsistent definitions of a green project, and the transparency and accountability issue. The above are the issues which should be solved to make sure that investors would be confident, and the green bonds market would be successful in the long perspective.

The green bonds market will be expanded with an increase in the demand of sustainable financing services. The reason behind this is the international consents to action like the Paris Climate Accord as well as the increased scope of investigations on corporate net-zero subcontracts. It includes an outstanding opportunity to promote environmental sustainability in the market and meet the goals of the global climate targets through investing in the market expansion (Stern and Valero, 2021). The most important players of the green bonds market such as banks, including KfW, the European Investment Bank, the World Bank, and the China Development Bank, are constantly expanding their market share and positioning by means of innovation (Lund et al., 2023). The fact that they have worked at issuing green bonds with transparent platforms and stringent post issue transparent platforms is critical to the further development of the market and the interest of more environmentally aware investors. Green bonds will remain the key to the shift to a low-carbon economy as long as the market continues to mature and face discontinuity between sustainability objectives and investment opportunities.

The growing international interest in green bonds is also being emphasized by recent initiatives. On December 16, 2024, the Climate Bonds Initiative, together with the Hokkaido government and the City of Sapporo, urged the speeding up of regional revitalization in Hokkaido by Green Transformation (GX) (OECD, 2025). This is an attempt to capitalize on renewable energy development and build industries such as semiconductors and data centers that rely on renewable energy, forming a positive feedback loop between the economy and the environment. On the same note, Jamaica issued its Green Bonds on January 23, 2025, to promote businesses to finance sustainable projects. Also, in January 2024, the African Development Bank launched its first social bond under its new Sustainable Bond Framework, which underscores a robust drive towards green and social financing (Institutional Shareholder Services, 2025).

Regarding regional performance, Europe had the largest share of the green bonds market in 2023 due to its high commitments to climate action and sustainability, including the EU Green Deal and the EU Green Bond Standard. Such efforts have established a positive climate towards green finance in the region. Conversely, LAMEA (Latin America, the Middle East, and Africa) will experience significant growth in the green bonds market over the forecast period. This is explained by the increasing interest in climate change, the need of sustainable infrastructure, and the increasing governmental interest in green initiatives. As nations in LAMEA move towards cleaner energy and environmental concerns, green financing is expanding at a fast rate, with favorable regulatory environments and greater interest among institutional investors.

1.5 Gold

Gold is investigated as a persistent safe-haven asset that, in this study, acts as a leading indicator of equity market movements across most APEC markets during COVID-19 and geopolitical war periods, consistent with its net receiver position ($NET = -19.38\%$) in the TVP-VAR connectedness network. Gold has been regarded as a strategic asset, but its significance in the global financial markets has become even more significant in the recent years. In a more fragmented and multipolar world, where geopolitical tensions, inflationary pressures, and financial market volatility are increasing, gold is again demonstrating its value as a significant part of diversified investment portfolios. This recovery is particularly evident in central bank demand, which has skyrocketed since 2021, particularly in emerging markets.

The necessity to diversify reserves and the desire to prevent excessive dependence on the US dollar because of the shifting geopolitical landscape is making central banks turn to gold increasingly (Chang, 2024).

The attractiveness of gold as a portfolio diversifier is also increasing. Gold is not highly correlated with traditional asset classes like equities and bonds, unlike other asset classes, and therefore it is particularly useful in times of market stress. Gold has been a stabilizing factor and a cushion against losses when traditional assets move in tandem, particularly in times of macroeconomic shocks or financial crises. As an example, a 60/20/20 portfolio of equities, bonds, and gold has performed better than the classic 60/40 equity-bond portfolio since 2020, providing superior risk-adjusted returns as inflation and market volatility have increased (Advani, 2025). This renders gold an effective instrument of enhancing portfolio resilience and risk management, especially during uncertain periods.

Gold also performs well in a higher inflation environment, particularly when inflation is sustained at moderate rates (CPI 0.4-0.6% per month). Although its price is determined by several factors, real interest rates, monetary policy, and market sentiment are the most important factors that determine its price (Benati & Bank of England, 2006). Gold has been known to do well when inflationary pressures are high, particularly during times when real interest rates (interest rates adjusted to inflation) are low or negative, and non-yielding assets such as gold are more appealing to investors.

The Mid-Year Outlook Report 2024 by the World Gold Council (WGC) is optimistic about gold. In the first half of the year, gold prices have experienced sharp rises due to inflationary pressures and geopolitical risks despite the global economic uncertainties (ANI, 2025). The central banks have been accumulating more gold, which highlights its importance as a stable and strategic asset in the face of financial turmoil. Indeed, this continued demand by central banks, and the increased investment in gold-backed Exchange Traded Funds (ETFs) has been a major boost to the gold market, which has further cemented its position as a hedge against economic fluctuations and financial market shocks (Khanna, 2025).

Besides the conventional investment channels, including physical gold and ETFs, gold has experienced increased demand in the contemporary technological and strategic sectors. The rise of AI and technological advancements has also led to an increased demand in gold, especially in sectors that need high precision and reliability in parts, including electronics and renewable energy technologies. The use of gold in these sectors, and the use of gold in the

financial market, shows its versatility and its applicability in the modern global economy (Ghosal, 2024).

The role of gold is also getting closer to the Environmental, Social, and Governance (ESG) principles. Due to the growing interest of investors in sustainable and responsible investment, the gold industry tries to enhance the process of mining and mining with less impact on the environment and to contribute to the social responsibility. All this has boosted gold as an ethical and responsible investment, which is attractive to the mushrooming demand in ESG-compliant funds.

In future, gold will continue to be a strategic source of diversified investments. Although the market does not lack challenges like the vagaries of the interest rates and geopolitical developments, the long-term demand of the gold by central banks, institutional investors and other upcoming sectors echo the worthiness. With the financial markets of the world still being marked by economic insecurity, gold is a safe, stable and flexible investment that can be tapped by the investor to sustain capital, hedge inflation and gain stability in the events of market fluctuations.

Conclusively, gold is not a mere conventional haven as it has always been, but a strategic investment tool that has the potential to provide diversification, stability as well as long-term increase to the contemporary investment portfolio. The necessity of gold as the relevant asset class to be taken by investors in the dynamic and complicated market environment today is due to the rise of its holding in the reserves of central banks, its capability of protecting the portfolio in the context of a financial crisis, and its role in the current environment of technology and ESG.

1.6. APEC Energy Investments

Asia-Pacific Economic Cooperation (APEC) region with some of the largest and most open economies in the world faces a critical point on the path towards the clean, more sustainable and resilient energy systems. Various urgent factors stimulate this transformation: the necessity to solve the problem of climate change, the increasing threats to energy security, and the accelerating changes in technologies, which revolutionize the energy industry. The concept of climate change is already impacting the enterprise of farming, the efficiency of labor, and infrastructure and is already expected to cost as high as 7.3 percent of GDP by the year 2100 in a base-case scenario as presented by PTI (2024). It will adversely impact the

lower-middle-income economies around the equator; however, the economies in Hong Kong and Singapore with a high population at the coast will be seriously hit at the economical level too (Lam et al., 2022). Along with these climatic changes, there is also a significant issue of energy security which is also the concern of the region economies that are now trying to find solutions to their reliance on oil energies and switch to a more ecologically safe and sustainable source of power.

APEC economies will require a massive investment in their energy systems by matching climate objectives based on the Paris treaty and by achieving long-term sustainable economic growth. These investments must take place so that low-carbon energy sources can be moved to and to reduce the consequences of climate change on societies and their economies. According to the recent reports, to achieve Paris-aligned climate policy, APEC will need to invest further 470 billion dollars annually in the energy sector to achieve it by 2050 (APEC, 2024). This huge investment demand is part of the indication of the urgency to switch to a clean energy future, whilst at the same time, making sure that APEC economies will be competitive in the global energy marketplace. By 2050, or with each economy spending an average of 1.4 percent of GDP, it is estimated that the total energy investment requirements of the APEC economies will amount to about 1.8 trillion dollars per annum (OECD, 2023). This investment will be focused on a few big economies especially China, the United States, Indonesia and Japan that are likely to contribute most of the extra energy investment required, approximately 90 percent. As an example, the United States and China will need some extra 220 billion and 160 billion dollars of energy investment per annum in 2050 annual, respectively, and a vital portion of the expansion will be dictated by the requirement to extend the transmission and distribution system to serve the booming demand in electricity (Amir et al., 2023).

The energy investment requirements in the APEC are complex, and this is where there are several areas which are of utmost importance, and which require immense capital inflow. Production of clean electricity is one of the most crucial places and renewable energy renewables including wind and solar power are inherent, and are necessary, but they could not provide the whole need alone. Diversified and technologically comprehensive energy mix including nuclear power, low-carbon hydrogen, and carbon capture technologies will require investment by the APEC economies, which will help them maintain reliability and sustainability in supply of energy. In addition to clean electricity generation grids, energy storage systems and electricity grid modernization will need investments (Sandaka & Kumar,

2023). With the rise of renewable energy, energy storage systems and well-built works of the grid are becoming ever more requested to ensure stable and effective energy supply. International Energy Agency predicts that minimum 3000-gigawatts of renewable power capacity will have reached a stage ready to be connected to the grid by 2040 and more than 80 million Km of new grid infrastructure will be needed (Amir et al., 2023).

Transportation can also be significantly improved to spend on batteries necessary to switch to electric vehicles (EVs) and artificial fuels (Sandaka & Kumar, 2023). As EVs become more popular, fossil fuels are being substituted by alternative fuels like biodiesel, green hydrogen, and sustainable aviation fuel. To address the increasing demand of low-carbon mobility solutions, APEC economies will have to invest in EV charging infrastructure and sustainable fuel production. Moreover, AI and digitalization are becoming more significant in terms of energy consumption optimization, grid operation, and energy efficiency. The innovations powered by AI can transform the energy management process and allow economies to minimize waste, control the demand fluctuations, and enhance the overall grid stability. As an example, the Republic of Korea is taking major steps towards improving access to energy data and advancing AI-enabled energy systems, which can enable APEC economies to realize smarter, more responsive energy systems (Shan, 2025).

Nevertheless, the estimated energy investment requirements in APEC are faced with challenges and uncertainties. The level of investment needed will be determined by a number of factors such as population and economic growth, the price of low-carbon technologies, and the design of climate policies. The decarbonization path is not clear, and the investment may be more or less depending on the changes in energy efficiency improvements, technology costs, and demand patterns. Also, there is a need to reallocate energy investments significantly to meet Paris climate targets, and low-carbon investments must surpass fossil fuel investments by approximately 2025. By 2050, it is estimated that about 80 percent of the overall energy investment will have to be channeled to low-carbon technologies, such as renewable energy, energy efficiency, and electricity system modernization. This transition poses a challenge to economies that rely heavily on fossil fuel industries, but also creates a great opportunity to those that can diversify their energy mix and adopt the clean energy transition.

Nevertheless, APEC economies can take the lead in energy transition investments, which will open up substantial economic and environmental opportunities. Figure indicates the

incremental annual energy investment requirements as a percentage of 2050 GDP that is necessary to achieve Paris targets in 2050, based on modelling in McCollum et al. (2018). The total energy investment requirements across APEC countries are estimated to be 1.8 trillion dollars per year in 2050, or about 1.4 percent of GDP on average. The extra investment required is approximately 90 percent in China, the United States, Indonesia and Japan. To attain Paris consistent climate policy, the United States and China need an extra 220 billion and 160 billion dollars of energy investment annually by 2050 respectively (OECD, 2025). The extra 470 billion dollars annually required to invest in energy will not only cut emissions but also open up new possibilities of economic growth, employment and technological advancement. With the emphasis on clean electricity production, energy storage, grid modernization, and AI-powered energy systems, APEC economies will be able to address their energy investment requirements and lead the world to a more sustainable energy future. The increasing focus on clean energy solutions in the region places APEC in a leading position to meet global climate targets, energy security, and economic competitiveness amid climate change and technological disruption (IRENA, 2018). APEC can revolutionize its energy systems and set the stage toward a cleaner, more resilient future with the right investments.

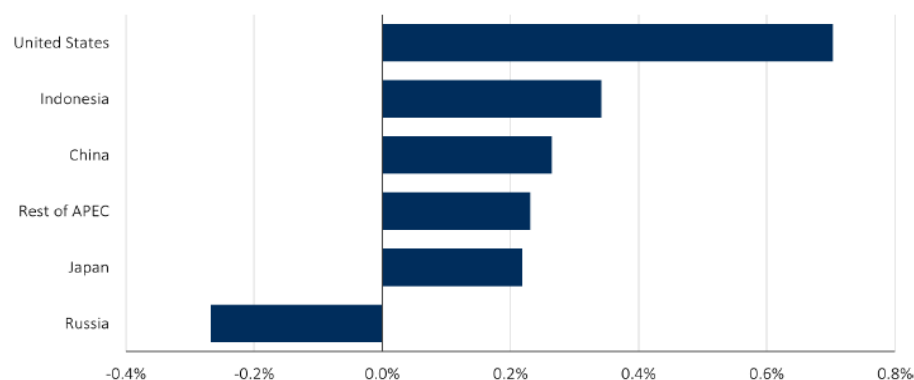


Fig. 1.5: Additional annual investment in the energy system needed per year as % of GDP compared to baseline (Source: Vivid Economics, based on McCollum et al. (2018))

1.7 APEC Technological Developments

Asia-Pacific Economic Cooperation (APEC) has also been in the limelight as far as economic integration and technological improvement is concerned in the region. APEC economies, which represent over 60% of the worldwide GDP, are actively on the way of welcoming

innovation, especially in the energy and environmental fields, to enhance the speed of transitioning into the low-carbon economy (Ximei et al., 2024). Another area of concern in the region is the potential of the new solutions and technologies that include artificial intelligence (AI), clean energy solutions, and digital transformation in addressing the challenges of climate change and guarantee the sustainable economic growth in the future.

The energy sector is one of the areas in which technological developments form the main part of the APEC plan to reduce greenhouse gas emissions and meet the sustainability targets. Green energy has emerged as a central concern of the APEC economies that are currently trying to give up the use of traditional fossil fuels to generate power, and adopt the alternative ones, which include wind, solar and hydropower. The proportion of renewable energy in the world energy mix is gradually on the rise and it is APEC that is leading in encouraging investment in clean energy. Indeed, the estimates are that the APEC economies will have to increase their investments in energy by 470 billion dollars per annum by 2050 in order to achieve the targets stipulated in the Paris Agreement (Koljonen & Lehtil, 2012). This growth in investment is mostly towards the construction of capacity to generate renewable energy, on energy saving and on energy storage.

Inclusion of energy storage systems and smart grids is one of the key technological changes which are underway in APEC. These technologies must provide reliable power and be able to respond to the variability of such renewable sources of energy. Another technology in which the region is also interested will be low-carbon hydrogen and carbon capture and storage (CCS) that will play a crucial role in helping to decarbonize heavy industries and power generation. Japan, South Korea, and Australia have already been investing heavily in the process of green hydrogen production, and the introduction of CCS technologies is perceived to be one of the potentially promising tools to reduce emissions to a minimum in emission-intensive sectors (APEC Secretariat, 2024).

The other transformation that has been going on in the region of APEC is the transport sector and this is being led by the production of electric vehicles (EVs) and alternative fuels. As EV adoption rises rapidly, there is a high rate of investment in EV charging infrastructure as well as battery technology in the region. It is projected that by 2030, more than 40 millions of EVs will be present within the APEC region, with China, Japan, and South Korea taking the lead (Ehsan et al., 2024; Walia, 2025). Also, biofuels, green hydrogen, and sustainable aviation fuels production are becoming more and more popular in transport, with which the

commitment to promoting a minimum carbon footprint in air travel and shipping is being addressed.

Technology advancement is also massive due to the emphasis on digitalisation in the APEC region. Machine learning and artificial intelligence (AI) are becoming relevant to energy management, optimization and automation. AI can be applied in enhancing grid management and optimizing energy as well as better incorporation of renewable energy sources into a power system. South Korea government is as well encouraging the adoption of AI and big data to improve on energy efficiency and emissions. Other industries where AI is being utilised to achieve efficiency and minimise impact on the environment include the agricultural sector, the manufacturing sector and in transport.

The productivity of the AI in global value chains is transforming the environment of trade within the APEC region. The AI technologies assist the companies to mitigate the risk of the supply chain, make the logistics operations easier and minimize trade costs. Most customs can also make use of AI to enhance the collection of taxes, classify their products, and assess the risks to the shipment. Besides, automation in production due to the assistance of AI will cause redistribution of labor worldwide, which will add onshoring of certain production processes and the character of the worldwide trade.

Other than, the development of AI products and services has introduced new requirements in trade. The development of AI systems requires the basic aspect, like Graphics Processing Unit (GPUs), which in turn, increases the necessity of the ICT services and network infrastructure. Talent accessibility especially AI engineers and data scientists is also becoming another vital factor in creating AI, and APEC economies are also increasing their investments in talent development programs to readily access the said talent.

Many APEC economies have given AI special attention and even developed AI-centric regulations and guidelines thus promoting its advancement. The tendency can be justified by the growing investments into the AI in the area as equity investment in APEC regional owners of the AI companies has grown by 156.9 percent since 2018 to USD 164.9 billion in 2024 (OECD, 2025). China, Japan, South Korea, and the United States are the APEC economies on the frontline and have been playing a pivotal role in the growth of AI-related patent and publication in the globe, most especially in the GenAI. As an example, according to statistics, in 2014, about 700 patents were issued around GenAI, and in the last ten years alone, this figure increased to 14000 (WIPO, 2024).

Even the Digital technologies like Internet of Things (IoT), blockchain, and 5G become popular in APEC economies. The technology is also applying it in order to enhance energy management, remote monitoring and control, and supply chain. Specifically, the smart houses, buildings, and cities are also being brought to the environment because of the introduction of the IoT devices, making them more sustainable, environmentally waste-free, and energy-smart. An example of this is smart meters which can enable consumers and utilities to monitor their real time consumption of energy which will enable an energy consumption pattern being more efficient.

Innovation in clean technology The APEC economies are also pumping huge investments in research and development (R&D) activities. Most of the regional economies are considering investing in R&D in ensuring that they come up with a next-generation clean energy using advancing nuclear power, or fusion energy and next-gen solar technologies. As an example, China has achieved a lot in the development of high-tech solar technologies and the nation is currently the largest solar panels manufacturer in the world. The area will most likely be devoted to innovation in clean energy technology and it is estimated that the APEC economies will be developing energy expenditure of 1.8 trillion dollars annually on average by 2050 (WEF, 2025).

Other than energy and transport, the agricultural sector in APEC is also reaping the benefits of technological improvement to ensure that it is more sustainable and lead to low-emission. AI, sensors and drones are being used to implement precision farming practices to get the best out of water use, minimize fertilizer and pesticide use and maximize crop yield with minimum negative environmental impacts. Such technologies especially apply to countries like Indonesia and Vietnam where the agricultural activity is a significant economic activity and subjected to enormous climatic change effects (Soussi et al., 2024).

APEC region is also dwelling on the development of the low-carbon technology via the convergence of policies and the regional cooperation. Development of similar standards and regulations on clean technologies is being proposed by the region economies to ensure that innovations could be scaled internationally. APEC has been in the frontline to support cooperation in renewable energy, energy-efficiency and climate-compatible technologies, and cooperation is also key in ensuring that the region will find itself in a favorable position to achieve climate commitments. The APEC is as well benefiting through its sustained improvement of the region with improvement in economic growth as well as sustainability,

due to the ongoing digitalization of the industries its members are having. The sharp transition to green technologies and digital innovations makes APEC a world leader in the fight against climate change.

Conclusively, APEC economies are going an extra mile in adopting the use of technology in a bid to achieve decarbonization and a sustainable struggle. In the priority areas of clean energy, digital transformation and technological innovation, APEC is also marching towards the low-carbon future, which would allow sustaining economic development and mitigation of the climate change effects. With this region investing even more in renewable energy, AI, and digital technologies, APEC is becoming a force that can lead the world towards the sustainable and low-carbon economy. The current technological progress in the sphere of energy, transportation, agriculture and industry, as well as the high organization of the cooperation at the regional level can be associated with the long-term sustainability goals of APEC.

1.7 Basic Theories on Financial Market

The Black Swan Theory and Capital Asset Pricing Model (CAPM) are considered to be the most crucial ones in the modern financial theory that have never lost the spotlight during the years. They both are based on some main assumptions and one of the main concepts underlying these models is the Efficient Market Hypothesis (EMH). The basis of EMH is rational analysis that presupposes the assumption of efficiency of markets, which means that all information is being used. Nevertheless, this position started to change since the time in the 1980s when the behavioural finance theory was introduced. Although the volume of the relevant research studies increased significantly over the past few decades, no unanimous opinion exists in this area, and it is challenging to evolve a unified direction of thought. This layering is one that Shiller (1999) remarks in saying that behavioural finance is a multidimensional, multilevel field which explains further why it is a challenge to come up with a coherent picture of this new field.

The number of common theories regarding the stock market and the investor behavioural study is huge and according to all of them, there is some kind of relation between the factors, including the following ones:

1.7.1 Efficient Capital Market Theory

The most commonly recognized theory in the efficient capital markets framework is the Efficient Market Hypothesis (EMH) which was proposed by Eugene Fama in 1970. EMH states that the price of stocks at any particular moment is a complete reflection of all the available and relevant information, and therefore securities are always sold at their fair value. This therefore means that no investor can always beat the market by using technical or fundamental analysis to get returns that are above the market. Fama (1970) believed that markets are efficient in the sense that they absorb new information and therefore asset prices change instantly to reflect any market occurrence. This ability improves the decision-making of investors by giving buyers confidence in the transparency of the market and giving sellers protection in fair valuation.

EMH has been a controversial topic despite its popularity. Although its claims are supported by many studies, many researchers are sceptical. Critics claim that markets are not perfectly efficient and that there are anomalies that enable some investors to earn excess returns without corresponding risk. These contrasting views have led to a lively debate in the financial academia. As Apiyeva (2007) and more recently Fama (2021) reiterated, a well-functioning market is one where security prices reflect all available information. This was supported by Jensen (1968) who said that it is almost impossible to beat the market consistently because price movements are mostly random. In the same way, Tursoy et al. (2008) claimed that price unpredictability does not allow making reliable forecasts on the basis of historical trends.

1.7.2 The EMH categorizes market efficiency into three types:

Weak Form Efficiency: This level holds that the current stock prices are based on all the past trading information, including past prices and volumes. Consequently, technical analysis based on chart patterns and historical market behaviour cannot be used to produce consistent excess returns.

Semi-Strong Form Efficiency: At this stage, the stock prices are assumed to reflect all the publicly available information such as financial statements, news releases, and macroeconomic indicators. Therefore, fundamental analysis is also not likely to give an advantage, since any new information is already rapidly incorporated into prices.

Strong Form Efficiency: This is the most demanding form, which assumes that stock prices incorporate all information, both public and non-public (including insider information). When a market is highly efficient, even insiders who have privileged access to company information cannot reliably beat the market.

Handa and Khan (2008) pointed out that strong-form efficiency presupposes a fully transparent market in which even internal auditors and executives are not able to use future corporate information to gain abnormal profits. Above-average profits in these markets are practically impossible. In general, the EMH offers a theoretical basis of the role of information in asset pricing. Nevertheless, the advent of behavioural finance and the discovery of market anomalies have posed serious challenges to its assumptions, making the debate about market efficiency dynamic and continuing.

1.7.3 Capital Asset Pricing Model (CAPM)

Capital Asset Pricing Model (CAPM) is a basic model in finance that seeks to determine the correlation between risk and expected returns. It implies that the anticipated yield of an asset is directly proportional to its Beta, which is a measure of the volatility of the asset relative to the market as a whole. Essentially, Beta measures the sensitivity of the asset to market fluctuations, the higher the Beta, the higher the risk and, therefore, the higher the expected return. Although CAPM is fundamental in finance, it has been criticized, mainly because of the simplifying assumptions it uses. The model presupposes, e.g., that all investors possess identical information and act rationally, and that markets are frictionless. Such assumptions are not always true in real life situations where there is plenty of information but little attention and processing capacity.

Cohen (1979) noted that investors have limited cognitive resources to allocate and therefore not all the available information is equally considered in investment decisions. This is in line with the theory of selective attention in financial behavior, which emphasizes the role of limited attention in affecting asset prices. Building on this, Merton (1987) came up with the concept of investor recognition, which suggests that the level of interest that investors show towards some stocks influences their pricing. Peng et al. (2006) argue that investors are likely to concentrate on information that attracts their attention, which subsequently influences the valuation of assets in the market. Therefore, the dynamics of investor attention is crucial to a more precise understanding of the behavior of financial markets.

The development of stock markets, commonly known as stock exchanges, has been influential in the development of the application of financial theories such as CAPM. Stock exchanges are as old as the 16th century, and the earliest known stock exchange was in Antwerp, Belgium. Technological innovations and market innovations have since then made stock markets very complex and regulated. In the modern financial world, nearly all countries have at least one stock exchange, each with its own regulatory framework and operating procedures. In short, although the CAPM offers a theoretical framework to explain the risk-return trade-off, its practical implementation should be put into perspective of the realities of the contemporary financial markets where the behavior of investors, the focus of their attention, and the market structure are all important factors.

1.7.4 Theory of International Portfolio Diversification

The International Portfolio Diversification theory focuses on the strategic use of different financial instruments available in the world like equities, bonds, and commodities like gold-into the portfolio of an investor. The reasoning behind this strategy is the advantages of diversification, especially when the assets involved are negatively correlated or uncorrelated with each other. Investors who diversify their funds in various global equity markets particularly those that are not correlated with each other are likely to minimize the risk of the portfolio and increase returns. This low or negative correlation is especially significant in times of financial crisis when markets are likely to respond differently based on geographical, political and economic conditions.

Gold has traditionally been viewed as a safe-haven asset, particularly in periods of uncertainty like wars, recessions, or global crises. Baur and Lucey (2010) argue that gold markets are usually considered more stable than equity markets in turbulent times because of its high liquidity and intrinsic value. This negative correlation enables investors to diversify their portfolio against the volatility of the equity market by adding gold to their portfolio. The two functions of diversification and safety are effective in defining the role of gold in a diversified portfolio. These attributes were examined in various studies that compared the pre and post crisis performance of gold against equities. The results indicate that a portfolio of gold and stocks can be used to substantially decrease the volatility of portfolio returns, thereby decreasing risk.

Portfolio risk is all about the concept of Beta. Beta is a measure of the volatility of a portfolio in comparison to the market. The more the different, uncorrelated assets in a portfolio, the

less the unsystematic risk, and the remaining risk is the systematic risk, which cannot be reduced by diversification. In a completely diversified domestic portfolio, a beta of 1 means that the portfolio has the same amount of risk as the market. Investors who decide to diversify internationally face opportunities and risks. Nevertheless, international diversification increases the possibility of higher returns and reduced portfolio volatility, especially when foreign markets respond differently to economic events than the home market of the investor. One of the first to promote this notion was Solnik (1974) who showed that investing in foreign equities could enhance portfolio performance considerably by means of effective diversification. This was recently reaffirmed by Huang and Wang (2021) who pointed out that the inclusion of U.S.-based assets in a global portfolio may assist in lowering the total risk. The diversity of global asset classes and financial instruments provides investors with the freedom to design customized portfolios that meet their risk tolerance and return goals.

1.8 Trends in APEC Stock Exchanges, Technology, Green Finance, and Gold Prices

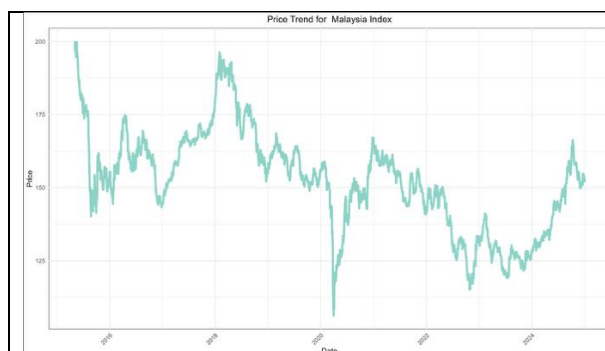


Fig. 1.6: Malaysia FBMKLCI Index price trends 2015 to 2024.

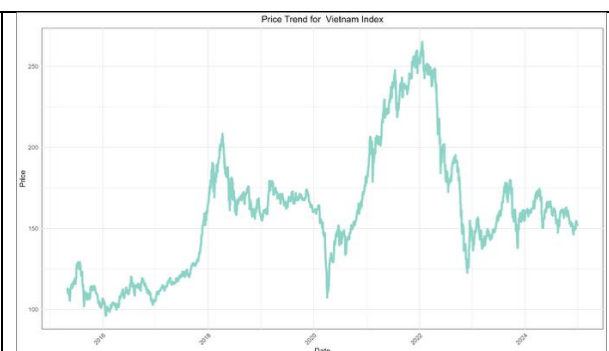


Fig. 1.7: Vietnam IDFPVNPD Index price trends 2015 to 2024.

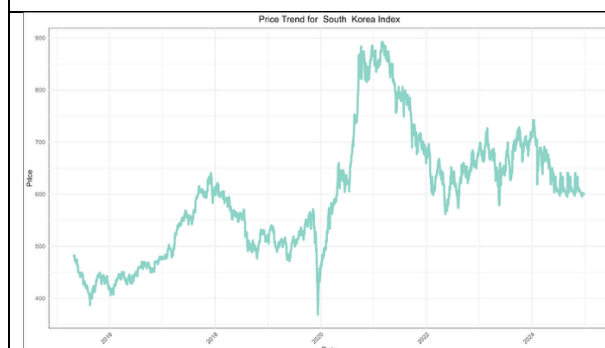


Fig. 1.8: South Korea KR30 Index price trends 2015 to 2024.

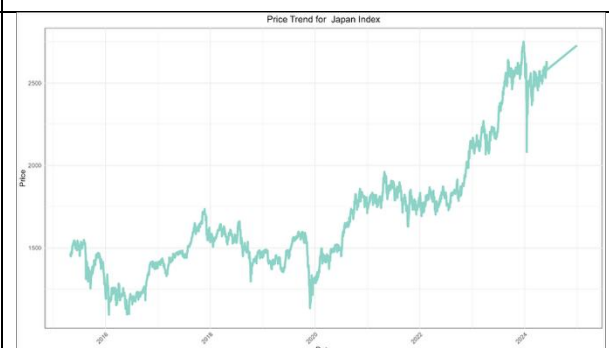


Fig. 1.9: Japan SPJ500 Index price trends 2015 to 2024.

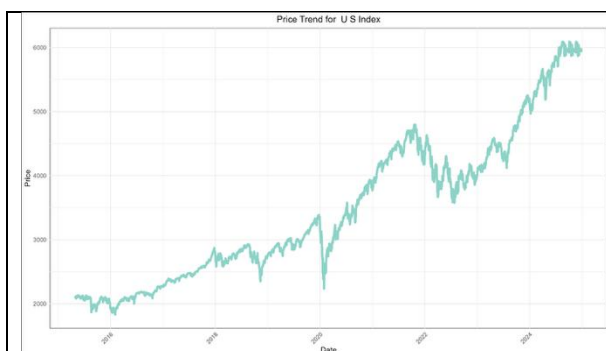


Fig. 1.10: U.S. USSPX Index price trends 2015 to 2024.

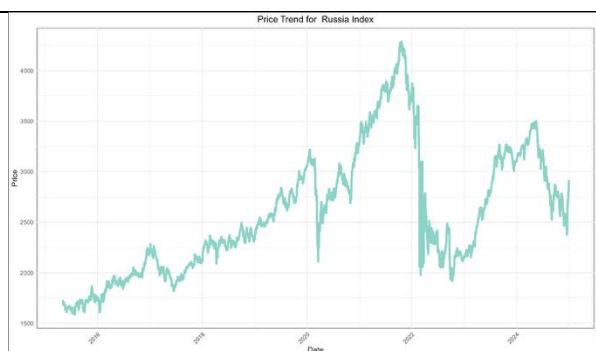


Fig. 1.11: Russia IMOEX Index price trends 2015 to 2024.

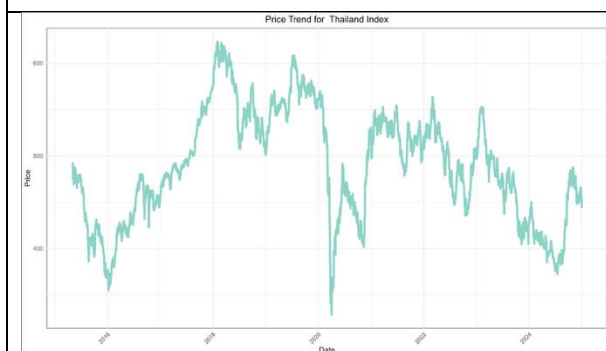


Fig. 1.12: Thailand SBBCTLU Index price trends 2015 to 2024.

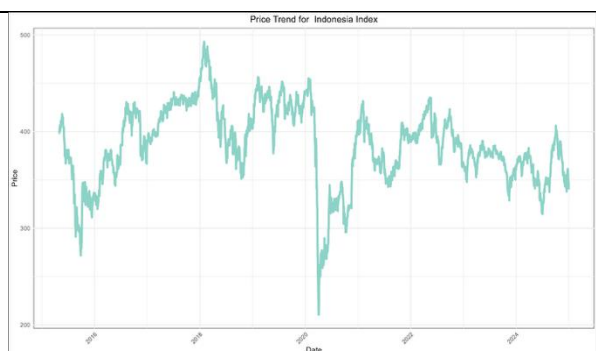


Fig. 1.13: Indonesia SBBCIDU Index price trends 2015 to 2024.

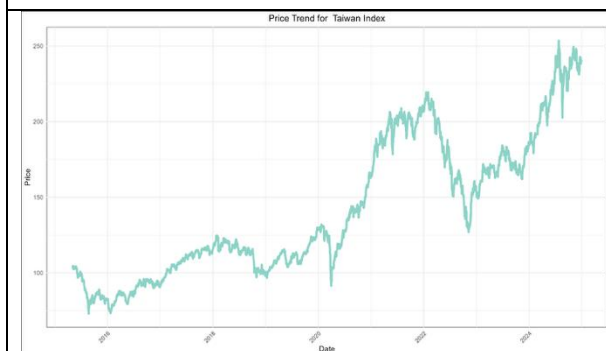


Fig. 1.14: Taiwan SBBCTAU Index price trends 2015 to 2024.

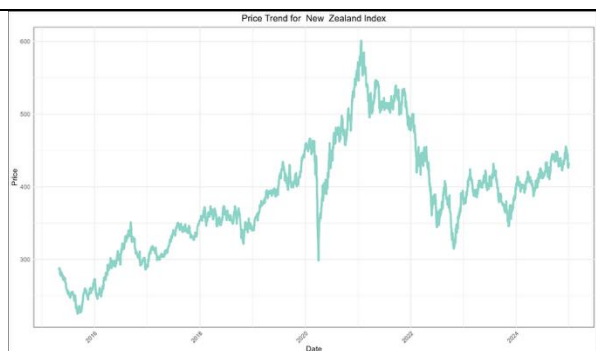


Fig. 1.15: New Zealand SBPCNZU Index price trends 2015 to 2024.

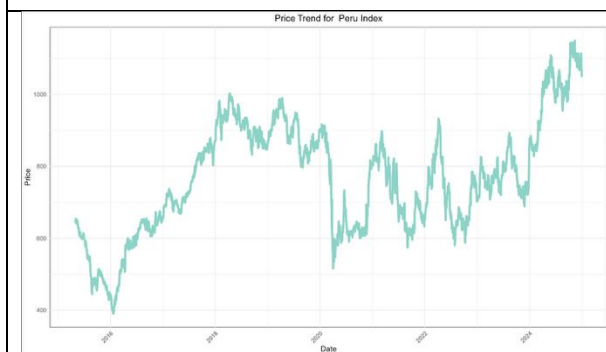


Fig. 1.16: Peru SBPCPEU Index price trends 2015 to 2024.

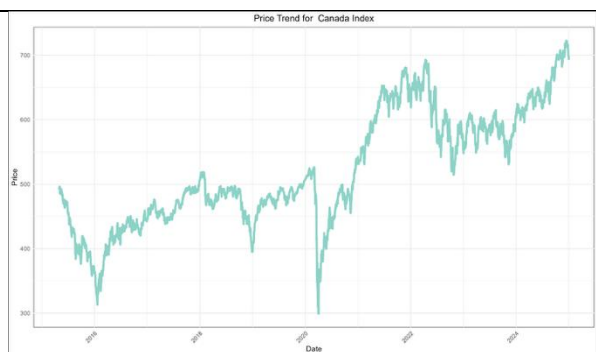


Fig. 1.17: Canada SBBCCAU Index price trends 2015 to 2024.

2015 to 2024.

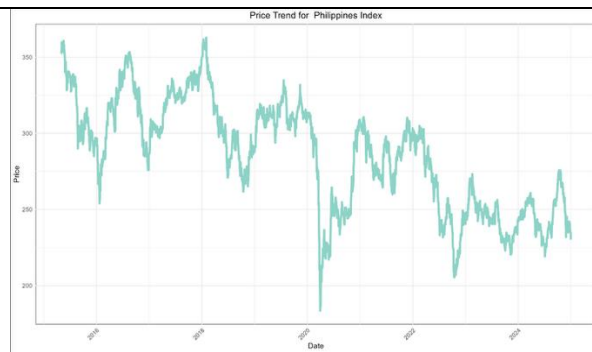


Fig. 1.18: Philippines SBBCPHU Index price trends 2015 to 2024.

trends 2015 to 2024.

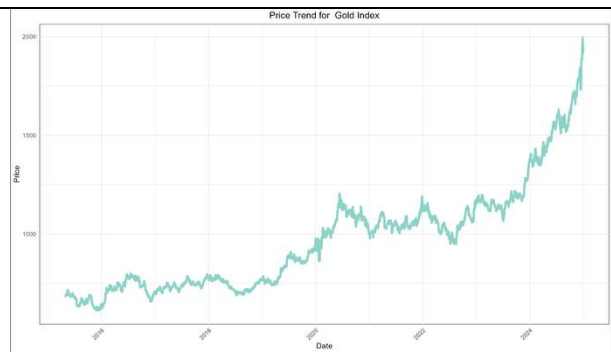


Fig. 1.19: Gold S&P SPGSGC Index price trends 2015 to 2024.

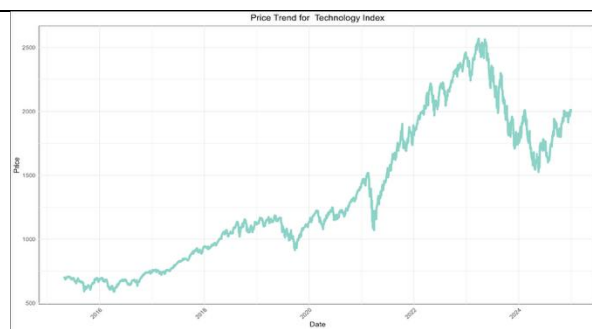


Fig. 1.20: Technology Dow Jones Global Technology Index W1TEC Index price trends 2015 to 2024.

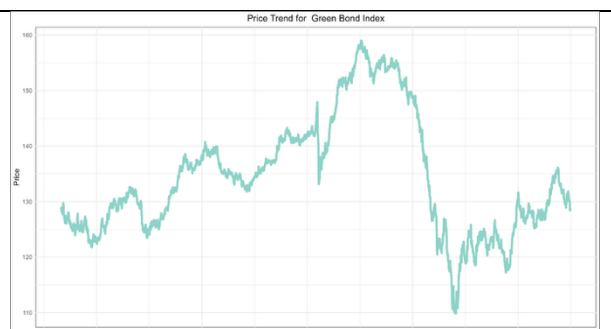


Fig. 1.21: Green Bonds S&P SPGRBND Index price trends 2015 to 2024.

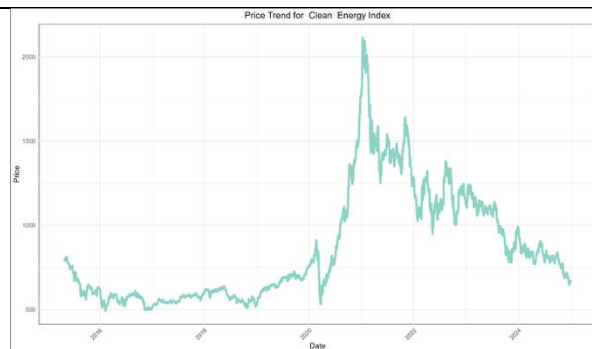


Fig. 1.22: Clean Energy S&P SPGTCSUP Index price trends 2015 to 2024.

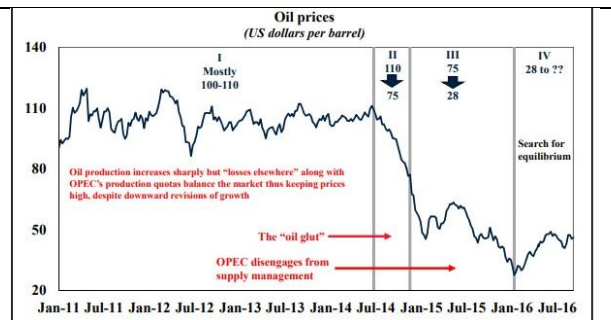


Fig. 1.23: Oil price trends 2011 to 2016
(Source: World Bank)

1.8.1 Malaysia Index

Fig-1.6 shows Oil Crisis (2015-16) was a stormy time in the Malaysia Index. As an oil-exporting country, the Malaysian economy was significantly influenced by the fluctuations in

the world oil prices. When oil prices plummeted in 2015, the stock markets of energy exporting countries like Malaysia plunged. One of the key sectors that contribute to the economic growth of Malaysia, the energy sector, lost a lot and this led to a general market decline. Nevertheless, towards the end of 2016, the market began to stabilize as the oil prices stabilized, and the economy adjusted to the new price environment. This recovery was also due to fiscal and monetary interventions and stabilization of the global market.

The COVID-19 pandemic (2020-21) hit Malaysia, and most of the world markets, hard. The stock market plummeted in March 2020, in response to the mass economic shutdowns, lockdowns, and uncertainty of the virus. As the world markets adjusted to the new normal, the Malaysian economy gradually began to recover, courtesy of the fiscal stimulus measures and the subsequent introduction of vaccines. The stabilization of the Malaysian market was the feature of the recovery period and the situation was getting better gradually as the investor confidence was restored and the international trade was re-established.

1.8.2 Vietnam Index

Fig-1.7 show, Similar to Malaysia, Vietnam was also hit by the Oil Crisis (2015-16), although perhaps not as severely due to its lesser reliance on oil exports. The recent plunge in oil prices since 2015 caused some volatility in the stock market as the world energy markets adjusted. The world economic downturn that accompanied the oil price collapse was bound to have impacted the economy of Vietnam which has a huge manufacturing and export sector. However, Vietnam might be able to recover quicker than oil-based economies since it had diversified its export markets and focused on its strong industrial sector, including electronics and textiles. By the end of 2016, the market began to stabilize and oil prices found a new equilibrium.

During the COVID-19 pandemic (2020-21), the stock market in Vietnam was in line with the global market. The initial months of 2020 were marked by sharp declines, and the pandemic led to enormous economic shocks worldwide. However, the fact that Vietnam was able to limit the spread of the virus relatively early, along with the global rollout of vaccines, helped to boost investor confidence. As a result, the market has rebounded strongly in late 2020 and into 2021, as government stimulus and the opening of international trade.

1.8.3 South Korea Index

Fig-1.8 shows, Oil Crisis (2015-16) impacted the stock market in South Korea, although the fact that the country relied heavily on energy imports meant that the market was likely to have been positively impacted by the low oil prices. As the world energy prices have fallen, the economy of South Korea, which is largely based on manufacturing and exports, may have enjoyed some short-term gains in the form of lower production costs. However, the overall economic recession in the world and the decrease in the demand of goods were likely to lead to some fluctuations in the market at this period. The stabilization of oil prices and the general economic readjustment was seen in the recovery of the South Korean market by 2016.

During the Russia-Ukraine War (2022-23), the market in South Korea was very volatile since the energy prices rose due to the disruption in the global oil and gas supply chains. The fact that South Korea is an energy-importing nation was directly impacted by the rising energy prices that increased the cost of production in key sectors like manufacturing and technology. The war also contributed to the broader geopolitical uncertainties, which led to market jitters and fluctuations. The reliance of South Korea on international supply chains and energy imports implied that it was more susceptible to these changes, and the market was in a state of continuous instability during this period.

1.8.4 Japan Index

Fig. 1.9 shows, Japan, which is a net importer of oil, had a more favorable experience in the Oil Crisis (2015-16), since the country enjoyed the low oil prices. The sudden decline in the world oil prices probably helped in lowering the energy prices in Japan, which gave a short-term economic stimulus. The manufacturing, technology, and industrial output-oriented Japanese economy would have experienced some positive impacts of the reduced cost of production. Nevertheless, Japan was not immune to the wider global economic downturn and this caused a certain amount of volatility in the stock market. By the end of 2016, the market stabilized as the global energy market adapted to the new lower prices.

In the COVID-19 pandemic (2020-21), the stock market in Japan declined sharply in early 2020, as did the rest of the world. The first economic impact of the pandemic, along with the interruption of international trade, resulted in substantial losses in the market. Nevertheless, the fast reaction of Japan to the pandemic and the successful policy response allowed the

market to stabilize gradually in 2020 and in 2021. The fiscal stimulus by the government and the slow recovery of the global trade were the main contributors to the recovery of Japan and by the middle of 2021, the market had recovered most of the losses incurred in the early days of the pandemic.

1.8.5 U.S. Index

Fig-1.10 shows, U.S. economy, which is diversified, was affected in both ways during the Oil Crisis (2015-16). Although the energy sector, especially oil and gas, suffered as a result of the sharp decline in oil prices, other sectors of the economy, including technology, finance, and consumer goods, might have fared better. The reduced energy prices probably gave a boost to the energy-intensive sectors such as manufacturing and transportation since their costs of operation were reduced. Although the oil industry experienced severe drops, other sectors cushioned the overall negative effect, resulting in a less drastic decline than in economies that depended heavily on oil exports. The stock market was volatile at this time but began to stabilize in 2016 when oil prices stabilized and the rest of the U.S. economy adjusted to the new energy environment.

The U.S. market experienced a sharp and steep drop in the early months of 2020 during the COVID-19 pandemic (2020-21). The panic about the virus, the shutdown of the global economy, and the uncertainty of the long-term consequences of the pandemic caused the market crash. Nevertheless, the U.S. market was one of the quickest to recover in the world, which was possible thanks to the massive fiscal stimulus plans, the active monetary policy, and the confidence of investors that was regained as the vaccination process continued. The rebound was driven by a mix of government stimulus, strong corporate profits in some industries (such as technology), and the general strength of the U.S. economy.

1.8.6 Russia Index

Fig-1.11 shows, Russia was particularly affected by the Oil Crisis (2015-16) as it relies heavily on oil exports. The sudden decline in oil prices had a devastating effect on the Russian economy and this was evident in a sharp decline in the stock market during this time. Since oil is one of the major export products of Russia, its depreciation negatively affected the income of the country, which led to a market crisis in 2015. Also, the general economic downturn in the world and the declining demand of Russian exports also contributed to the

situation. The stabilization of the economy by the Russian government and the gradual increase in the global oil prices by the end of 2016 helped the market to recover, but the recovery was not as fast as in the non-oil-dependent economies.

The Russia-Ukraine War (2022-23) was a time of high volatility in the Russian stock market. The war resulted in high energy prices that resulted in temporary market imbalances. Meanwhile, the war led to global sanctions against Russia, which caused uncertainty in the market, capital flight, and trade disruptions. These sanctions, along with the general geopolitical instability, caused the Russian index to plummet in 2022 and into 2023. Nevertheless, the market experienced a temporary surge in 2022, probably due to the changes in global energy prices as the war affected supply chains. The post-war situation and the impact of international sanctions still burdened the market, making it unstable in general.

1.8.7 Thailand Index

Fig-1.12 shows, Oil Crisis (2015-16) impacted Thailand relatively quietly as compared to oil-exporting countries. Thailand being an emerging market is less reliant on oil exports and is thus somewhat immune to the worst of the declining oil prices. Nevertheless, the market was still affected by the global oil price fluctuations, especially in the energy-related industries and export-related industries. The market in Thailand was somewhat volatile at this time, but the effects were not as drastic as in other countries whose economies were highly dependent on energy exports. As oil prices stabilized towards the end of 2016, the Thai market was also recovering, with the wider region growing and global trade picking up.

Thailand, as well as most other countries, suffered major losses in its stock market during the COVID-19 pandemic (2020-21). The sudden decline in 2020 was caused by mass lockdowns, global trade disruptions, and the devastating effect of the virus on the economy. Being an export-oriented economy, the industries in Thailand, especially tourism, manufacturing, and agriculture were severely affected. Nevertheless, with the global economy adapting and governments implementing fiscal stimulus policies, the Thai stock market started to rebound in stages in 2021. The recovery was fuelled by a slow reopening of the economy, vaccination programs, and the restart of international trade.

1.8.8 Indonesia Index

Fig-1.13 shows, Indonesia is an emerging market that is closely connected to energy industries, and it was affected to some extent by the Oil Crisis (2015-16). The nation is a major exporter of oil and natural gas and therefore the sudden decline in oil prices would have impacted its market. The energy-dependent sectors especially would have suffered, but the Indonesian economy, which is diversified and manufacturing, agriculture, and natural resources-driven, was not as susceptible as the oil-exporting economies. With oil prices stabilizing towards the end of 2016, the Indonesian market started to recover, as the demand of commodities increased and the global trade recovered.

The COVID-19 pandemic (2020-21) affected the Indonesian stock market, like most other markets around the world. At the beginning of 2020, the Indonesian market was hit by a sharp drop caused by the global economic shocks, lockdowns, and investor uncertainty. Nevertheless, the market in Indonesia started to recover in 2021 as the impact of the pandemic began to stabilize and government stimulus plans were implemented. The recovery was slow and was mainly fuelled by government interventions, the slow reopening of the economy and the global revival of demand in major export industries.

1.8.9 Taiwan Index

Fig-1.14 shows, The Oil Crisis (2015-16) did not have as much impact on the economy of Taiwan, which has a robust technological and industrial sector, as it did on oil-exporting countries (2015-16). Although the market was somewhat volatile due to the fluctuation in global oil prices, the export-oriented economy of Taiwan, especially the high-tech industry, was not as sensitive to energy prices. The market was a bit volatile in the year 2015, but generally, the economy of Taiwan was stable because of its high industrial and technological production. With the stabilization of oil prices in 2016, the Taiwanese market has recovered, and the increasing demand in technology and electronics has helped it.

The market in Taiwan probably experienced its ups and downs during the Russia-Ukraine War (2022-23), as the global energy prices fluctuated and the international supply chains were disrupted. The war worsened the rise in energy prices globally, which impacted supply chains and trade routes. Nevertheless, the robust technology industry in Taiwan, such as semiconductor manufacturing, probably served to mitigate the effects, with the demand of

technology products in the world being strong. Although there was some volatility, Taiwan was more resilient than other regional markets due to its technological prowess and the stock market must have enjoyed some form of stability. In 2024, the stock market in Taiwan was still growing steadily.

1.8.10 New Zealand Index

Fig-1.15 shows, The New Zealand Index experienced some volatility during the Oil Crisis (2015-2016), but it was not as pronounced as in the case of countries that are highly dependent on oil exports. Since the economy of New Zealand is diversified, it was not as sensitive to the sharp decline in oil prices. Although the export-oriented industries in the country, including agriculture and tourism, might have been affected to some extent, the impact was not as acute as experienced by the oil-exporting countries. By the end of 2016, the market demonstrated a slow recovery, which was a sign of the overall stabilization of the global market following the oil price crash and the adaptation to the new economic reality.

The New Zealand Index was stable in 2017, and there was no volatility in the index during the Climate Crisis. This was probably because of the worldwide trend towards sustainability and green investments, which could have had a positive effect on the market, but in a more long-term way. The high reputation of New Zealand as an environmentally conscious country and its investment in sustainable industries could have caused a slight positive trend in this period. The market was probably slightly strengthened by a gradual rise in green investments and climate change awareness among the population.

The COVID-19 pandemic (2020-2021) caused a sharp decline in the New Zealand Index in early 2020, reflecting the general decline in the global market caused by the pandemic. This was probably due to the economic slowdown in the world, closure of businesses and panic in the market. Nevertheless, by the middle of 2020, the stock market in New Zealand started to recover, following the rest of the world, as fiscal stimulus packages were implemented, and the rollout of vaccines gave hope of a normalcy. The index was resilient in 2021, and its recovery was steady in line with the global economic recovery.

The Russia-Ukraine War (2022-2023) led to certain volatility in the New Zealand Index, but not as significant as in other countries that are more directly affected by changes in energy prices. Although the economy of New Zealand is not as reliant on energy imports as Europe or other parts of the world, the uncertainty in the global economy, which was caused by

geopolitical tensions and energy market disruptions, probably led to some slight price fluctuations during this period. Nevertheless, the diversified economy of New Zealand stabilized the market compared to more energy-sensitive countries.

The New Zealand Index showed significant declines in 2024 when the Iran-Israel Conflict intensified. This is indicative of uncertainty in the global markets, particularly with energy prices rising, and risk-off sentiment rising. But the geographic distance and the less direct exposure to the Middle East crisis probably softened the blow to some extent in New Zealand. The geopolitical tensions played a role, but the country was in a better position to absorb the short-term volatility than more open economies.

1.8.11 Peru Index

Fig-1.16 shows, The Oil Crisis (2015-2016) caused a sharp decline in the Peru Index, as it is dependent on commodity exports, such as oil. When the world oil prices crashed in 2015, Peru, among other Latin American economies, was adversely affected. The economy of the country is highly dependent on the demand of its exports in the world market and therefore the fall in the price of oil had a direct impact on its stock market. By the end of 2016, the market started recovering, as it adapted to the new economic reality, and the global oil prices stabilized. Nevertheless, the recovery was slow and more evident when the world commodity prices started to stabilize, which favoured the mining and agricultural sectors in Peru.

In 2017, there was no significant change in Peru Index due to Climate Crisis. However, as the country is over-reliant on mining and agriculture, a few investments increase might have been diverted to more sustainable mining activities and renewable sources. The impact was not so bidirectional and instant as in those countries, in which green finance has been developed, but the gradual shift to sustainability was likely to cause the development of these industries to a certain degree. Peru applying to the economy may have seen some increase in investments in the mining technologies and renewable energy at the light of the existing global panic about the environmental issues.

The COVID-19 pandemic caused a significant drop in the Peru Index in 2020. The world economic lockdown, which was further aggravated by the ban on trade, tourism, and industry, had a devastating effect on the economy of Peru. Being a significant exporter, the global supply chain disruptions, along with the sudden decline in commodity prices, probably led to a significant market decline at the beginning of 2020. Nevertheless, with the global

economies adapting and stimulus packages being implemented, the market started recovering in the middle of 2020. The economic recovery in Peru was similar to the rest of the world, as the stock market recovered in tandem with the rest of the world as it tried to contain the pandemic and reopen the global economy.

The Peru Index was volatile during the Russia-Ukraine War (2022-2023), although not as acute as in countries that depend more on energy exports. Even though Peru is not directly affected by the energy price spikes as many European or energy-importing countries, the shocks in the global markets, especially the energy prices and the overall economic uncertainty, probably influenced the trade and investment prospects of the country. Being a country that relies on commodity exports, such as copper, the effects of the war on the world markets could have caused some price changes in the stock market.

The Iran-Israel conflict in 2024 led to a visible volatility in the Peru Index, with short-term declines related to increased geopolitical tensions. The high dependence on commodity exports exposed the economy of Peru to the changes in the global markets, particularly energy prices. In case the conflict resulted in major disturbances in the global supply of oil or gas, this would have resulted in instability in the global supply chains and adversely affected the economic performance of Peru. Nevertheless, the market in Peru demonstrated its ability to overcome the initial shocks of the pandemic, but it is still vulnerable to the overall geopolitical and market changes.

1.8.12 Canada Index

The Fig-1.17 shows, Canada Index was quite volatile during the Oil Crisis (2015-2016), primarily due to the fact that Canada depends on oil exports. When oil prices crashed in 2015, the energy sector was hit hard, and this dragged the rest of the stock market. The fall in oil prices caused a decline in the resource-based industries in Canada, including energy and mining. Nevertheless, towards the end of 2016, when the global oil prices started to stabilize, the market in Canada started to recover. This recovery was in tandem with the global adaptation to the new lower oil price environment and the Canadian stock indices recovered the previous losses.

In the COVID-19 Pandemic (2020-2021), the stock market in Canada saw a sudden decline in early 2020, reflecting the global economic recession. The pandemic brought about a lot of disruptions particularly in energy, manufacturing and export sectors. The first market decline

was caused by the economic shutdowns, the disruption of global trade, and the abrupt demand stoppage of energy. But towards the end of 2020, the market started to recover as fiscal stimulus packages, economic recovery plans, and the worldwide vaccination process started to alleviate the adverse effects of the pandemic. Canada, which has a diversified economy, especially enjoyed the rebound in such sectors as technology, healthcare, and consumer goods.

After 2024, when the Iran-Israel Conflict intensified, the stock market in Canada still demonstrated the positive tendency, and the overall situation was rather optimistic. Canada was not as directly affected by the geopolitical tensions in the Middle East, but it was sensitive to the changes in the global markets, especially energy prices, since the country is a large oil producer. The fluctuation in the world oil markets as a result of the Iran-Israel conflict must have had some effect on the Canadian stocks, although not as much as the countries that are more directly involved in the energy markets of the Middle East. The market in Canada was still affected by the global concerns but was resilient because of its diversified economy and stable recovery after the pandemic.

1.8.13 Philippines Index

The Fig-1.18 shows, Philippines being a non-oil-exporting country demonstrated a more moderate reaction to the Oil Crisis (2015-2016). Although the country had some fluctuations during this time, they were not as high as in the oil-exporting countries. In 2015, it experienced a moderate decline, probably as a result of the instability in the global markets as a result of the oil price crash. Nevertheless, by 2016, the market stabilized and started recovering, with the country not being as severely hit by the decline in oil prices as other countries.

The Philippines Index was no exception, as it dropped significantly in early 2020 during the COVID-19 Pandemic (2020-2021). With the development of the pandemic, the nation experienced a massive disruption of such industries as tourism, manufacturing, and trade. The Philippines was highly dependent on international trade and thus it was highly affected by the global slowdown. Nevertheless, with the lockdown restrictions being relaxed around the world and the world adapting to the new realities of the pandemic, the Philippines experienced a rebound in the middle of 2020. Similar to other markets, this recovery was

facilitated by stimulus packages, the introduction of vaccines, and the slow resumption of economic activity.

In 2024, the Philippines experienced volatility that was probably connected to the global uncertainties of the Iran-Israel conflict. Although the Philippines does not rely on oil exports as much as other countries, it is still vulnerable to global energy price changes and global supply chain shocks. The geopolitical instability especially in the energy markets may have a knock-on effect on the Philippine stock market, but the effect is likely to be less pronounced than in oil-dependent economies.

1.8.14 Gold Index

The Fig-1.19 shows, Gold as a commodity that is considered a safe-haven asset, the Gold Index reacted to the Oil Crisis (2015-2016) significantly. Investors tend to rush to gold as a store of value during times of economic uncertainty and market volatility, and this is what caused the rise in the price of gold during this period. In 2015, when the oil prices plummeted and the world markets were in turmoil, the Gold Index soared, which was an indication of the increased demand of gold during the crisis.

Likewise, another surge in gold prices was caused by the COVID-19 Pandemic (2020-2021). The first market crash in early 2020 caused investors to flee to safety, which led to a sudden rise in gold prices as people turned to safe, tangible assets. The spike in the Gold Index in 2020 was a direct consequence of the global financial uncertainty, which was further enhanced by lockdowns, mass economic shutdowns, and the general panic in the market due to the pandemic.

Another dramatic rise in the Gold Index occurred in 2024, during the Iran-Israel Conflict. The geopolitical instability especially in the Middle East contributed to the uncertainty in the global markets. The threat of the global oil supply being disrupted, along with the threat of wider geopolitical consequences, caused investors to turn to the safety of gold once more. Consequently, the price of gold increased dramatically in 2024, as the demand of a safe asset in the period of global uncertainty was high.

1.8.15 Technology Index (Price Trend)

The Fig-1.20 shows, Technology Index experienced a relatively stable growth throughout the Oil Crisis (2015-16), with the sector being less directly affected by the oil price volatility that led to energy market instability. Although the oil crisis had devastating impacts on oil-exporting economies and energy markets, the technology sector was relatively cushioned because of its increasing relevance and demand at this time. The growing dependence on technology-based solutions to different industries must have given some form of stability and growth, despite the global economic turbulence.

The Technology Index fell precipitously in early 2020, as the rest of the market responded to global lockdowns and recession fears during the COVID-19 Pandemic (2020-2021). Nevertheless, the rebound was rapid, with the pandemic-induced acceleration of digital transformation. With businesses and individuals relying on technology to work remotely, communicate, and engage in e-commerce, the need to find tech solutions increased. This sudden transition to online services and digital platforms resulted in a massive increase in the technology sector, and the index has experienced a sharp recovery in the second half of 2020 and into 2021.

During the Russia-Ukraine War (2022-2023), the Technology Index was somewhat volatile, which can be explained by global supply chain issues and overall economic uncertainty. Nevertheless, the technology industry was relatively stable, probably due to the growing demand in tech solutions during the disruptions caused by the war. The technology index was supported by the ongoing global trend of digital transformation and technological innovation, despite geopolitical tensions and inflationary pressures impacting other sectors.

In 2024, in the Iran-Israel Conflict Escalation, the Technology Index indicated resilience amidst geopolitical tensions around the world. Although the market was jittery to some extent in reaction to the conflict, the technology sector still showed its long-term growth potential. The resilience of the sector is explained by its importance in the contemporary economies, and the confidence of investors in tech stocks, which have been regarded as the key to innovation and growth.

1.8.16 Green Bond Index (Price Trend)

The Fig-1.21 shows, Green Bond Index probably had a dull price action during the Oil Crisis (2015-16). Although the crisis resulted in a greater interest in energy markets, the short-term

economic recovery and oil price fluctuations might have diverted investors away from the long-term investments that are linked to sustainable finance. Therefore, green bonds, which are sustainability-oriented, would have grown relatively slower than other financial assets, but the sustainability movement as a whole started gaining momentum at this point.

The Green Bond Index experienced a positive trend in 2017, during the Climate Crisis. This was a transition to sustainability, with the world becoming more aware of climate change and environmental problems. The increasing demand of sustainable investments was clear, and the green bond market started to grow. The index continued to grow steadily as investors were more interested in green bonds as a means of financing climate-related projects.

The Green Bond Index showed a slight recovery in the COVID-19 Pandemic (2020-2021). Although the pandemic caused a huge economic shock, the crisis also showed the importance of climate resilience and sustainable investments. Governments across the world introduced stimulus packages, which included green projects and sustainable recovery funds. The green bond market thus gained momentum as investors saw the long term value of sustainable investments in an uncertain economic environment.

The green bond market was impacted by the Russia-Ukraine War (2022-2023) both positively and negatively. The short-term volatility in the global energy markets may have caused some disruption, but the ongoing focus on energy independence and the need to take action on climate likely benefited the green bond market. As the countries attempted to reduce the reliance on Russian energy and diversify the energy supply, the investments in clean and renewable energy became more attractive. This increased awareness of the necessity of sustainable solutions contributed to the green bond market, despite the geopolitical turbulence.

In the Iran-Israel Conflict Escalation, the Green Bond Index was relatively stable by 2024. Sustainable investments were promising despite geopolitical instability. Green bonds, which are a part of the increasing trend of environmental responsibility, were less impacted by the immediate shocks of the conflict, indicating that the overall trend of climate change and sustainability is a long-term market driver.

1.8.17 Clean Energy Index (Price Trend)

The fig-1.22 shows, Clean Energy Index grew more subdued during the Oil Crisis (2015-16). Although the world was concerned with the fall in oil prices, the renewable energy focus at

this time might not have been as strong. The oil crisis shifted most of the focus to the short-term economic recovery and therefore the clean energy sector did not experience as much growth in this time. Nevertheless, clean energy investments were still increasing gradually, as the necessity to diversify beyond fossil fuels started to gain traction.

The Clean Energy Index showed a significant positive trend in 2017, in the context of the Climate Crisis. With the world increasingly worried about climate change, investments in clean technologies and renewable energy started to increase. The 2017 sustainability drive has led to a sharp rise in the demand of clean energy, which is being fuelled by international climate agreements and national policies to cut carbon emissions. It was during this period that more aggressive investments in the clean energy sector began.

The COVID-19 Pandemic (2020-2021) was a great supporter of the Clean Energy Index. Green recovery and cleaner technologies became a priority with the introduction of recovery plans in countries across the world. The pandemic increased the consumption of renewable energy sources and green technologies, and nations invested in sustainable infrastructure. The emergence of the clean energy industry during this period was a sign of the world realizing the need to have environmental sustainability as a component of the post-pandemic economic recovery.

In 2022, the Clean Energy Index rose sharply during the Russia-Ukraine War (2022-2023). The need to seek alternative sources of energy, which are renewable, rose as countries attempted to reduce their dependence on Russian sources of energy. The war acted as a catalyst to the pace of clean energy transitions in Europe and other parts of the world. However, this growth was followed by a decline in the second half of the period, which was likely influenced by the general geopolitical instabilities and volatility in the energy market.

In 2024, the Clean Energy Index was on a downward trend, as the Iran-Israel Conflict Escalation took place. The more short-term geopolitical risks likely outweighed the long-term investments in clean energy, leading to some volatility. Nevertheless, the future of clean energy investments is still optimistic, with the world shift towards renewable energy still being a priority of most countries.

To sum up, the stock market indices discussed in the course of this report have different responses to different global crises depending on their economic structure, dependence on certain industries, and vulnerability to the global energy markets. These indices offer useful

information on how various economies have managed to go through global shocks, and the need to diversify and be flexible in the face of crisis.

1.9 Crisis and APEC's Responses: Navigating Through Global Challenges

1.9.1 Oil Crisis (2015-2016):

The Fig-1.23 shows, 2015-2016 Oil Crisis, characterized by a sharp and prolonged fall in world oil prices, was caused by an oversupply of oil, especially in the United States, and a lack of demand in the world. Between 2014 and early 2016, the price of crude oil dropped by more than 70 percent, to less than 30 dollars per barrel (Prest, 2018). This sharp price decline was among the biggest declines in modern history, caused by a boom in U.S. shale oil production, a move by OPEC to keep production steady, and a slowing global economy, especially in emerging markets. The U.S. shale oil boom turned the U.S. into a major participant in the international oil market, causing a major supply surplus (Khan, 2016). These dynamics notwithstanding, the oil prices were low over a long period because of low demand especially in China and other emerging economies which reduced the anticipated gains of cheaper oil to the global economy.

The effects of the oil crisis were not evenly spread in the world. Countries that export oil were hit hard, especially those that depended heavily on oil revenues. Oil-dependent countries like Russia, Venezuela, Nigeria, and Malaysia, which rely on oil exports to finance their government budgets and economies, were in dire economic straits as their main source of revenue dried up (Zhang et al., 2024; Ikein, 2017). These nations were faced with depreciation of their currencies, increased inflation and severe recessions. Conversely, oil-importing countries, particularly in Asia and the Pacific, had mixed results, with the reduced oil prices offering economic reprieve but also posing problems in other areas. The Asia-Pacific Economic Cooperation (APEC) countries such as China, Japan, South Korea, and Australia responded differently to the crisis because of the differences in their economic systems and the degree of oil dependence (Zhang & Khan, 2024).

The lower prices were beneficial to China, the largest importer of oil in the world, as it helped to alleviate inflationary pressures and enhance its trade balance. Nevertheless, the

general economic slowdown in China, which was compounded by the collapse of oil prices, dragged on its growth prospects. The economy of China had been shifting towards a consumption-driven economy, but the decline in the world demand hit the major industries and its slowdown added to the global recession (Somasekhar, 2024). Japan, another large oil importer, also experienced some reprieve with the declining oil prices as energy prices fell especially in the manufacturing and transport industries. But Japan has long been grappling with deflation and slow growth, so the positive effects of cheaper oil prices did not translate into a meaningful increase in overall economic activity (Thorbecke, 2025). In the example of South Korea, another oil-importing country in the APEC group, the fall in oil prices provided a temporary relief to its manufacturing sector, which is energy-intensive. However, the favorable economic impacts were offset by the reduced demand in the world and regional uncertainties (Thorbecke, 2025).

Australia, which is an importer of oil and a producer of natural resources, including coal and liquefied natural gas, had quite a mixed experience. On the one hand, the fall in oil prices led to the fall in energy prices, which was beneficial to the transportation and manufacturing sectors. However, the decline in global energy prices also hurt the Australian resource sector, which is a major part of the Australian economy. Therefore, despite the fact that the Australian economy was not directly impacted by the oil price collapse as the oil-exporting countries, the oil price decline did play a role in the uncertainty that the mining and resource industries in Australia were facing (Liu et al., 2023).

The crisis also had a significant impact on other economies within the APEC group. The fall in prices was both a curse and a blessing to oil importing countries like Indonesia and the Philippines. Despite the fact that the low oil prices helped to decrease the energy costs and inflation, the effect on the economy of these countries was not so strong because of the decrease in international trade and investment (Ji et al., 2018; Sovacool, 2017). The benefits of low oil prices in these nations were offset by the reduction in demand of their exports, particularly by China. On the other hand, the oil price crash severely affected oil-based economies like Brunei and Malaysia. In the Malaysian case, the currency was devalued and the government was facing mounting fiscal pressures as oil revenues were running out. The fall in oil prices exposed the vulnerability of these economies that have long been excessively reliant on energy exports (Wang, 1993).

The crisis also highlighted the importance of diversifying the economy in the oil-exporting nations of APEC. The loss of oil revenues forced oil-rich nations like Brunei and Malaysia to alter their fiscal policies, cut subsidies, and find alternative sources of income (Dagher and Hasanov, 2022). Malaysia government introduced policies like Goods and Services Tax (GST) to counter the falling oil revenues, yet these measures were not without criticism at home, which shows the challenges of economic reform in oil-based economies (Alappatt & Shaikh, 2014). The crisis also caused most of these countries to reconsider their long-term economic policies, and the emphasis was on diversification to reduce the dependence on oil exports.

The collapse of oil prices also had a broader impact on the energy market. The shift in the global energy balance gave an opportunity to countries that had invested in renewable energy as oil-exporting countries in APEC were damaged (Agboola et al., 2024). To illustrate, Australia has been increasingly focusing on the diversification of its energy mix, moving towards cleaner sources of energy, including solar and wind. Other APEC economies, such as Japan and South Korea, also made advances in the utilization of renewable energy, which can ultimately reduce their reliance on oil imports (McCauley & Pettigrew, 2023).

The crisis also reduced the long-term prospects of oil prices and majority of analysts believed that the price of oil would be low in the foreseeable future. The rise of shale oil production in the U.S., the growing popularity of alternative energy sources, and the emergence of energy efficiency all pointed to the fact that oil prices would not be as high as they used to be (Shakya et al., 2022). This meant to the APEC countries that oil-exporting economies needed to adjust to a new energy reality and oil-importing economies had new challenges in the form of global economic volatility, trade and investment.

In conclusion, the oil crisis of 2015-2016 was a revolutionary experience in the world energy market and had a long-term effect on the economies of APEC. Even though the oil-importing nations, particularly in Asia, enjoyed a short-term relief as the energy prices went down, the crisis revealed the vulnerability of the oil-exporting economies in the region and the need to diversify their economies further. The shift towards renewable energy sources and energy efficiency during the post-crisis years also changed the energy situation in the region. Lastly, the oil price collapse showed how the world economies are interdependent and how the APEC countries need to adapt to the new energy markets in a more complex and uncertain world.

1.9.2 Climate Crisis (2017):

In 2017, the climate crisis in the world became more apparent, as record temperatures, extreme weather, and a feeling of international alarm were recorded. It was marked by several significant environmental changes and the growing impact of climate change, which highlights the need to take coordinated international action to minimize its impact (Xu et al., 2023; Seneviratne et al., 2021). According to NASA, 2017 was one of the hottest years in history, being the second warmest year in the world, together with 2015 (NASA Earth Observatory, 2017). This increase in temperature was a part of the alarming trend of the global average temperature increase, and certain regions were exposed to severe heat waves, droughts, and wildfires. These changes in temperature were largely attributed to human induced activities such as burning of fossil fuels and deforestation which have contributed to the rising concentration of greenhouse gases in the atmosphere.

One of the most notable political events of 2017 was the decision of the U.S. President Donald Trump to announce the withdrawal of the nation out of the Paris Agreement, a historic international agreement to combat climate change (Gibson, 2025). World leaders, scientists and environmental groups criticized this move. Nevertheless, this failure did not stop numerous state and local governments, as well as businesses throughout the United States, to commit to the objectives of the Paris Agreement and to keep on working to minimize emissions. The international reaction highlighted the conflict between national political agendas and the scientific consensus that urgent action is required to avoid the most disastrous consequences of climate change. At the international level, although other nations demonstrated strength in their adherence to the Paris accord, the U.S. withdrawal posed a major threat to global climate diplomacy (Alam et al., 2024).

Natural disasters were also devastating in 2017, with most of them being worsened by climate change. The Atlantic hurricane season was especially active, and Hurricane Harvey struck Texas, resulting in devastating floods and economic losses (Ruiz-Campillo, 2024). The aftermath of Harvey caused an estimated 125 billion dollars in damages and was one of the most costly natural disasters in American history. Soon after, Hurricanes Irma and Maria devastated the Caribbean and some areas of the U.S., with Maria leaving Puerto Rico without power for months and creating a humanitarian crisis (Mooney, 2024). These hurricanes were a grim reminder of the increasing severity and frequency of extreme weather events related to climate change crisis (Lele, 2020). Besides hurricanes, wildfires in California and other

regions of the western United States destroyed communities, which were caused by increasing temperatures, long-term droughts, and dry vegetation. As an example, the Tubbs Fire in California turned out to be one of the most devastating and deadly wildfires in the history of the state, killing people and burning thousands of houses (Convoy of Hope, 2025).

As hurricanes and wildfires took center stage in the news, the year also witnessed some worrying developments in the polar regions, where climate change is occurring at a faster pace. The Arctic was still warming at a rapid rate, and sea ice levels reached record lows in the summer. This is referred to as Arctic amplification and it has severe consequences to the planet such as the increase in sea levels and the destabilization of weather patterns all over the world (Malik et al., 2025). The ice sheet in Antarctica was also experiencing a lot of instability as huge icebergs were breaking off and adding to the already increasing sea levels in the world. These shifts were attributed to the direct consequence of the warming global temperatures, which are melting the polar regions at a rate that is higher than the forecasted, further increasing the risk of rising seas that threaten coastal communities across the globe (Naughten et al., 2023).

In 2017, the scientific community also gained a better understanding of climate change, as the Intergovernmental Panel on Climate Change (IPCC) released another report on the grim effects of doing nothing. The IPCC highlighted that the global temperature increase should be restricted to 1.5 °C to prevent disastrous effects on biodiversity, agriculture, water resources, and human health (IPCC, 2019). The report emphasized that such a goal would necessitate a higher degree of international collaboration than ever before and urgent measures to reduce carbon emissions, adopt sustainable practices, and switch to renewable energy sources. Scientific reports also pointed out that unless the rate of emissions is reduced, the effects of climate change will be irreversible, and the world will experience more extreme weather conditions, food and water insecurity, and mass displacement of people (Ghorbani et al., 2023).

As political leaders and governments struggled with the problem, 2017 also witnessed a rise in awareness and activism about climate change. The world activists, particularly the youth movements, started to speak louder than ever before, asking leaders to take more serious action (Wang et al., 2021). The year was characterized by an increasing awareness of the climate crisis as a major problem that cuts across national boundaries, economic models, and political philosophies. One of the most recognizable faces of the climate movement was

Greta Thunberg, a Swedish teenager who began striking out of school in 2018 to demand more action on climate, and who would become the face of the youth-led climate action movement that would only grow exponentially in the years to come (Smith, 2022).

The increase in renewable energy in 2017 continued to rise despite political and environmental setbacks. Technological innovations and the declining cost of production were increasing the rate of renewable energy sources like solar, wind, and others. Other nations like China, India, and European nations were still at the forefront of increasing their renewable energy capacity (Hassan et al., 2024). In particular, China was the biggest investor in renewable energy globally, and in 2017, it had more than 30 percent of the global investment in this area (IEA, 2024). This growth in renewables, however, also indicated that more investment in infrastructure and policy incentives were needed to make sure that clean energy becomes the main source of power in the world. The pace at which the energy transition was occurring was still an issue as the crisis was of such a scale (Nunes, 2023).

In conclusion, 2017 marked a new era in the debate on climate change in the global arena. It was the year of the increasing impacts of a warming world, the politics of international agreements, and the increasing necessity to act on climate now. However, the growing resilience of cities, businesses, and individuals, and technological advances in renewable energy provided a positive perspective on the future (Abbass et al., 2022). However, the window of opportunity to take meaningful action was closing rapidly, and the need to collaborate and innovate internationally had never been more urgent. The 2017 events served as a stark reminder that the climate crisis is not just an environmental issue, but a security, health, and economic stability concern at the global level (Hariram et al., 2023). The global economic losses due to climate change are likely to be incurred because of the decrease in productive capacity and the likelihood of land, capital stock, and people being damaged by higher temperatures. The increase in temperature and alteration of rainfall patterns are likely to decrease agricultural production, and the rise in temperature decreases the productivity of labour and raises the degree of heat-related illness and death among workers. Rising sea levels have the potential to flood productive coastal land and augment the harm of coastal floods. The occurrence of extreme rainfall more often leads to the aggravation of river floods that may lead to the destruction of capital. Recent studies have indicated that the physical effects of climate change could lead to a net global economic effect of 6.6 percent of GDP by the end of the century. The economic effects will differ among countries based on the present and future temperatures, exposure to extreme weather, and economic systems.

The physical impacts of climate change under a baseline scenario are projected to cause long-term economic losses of 7.3 percent of GDP in the APEC region by 2100 (Kumar, 2024; Akhtar, 2016). Lower-middle-income APEC member economies near the equator will be the worst hit by these economic losses. As an example, Singapore, Thailand, Indonesia, and Vietnam may lose over 20 percent of GDP by 2100 (ADB, 2009). Conversely, the developed APEC economies in higher latitudes, including Canada, the United States, South Korea, Australia, and New Zealand, will experience reduced losses, less than 5 percent of GDP by 2100 (Shirley & Swanson, 2025). Nevertheless, the greatest losses are likely to be incurred in developing economies, but the effects are also high in developed economies such as Hong Kong and Singapore. The differences between countries emphasize the differences in exposure to the effects of flooding, which may have greater economic implications in countries with high coastal populations, including Singapore and Hong Kong (Overland et al., 2020).

1.8.3. Mean temperatures and extreme heat days

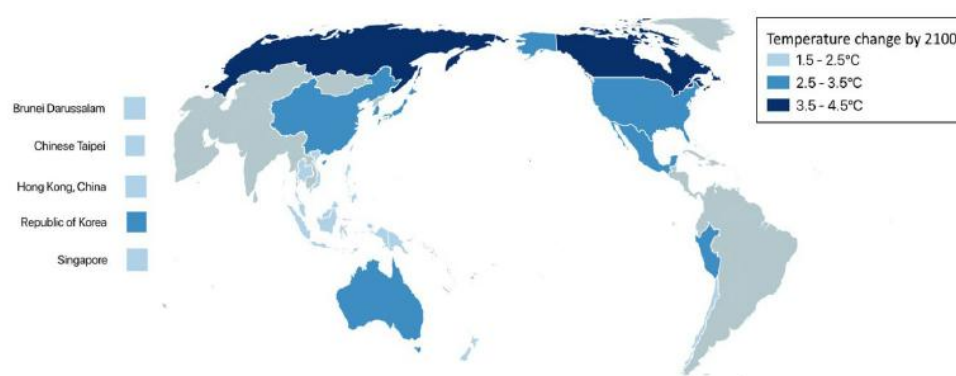


Fig. 1.24: Country Level Temperature Change, Baseline

Note: APEC member economies, average warming of 2.5°C compared to 1986-2005.

Source: World Bank Change Knowledge Portal, Vivid Economics

In the APEC member economies, the baseline scenario projects an average warming of 2.5°C compared to 1986-2005 by the end of the century, Figure 1.24 and Table 1.2 illustrates the projected rise in temperature of each APEC member economy. The annual average surface air temperature changes are greater in countries that are more northerly. Canada and Russia are projected to warm by more than 4C by the end of the century. Other studies, such as the IPCC report on Global Warming of 1.5°C, have also pointed out this possibility of greater

warming at higher latitudes (IPCC, 2018). Due to the rise in temperatures, the number of days with hazardous heat (more than 35°C) is likely to increase significantly by 2100. This rise is worst in equatorial nations that have high average temperatures in the present day. The number of days per year with dangerous heat is expected to rise by 144 days in Singapore by 2100. The effects of climate change on temperature are not as severe in 2050, with average temperatures expected to increase by 1.3°C, and a smaller increase in the number of days with hazardous heat (Ravindra et al., 2024).

The temperature changes shown at the country level are what would be expected in the baseline emissions scenario. Nevertheless, the consequences may be more radical. The temperature increase varies between 0.3°C and 2.8°C by 2050 and 0.9°C and 4.9°C by 2100, averaged across APEC member economies, compared to 1986-2005 levels (ESCAP, 2016).

Table-1.2: Changes in temperature related variables in baseline scenario of APEC countries.

Member	Change in annual average (°C)		Change in days with dangerous heat	
	2050	2100	2050	2100
Australia	1.4°C	2.6°C	19	37
Brunei Darussalam	1.6°C	1.9°C	15	59
Canada	1.1°C	2.0°C	0	0
Chinese Taipei	1.0°C	2.1°C	28	64
Hong Kong, China	1.1°C	2.2°C	5	54
Indonesia	1.3°C	1.9°C	18	77
Japan	1.1°C	2.0°C	18	67
Malaysia	1.4°C	2.6°C	-1	9
Mexico	1.0°C	1.8°C	7	0
New Zealand	1.1°C	1.9°C	0	35
Papua New Guinea	1.1°C	1.9°C	7	0
People's Republic of China	1.6°C	3.1°C	0	5
Peru	1.4°C	2.7°C	11	32

Philippines	1.0°C	1.9°C	11	124
Republic of Korea	1.4°C	2.7°C	4	4
Russia	2.2°C	4.1°C	0	0
Singapore	1.1°C	1.9°C	61	144
Thailand	1.1°C	2.2°C	-25	26
United States	1.7°C	3.3°C	2	8
Viet Nam	1.1°C	2.1°C	-13	28

Note: Relative to baseline period of 1986-2005, based on average of 16 Global Circulation Models

Source: World Bank Climate Portal, Vivid Economics

Climate change will lead to economic losses in terms of long-term declines in productive capacity as well as in terms of greater losses due to more frequent extreme weather events. Higher temperatures have a direct effect on labor and agricultural productivity, and rising sea levels can flood productive coastal land. Climate change is likely to adversely affect agricultural production in most APEC member countries, although the effects will vary by crop, region, and adaptive measures. As an example, wheat production will decrease by almost 20 percent in Malaysia, Vietnam, and the United States. These effects may however be greater or lesser depending on the extent of adaptation by farmers and industries, availability of water and other factors like increased CO₂ levels which in some cases may increase crop growth.

Also, the increase in temperature is almost bound to lead to the increase in sea level, which may flood the low-lying coastal areas. Small coastal economies such as Singapore and Hong Kong are likely to experience the most drastic losses of available land as a result of sea level rise, with up to 7.7 percent and 4.4 percent of land being lost respectively (Hallegatte et al., 2016). Even though adaptation measures can reduce some of these effects, including building sea dikes or investing in resilient infrastructure, the economic costs of both chronic effects and acute events like coastal and river flooding are expected to increase dramatically in the next few decades.

Climate change will also lead to extreme supply chain disruptions and the rise in the frequency and intensity of natural disasters, which will further worsen economic losses. Although the economic effects of such disruptions will be felt most in countries that are highly exposed to extreme weather events, such as coastal flooding or river floods, the total

costs will be pervasive. These effects are likely to be experienced more severely as global warming continues and losses are estimated to be 7.3 percent of GDP in the APEC region by 2100 (Kumar, 2024). It is important to note, however, that this estimate is done based on the assumption of current policy scenarios, and should global temperatures rise more than the projected 3C, the economic costs could be even higher. These risks are also exacerbated by the potential of climate tipping points, where small changes in the climate system can lead to more severe and irreversible changes.

Such measures as the transition to a low-carbon economy and clean energy technologies could help to reduce the economic impact of climate change to a considerable extent. The costs of such actions are estimated to be high, but the benefits of limiting the global temperature increase to 2°C are likely to be far more than the costs (Gao et al., 2017). To illustrate, the introduction of stricter climate policies and the reduction of fossil fuel dependence would save billions of dollars in economic losses. In addition, investments in renewable energy and energy efficiency, and the development of climate-resilient infrastructure can generate new sources of economic growth and reduce the long-term costs of climate change. Such actions are estimated to unlock new energy investment opportunities of up to 470 billion dollars annually in the APEC region alone by 2050, which would contribute to the creation of jobs and economic growth development (OECD,2025)

Overall, the economic and human costs of climate change in APEC are high, but the mitigation and adaptation measures have a high potential to reduce the impact. Investments in low-carbon infrastructure, clean energy, and resilient systems could lead to long-term economic benefits, as the region would be better prepared to deal with the risks of climate change (Liza et al., 2024).

The literature available shows that the physical risks of climate are already causing a significant effect on asset prices. To illustrate, the stock returns of firms in the countries of the APEC where the event occurred, e.g. in the agricultural or real estate sector, are observed to plummet after the occurrence of climate-related phenomena, e.g. hurricanes or droughts. Similarly, transition risks are already being felt in other industries like energy where firms that are slow to adopt low-carbon technologies are facing increased costs and lower profits (Mehmood et al., 2023). The APEC countries are especially vulnerable to these changes, and the majority of the economies in the region are highly dependent on carbon-intensive industries.

However, the most critical question is whether climate risks are being adequately priced in financial markets. The early evidence is that financial markets are under-pricing these risks, and when investors finally factor in climate-related costs into their models, there may be substantial downward revaluations of asset prices. This under-pricing is a problem to APEC economies because climate risks are increasingly material but not reflected in asset prices, which will be rectified in the future.

As a result, financial regulators in the APEC region are beginning to recognize the importance of integrating climate risks into financial supervision and regulation. Regulators are also promoting better integration of climate risks into financial stability monitoring, including through the NGFS (Network for Greening the Financial System). This includes developing climate scenarios to assess the impact of climate risks on financial systems and the necessity to make financial institutions conduct stress tests to identify their resilience to climate risks risk (NGFS,2019).

The APEC member economies need these regulatory changes. The region will probably improve the climate risk management of financial institutions to international standards, such as the Task Force on Climate-related Financial Disclosures (TCFD) recommendations. This transition to complete climate risk disclosure is essential to providing investors with the information they need to better price climate-related risks and position portfolios to the low-carbon transition.

Moreover, APEC regulators are encouraging financial institutions to understand more about the risks of climate change and how to deal with them, including requiring them to incorporate climate risk into their investment policies and governance structures. Financial supervisors are also trying to ensure that firms are reporting properly on their climate-related exposures, and they can introduce new regulatory requirements, such as capital buffers on firms with concentrated exposure to high-risk sectors, in case they are necessary.

The integration of climate risks into the financial market models will eventually lead to the reorganization of the financial markets in the APEC region. As nations work towards achieving climate goals in the Paris Agreement, low-carbon investments will be needed and investors will get an opportunity to shift capital to sustainable sectors. The financial institutions that can effectively deal with the climate risks will be able to enjoy the benefits in the long run, but those that fail to adapt will be financially unstable when the climate-related risks become a reality (ADB, 2024).

In conclusion, physical and transition costs of climate change are a significant threat to APEC economies. The financial markets will need to adapt to these risks as the region grapples with them, and regulators will play a key role in ensuring the financial system is more resilient to climate-related shocks. The growing interest in climate risk integration into financial practices will ultimately result in a change in the APEC financial environment, which will present both challenges and opportunities to the financial institutions and investors of the region (Shirley et al., 2025).

1.10 Green Credit Markets: Funding the Low-Carbon Transition

A green credit market is probably one of the most potential areas in the mitigation of climate-related financial risks. The transition towards low-carbon economy will imply massive investments in clean energy, sustainable infrastructure, and climate-resilient technologies (Wen et al., 2025). This movement will be helpful to the APEC region and the green credit markets will be able to provide the necessitated financing to these efforts.

1.10.1 Green Loans and Green Bonds

Green bonds and green loans are those financial instruments that are specifically issued to fund environmentally sustainable projects. Green bonds, one of the most important categories to have gained popularity over the last few years, constituted about three-fourths of the amount of sustainable bonds issued in 2018 (Fatica et al., 2021; Zhou and Kythreotis, 2024). In the same year, global green bond issuances totalled to 168 billion, with China and the United States as the biggest issuers (Lin and Hong, 2022).. Green bond market in APEC economies, particularly in Southeast Asia, is growing as nations start to adopt sustainable investment opportunities. The green bonds are sold at a premium, with lower yields than the traditional bonds, which is an incentive to companies to issue them. This premium indicates high demand and limited supply of green bonds, which implies that the market has a high growth potential.

Besides green bonds, green loans are a new niche in the market. Although not as advanced as the green bond market, green loans are becoming an opportunity to financial institutions, especially banks. The total amount of green loans issued in the world in 2018 was about 60 billion dollars, which is 30 percent more than in 2017 (Tommaso et al., 2025). Green loans are less than 1 percent of the total bank loans in the world, but they have a good growth path. Green loans can be used to finance low-carbon projects as well as to manage financial risks.

In China, evidence indicates that green loans have a lower non-performing loan ratio than traditional loans, which makes them a safer investment to banks.

1.10.2 Green Credit and Financial Risks

Green bonds and loans are green credit instruments that are very beneficial to financial institutions because they reduce the exposure to climate-related financial risks. These instruments are less vulnerable to transition risks criteria since they fund projects and companies that meet low-carbon standards (Maltais and Nykvist, 2020). As the shift towards a low-carbon economy continues, green credit instruments will perform better than traditional credit instruments linked to carbon-intensive industries (Wu et al., 2023). In fact, financial institutions and banks that engage in green credit will have low default rates and non-performing loans compared to those that invest in non-sustainable activities.

This is backed by empirical evidence in China. It has been shown that banks with a greater proportion of green loans are less prone to default. Conversely, the default rates are higher in banks with a high portfolio in carbon-intensive industries (Cheng et al., 2025). This fact proves the risk mitigation potential of green credit instruments, which give financial institutions a chance to control their exposure to transition risks and physical climate risks (Cumming et al., 2024).

1.10.3 Encouraging the Green Credit Markets

Green credit markets in APEC economies are developed through policy-based and market-based efforts. The Sustainable Banking Network (SBN) which is a group of financial regulators and banking associations in emerging economies provides recommendations on how to promote green lending (Chen et al., 2024). They include standardization of green bonds and loans, market integrity, and clear guidelines on issuance of green financial products.

The green credit market in China is fast growing and offers valuable lessons to other APEC economies. Some of the measures that the Chinese government has implemented to reduce the cost of issuing green bonds include transparent eligibility of projects, issuer subsidies, and faster procedures (Liu, 2020). In addition, China has improved the integrity of its green bond market by establishing high standards of transparency and external verification process (Chen

and Long, 2023). These efforts have helped to increase the credibility of green bonds and the appeal to foreign investors.

In order to successfully develop their green credit markets, the APEC economies ought to make sure that the policymakers collaborate with the private stakeholders to come up with clear and internationally harmonized standards of green bonds and loans. The national definitions of green credit products should be in line with international standards, such as the Green Bond Principles and the Climate Bond Standards. In addition, regulators should ensure that green credit markets are credible by preventing greenwashing and ensuring that the funds raised in green bonds are used on genuinely sustainable projects.

1.11 Conclusion: Future of Climate-Resilient Financial Markets in APEC

As climate change continues to pose a significant threat to the economic stability of APEC economies, the role of financial markets in managing the risks will be more important. Climate-related physical and transition risks can lead to significant financial losses unless adequately priced in asset prices. However, green credit markets provide a decent opportunity to financial institutions to mitigate these risks as they finance the transition to a low-carbon economy.

Green bonds and loans are one of the ways through which the financial institutions can invest in order to reduce their exposure to the climate-related risks and make the region more sustainable in the long run. Furthermore, financial regulators in APEC are beginning to value the importance of integrating climate risks into financial supervision and regulation. The assessment and disclosure of climate risks by financial institutions are encouraged by regulators through the Network for Greening the Financial System (NGFS) and the adoption of the Task Force on Climate-related Financial Disclosures (TCFD).

The inclusion of climate risks in financial models and the development of green credit markets will change the financial landscape in APEC over the next few years. With countries still striving to meet climate targets under the Paris Agreement, low-carbon investments will be in demand, and financial institutions will have a chance to adjust their portfolios to sustainable sectors. Banks and other financial institutions that are able to manage climate risks will be in a better position to succeed in the long term, whereas those that do not adapt may become more financially unstable.

Finally, APEC economies should accept the increasing significance of green credit markets and climate risk management. In this way, they will not only be able to better cope with the risks of climate change but also take advantage of new investment opportunities that will make the economy more sustainable and resilient. By working together, regulators, financial institutions, and the private sector, APEC can open the door to a future in which financial markets facilitate the shift to a low-carbon, climate-resilient economy.

The Climate Crisis introduced slow changes to sustainability, which resulted in an increase in green investments. Although this transition did not lead to radical changes in the overall stock market indices, the areas that are concentrated on sustainability, including green bonds and clean energy, experienced significant growth. This was the time when the world started to shift towards sustainable investments, and the trend of green finance is evidently on the rise. Nevertheless, the majority of stock indices were not very volatile during this time, which indicates the gradual shift in investor attitudes towards sustainability.

1.12 COVID-19 Pandemic (2020-2021):

The COVID-19 pandemic, initially reported in December 2019, quickly turned into a worldwide health emergency and caused major economic shocks (Peng, 2020). The pandemic has caused significant loss of life and economic hardship on a massive scale, and the challenges it has presented were not only unprecedented but also revealed pre-existing weaknesses on a global scale. Economies have been hit hard by the pandemic, with millions of individuals losing their jobs, mass business shutdowns, and a contraction in global economic output that has never been seen before (Naseer et al., 2023).. The governments of different countries had to introduce numerous containment strategies including lockdowns, border closures, social distancing, and limitations on gatherings, which, although needed to reduce the spread of the virus, slowed down economic activities considerably and disrupted global supply chains (McKibbin & Fernando, 2023).

The pandemic had a profound effect on APEC economies, which constitute a large part of the world economy. The region experienced a decline in GDP growth by 3.7 percent in the first half of 2020 compared to the 3.4 percent growth in the same period in 2019. Household consumption, a stable growth driver of APEC economies, declined by 7.1 percent in the first half of 2020, and investments fell even more steeply by 11.2 percent (Lim et al., 2021). The pandemic devastated the industries that depended on face-to-face interactions, including

retail, tourism, hospitality, and travel (Ishido, 2023; Liu et al., 2022). These industries faced an existential crisis because travel bans and forced lockdowns left individuals at home, resulting in a drop in demand and jobs. With businesses being compelled to close down or reduce their operations, the loss of jobs in these sectors was very clear, with millions of people in the region losing their sources of income (Mamgain, 2021).

The manufacturing industry was also hit hard in the initial months of the pandemic. Factories had to be closed to limit infections, and the limited capacity of the workforce because of staggered shifts and social distancing also slowed down production. These challenges were exacerbated by supply chain disruptions, especially in the key manufacturing canter in APEC economies, which led to a 8.2 percent contraction in manufacturing output in the APEC region during the first eight months of 2020 (Moosavi et al., 2022).

With the spread of the pandemic, the APEC region had over 14 million people infected, which is approximately 32 percent of the world cases, and over 400,000 deaths (Benton et al., 2022). The economic consequences were devastating, with an estimated GDP decline of 2.5 percent in 2020, which equates to a loss of output of about USD 1.8 trillion (International Monetary Fund, 2025). The unemployment rates also increased to an average of 4.8 percent with over 74 million individuals seeking employment in the APEC economies (OECD, 2021). It was the first time in 30 years that the economy of the APEC region shrank so much.

The pandemic also impacted the environment greatly. The health crisis showed how closely environmental degradation and the spread of infectious diseases are interconnected. Environmental degradation such as deforestation and destruction of habitats puts humans at risk of diseases because it drives wildlife to human settlements, which facilitates the transmission of zoonotic diseases, including COVID-19 (Raza et al., 2022; Rahman et al., 2021). In addition, the pandemic demonstrated the need of climate change. The temporary reduction in pollution caused by the reduced travel and temporary closure of industries showed the benefits of cleaner and more sustainable practices. However, the long-term impacts on the environment remain unclear, and governments must strike a balance between economic recovery and sustainability (Escario et al., 2022).

The digital divide was also brought to the fore during the pandemic as remote working, online learning, and online shopping became essential. The lack of access to digital technology and the internet affected many vulnerable groups disproportionately, including the poor, women, youth, and marginalized communities (Dubois et al., 2022). This widened

the gap, as those who could afford to work and study at home were successful, and others could not continue their education or make a living (Philip & Williams, 2018). This impacted women, in particular, who had a higher chance of working in such industries as retail and hospitality that were under direct influence of the lockdowns (Haman, 2025). In addition, women are more likely to be those who are forced to perform more unpaid care work, such as child-rearing and elder care, which was even more challenging when families had to cope with lockdowns and school closures.

Trade performance in APEC was also affected negatively, which is reflective of the impacts of COVID-19 restrictions and the trade tensions that had been accumulating prior to the pandemic. Merchandise trade decreased by 6.2 percent in the first half of 2020, and imports decreased by 7.2 percent. Merchandise exports and imports also declined by even greater margins of 11.0 and 10.8 percent, respectively (Chakraborty, 2020). The commercial services sector, especially travel and tourism, was even more affected, with international tourism revenues declining by 65 percent, or a loss of about USD 460 billion (Abbas et al., 2021). This was fivefold the loss in tourism receipts during the global financial crisis of 2009.

APEC economies implemented a wide range of fiscal and monetary policies to deal with these economic problems. Governments were quick to introduce support packages to safeguard the health of the population, increase medical infrastructure, and provide financial assistance to households and businesses (Lee, 2025). These included cash transfers, subsidies, loan moratoriums and tax cuts. Governments also did their best to support micro, small, and medium enterprises (MSMEs) that were particularly vulnerable to the lockdowns. Mass testing, contact tracing, and protective equipment became a priority as an investment in healthcare.

Despite the negative economic impact of the pandemic, it provided APEC economies with an opportunity to reconsider their development policy and focus on resilience. The crisis showed that a stronger digital infrastructure and wider access to technology was needed. The recovery of economies in a more sustainable and inclusive way may be supported by investments in greener technologies, supply chain resilience, and innovation (OECD, 2021). The pandemic also demonstrated the importance of regional cooperation, and APEC can be employed as a platform to align policies, share best practices, and ensure that recovery efforts are aligned with the long-term goals of sustainability and inclusivity.

The economic outlook of APEC remains uncertain and there are risks of a second wave of infections and global demand. However, the growth of GDP in the region is expected to rebound in 2021 to 5.2%, although it will be uneven (Hernando et al., 2025). The economies that have managed to control the virus and reopen earlier will recover faster, and the rest will lag behind due to the continued health risks or the pace of vaccination.

To sum up, the COVID-19 crisis has revealed the weaknesses of the APEC region, yet it also offers a chance to restructure in a more resilient, inclusive, and sustainable manner. Although the path to recovery is unclear, the APEC economies can use the experience of the pandemic to transform their economies, so that the growth in the future is greener, more equitable, and more resilient to future shocks. The crisis has demonstrated that regional collaboration, digitalization, and green investments are the keys to moving through the post-pandemic world and long-term prosperity (Didier et al., 2021). The COVID-19 Pandemic affected the world stock markets universally. Almost all indices plummeted in early 2020 when the pandemic caused mass economic shocks, panic, and lockdowns (Basuony et al., 2021). The next recovery started in the middle of 2020, with the help of huge fiscal stimulus packages, government interventions, and the boost of digital and remote activities. Technology, green energy, and green bonds markets experienced strong recoveries, as they were directly correlated with the fast global transition to remote work, digitalization, and sustainable recovery processes (Aljohani et al., 2025). Although the recovery was fast in most areas, the rate of recovery differed according to the economic structure of each country and the sectors that led to their growth.

1.13 Russia-Ukraine War (2022-2023):

The current Russia-Ukraine war has significantly affected the economies of the Asia-Pacific Economic Cooperation (APEC) member economies, despite the fact that these countries have different opinions regarding the war. Unlike other countries like the United States, Japan, and Australia, which have been quite vocal in condemning the actions of Russia, China has been relatively silent, not criticizing Russia directly (Wishnick, 2023). Despite these conflicting positions, the war has created economic imbalances that have affected all the APEC countries, compounding the already existing problems and introducing new ones.

One of the most direct effects of the war has been the sharp rise in energy prices. The international sanctions have adversely impacted the energy exports of Russia, which is one of the largest energy exporters in the world (Sun et al., 2024). The APEC region which consists

of many countries that are very reliant on energy imports like Japan, South Korea and Taiwan has been facing soaring energy prices. These price increments have resulted in inflationary pressures that have negatively impacted household consumption and economic stability (Nguyen et al., 2024). To give an example, Japan, which is a major energy importer, has been particularly vulnerable to fluctuations in international oil and gas prices. This has also made the problem of maintaining economic growth more complicated as businesses are forced to pass the higher energy prices to the consumers (G. Huang et al., 2024). Besides the volatility of energy prices, the war has worsened food insecurity in the region. Ukraine, which is commonly known as the breadbasket of Europe, is a major exporter of grain, such as wheat and corn, most of which is imported by the APEC countries (Perga, 2025).. The Ukrainian agricultural production and trade routes have been disrupted, which has caused an increase in food prices, posing a challenge to countries in the region, especially Southeast Asia. This disruption has been experienced in countries like Indonesia and the Philippines that depend on imports to supply them with basic foodstuffs (Tchoukouang et al., 2024). With the rising food prices, inflation in the region has been on the rise, which has further burdened the household budgets and constrained economic recovery.

Global supply chains have also been badly affected by the war, which was already strained by the COVID-19 pandemic. The Ukrainian ports and Russian transport infrastructure blockade have caused delays and higher prices of basic goods and raw materials (Fernandes et al., 2023). Large manufacturing nations in the region such as China, Japan, and South Korea have struggled to maintain smooth supply chains. This has led to delays in production, especially in the electronics and automotive sectors, which depend on the availability of parts and components on time (Bednarski et al., 2023). These shocks have in some cases caused inflationary pressures as manufacturers are forced to pass their increased costs to the consumers.

In addition, the war has led to the emergence of economic uncertainty that has impacted on investment in the region. The majority of investors are not ready to invest in geopolitically unstable areas and the ongoing conflict in Ukraine has led to a cautious approach to foreign direct investment (FDI) in most countries of the APEC region (Truong et al., 2024). The inflow of capital has reduced in countries like Vietnam, Indonesia and Malaysia that rely on FDI to stimulate their economies (R. Wang, 2023). On the other hand, Russia, a victim of international sanctions, has been facing capital flight and a reduction in foreign investments, which further deteriorate the economic situation in the country.

The war has also revealed the disparities in APEC as far as trade relations are concerned. Most of the APEC members have sanctioned Russia, but some, particularly China, India, and some Southeast Asian countries, have decided to keep trading with Russia (Denisov et al., 2021). This division has complicated the possibility of a cohesive economic response to the crisis in APEC (Truong et al., 2024). The US and its allies have been pressuring to condemn Russia more, and other countries have been attempting to maintain economic ties with Moscow, which has made the situation of trade negotiations in the region complicated (Lee et al., 2025).

In conclusion, the Russia-Ukraine war has demonstrated the interdependence of the world economies, particularly in the APEC region. Rising inflation, energy insecurity, food shortages, supply chain disruptions, and a decrease in foreign investment are just a few of the issues that APEC economies are facing at the moment (Jagtap et al., 2022). The member nations have all felt the economic impact of the war despite the different views they have had regarding the war. As the region continues to grapple with these problems, the need to work more closely and reposition the economy is increasingly becoming important (Amadi, 2020).

The war has revealed the flaws in the international trade and investment regimes and it is clear that multilateral institutions like APEC must take a central role in addressing the economic fallout and stability and growth in the region.

The Russia-Ukraine War led to a lot of volatility, particularly in energy-dependent economies such as South Korea, Russia, and the U.S. As energy prices increased due to supply chain problems and uncertainty about Russian energy exports, markets in these countries were highly volatile (Sun et al., 2024). But the economies that were driven by technology such as Japan and Taiwan were resilient because their markets were not so sensitive to energy prices. The clean energy sector was also resilient, as the world was increasingly moving towards energy diversification and energy independence, which was especially highlighted during this time.

1.14 Iran-Israel Conflict (2024):

The Iran-Israel war, which has been a proxy war that turned into direct confrontations in 2024, has significantly affected the global economy, especially in the Middle East, Europe, and the Asia-Pacific region. The war, which started with a series of Israeli attacks on Iranian

targets in early 2024, has escalated to direct military operations by both parties, and has caused major regional instability and global economic shocks (Wright, 2025).

In 2024, the conflict started in April when Israel bombed an Iranian consulate complex in Damascus, Syria, killing several senior Iranian officials, prompting Iranian retaliation. The Axis of Resistance in Iran, comprising Hezbollah, Hamas, and the Houthis, carried out synchronized missile and drone attacks on Israeli targets, which led to serious disruptions. The rising violence in the Middle East, especially the Iranian missile attacks on Israeli cities, also led to military and diplomatic action by other nations, with the United States offering defensive assistance to Israel.

The economic effects of the conflict were experienced almost instantly. The strikes had a major effect on Israel, which is one of the most technologically advanced economies in the region, and the tech industry, defense, and tourism were the most affected sectors. One of the issues was the rise in security expenditure that took away funds to other important sectors of the economy. Israeli major defense contractors and technology companies saw their stock markets fluctuate, and the infrastructure of the country was hit multiple times, raising concerns over the long-term economic recovery (Batool, 2025).

In the case of Iran, the war worsened an already weak economy, which had been struggling with the burden of U.S. sanctions and domestic mismanagement. The Iranian economy, which was largely dependent on oil exports, was further hit by further military attacks on its oil installations, which resulted in a reduction in production and exports. This interference also weakened the Iranian currency, which plunged into a sharp fall against major currencies. Inflation was at its peak and this was experienced by the general population particularly when unemployment was on the increase and there was a shortage of basic commodities (Blanc & Z. Brown, 2020). The war also increased the isolation of Iran and the country found it harder to trade and have financial ties with the rest of the world.

The economic ripple effects were worsened in the broader Middle East and North Africa (MENA) region. Nations that depend on trade routes through the Strait of Hormuz, including the United Arab Emirates and Saudi Arabia, experienced severe shipping industry disruptions. This together with the increase in fuel prices caused by the Iranian interference with the world oil exports caused inflationary pressures on the oil importing nations in the region.

In the case of the Asia-Pacific region, the economic effects of the war were equally significant. The conflict had a direct impact on Asia, which relied heavily on Middle Eastern oil. Energy import costs increased in countries such as Japan, South Korea, and India, exacerbating inflationary pressures in the region. Manufacturing industries were also affected by the rise in fuel prices, particularly in China and India, where the cost of transport and production rose. In addition, the war disrupted global supply chains, which were already weakened by the ongoing impacts of the COVID-19 pandemic, causing delays in shipments and rising prices of goods, including raw materials and consumer goods.

Foreign direct investment (FDI) in the region was also slowed down by the conflict. Investors were cautious of the growing instability in the Middle East and the inflows of FDI to countries in the Asia-Pacific region that depended on FDI to drive their economies declined (Alfar et al., 2023). Countries like Vietnam and Indonesia that are big exporters of goods especially in the manufacturing and technology industries were competing over a smaller amount of foreign investment. In addition, the stock markets in the region were volatile as foreign investors withdrew their investments in high-risk regions because of the uncertainty brought about by the war (Deshmukh, 2021).

The economic consequences of the conflict did not spare the global financial markets as well. The rise in oil prices resulted in the rise of costs in many sectors of the world such as transportation, manufacturing and agriculture (Cappelli et al., 2023). Oil importing countries like European countries and most Asian economies experienced stagflationary pressures, with inflation and unemployment increasing, making economic conditions hard on both consumers and businesses (Cao et al., 2025).

Diplomatic efforts to reduce the economic impact of the conflict were underway as the conflict was taking place. The United Nations and the World Trade Organization (WTO) among other international bodies demanded de-escalation and peace negotiations, and nations such as the United States and China were unable to balance their conflicting interests in the Middle East. The U.S., which was on the same side as Israel, was instrumental in offering military and financial assistance, whereas China, which has increasingly close relations with Iran, had to struggle with diplomatic issues of maintaining a balance between the two countries.

The economic impact was already far-reaching by the time the war officially became a full-scale conflict in June 2025, when full-scale military operations between Israel and Iran were

taking place. The war also destabilized the economies of the region as Israel struck a surprise attack on major Iranian military and nuclear installations and markets in the Middle East, Europe, and Asia-Pacific reacted to the growing uncertainty. Energy costs skyrocketed and nations that were highly dependent on trade with the Middle East experienced severe economic downturns.

To sum up, the Iran-Israel war of 2024 has had extensive economic effects on the Middle East and the world economy. Whether it is the increase in oil prices and inflation in the Asia-Pacific region or the disruption of trade and investment flows, the economic impact of this growing conflict is likely to be felt well into 2025 and beyond. With the conflict dragging on, the attempts to stabilize the global economy will be challenged further, especially in the energy-dependent regions, and the diplomatic attempts to reach a ceasefire and resolve tensions will be essential in preventing further economic losses.

In 2024, the Iran-Israel Conflict intensified, leading to temporary market volatility in the global markets, particularly in energy-sensitive economies such as the U.S., China, and Russia. The war led to the volatility of oil prices, which affected the stock indices related to the energy sector. But markets that were less dependent on energy exports, like Taiwan, kept on rising, showing the strength of other sectors, like technology and clean energy (Pandey, 2024). The higher volatility in the energy markets caused investors to rush to safe-haven assets, including gold, which experienced a massive rise in 2024. The long-term growth outlook of some sectors, particularly technology and clean energy, is still robust, and investor confidence has not been shaken by geopolitical tensions.

1.15 Sectoral Insights

Economies that were technology-driven like Taiwan, Japan, and the U.S. were very resilient in times of global crisis. The industry was boosted by the rise in demand of digital solutions during the COVID-19 Pandemic and has been performing well despite geopolitical tensions such as the Russia-Ukraine War and Iran-Israel Conflict. The Technology Index showed steady growth, which indicated the long-term investor confidence in the sector as a part of the global economic recovery and innovation. The Green Bond Index and Clean Energy Index were indicative of the global trend towards sustainability, particularly in the Climate Crisis and the COVID-19 Pandemic (Sunge et al., 2024). Green bonds experienced a stable increase, with more investments in climate resilience and sustainable infrastructure. Clean

energy also experienced a massive rise, especially after the pandemic, with nations across the globe trying to diversify their energy sources and lessen their reliance on fossil fuels. These industries were resilient even in geopolitical tensions, and clean energy was a beneficiary of the current transition to renewable energy (Y. Zhang, 2024). The Oil Crisis, Russia-Ukraine War, and Iran-Israel Conflict demonstrated the susceptibility of energy-dependent economies to the changes in the global energy prices. During the Oil Crisis and the Russia-Ukraine War, countries such as Russia, Malaysia, and Vietnam experienced a significant market decline because of their dependence on energy exports (Kumari et al., 2024). The Crude Oil and Natural Gas markets experienced steep falls in the Oil Crisis, and high volatility in the Russia-Ukraine War and Iran-Israel Conflict (Seba, 2025). Nonetheless, clean energy investments were resilient, and the shift towards sustainability in the world economy softened the impact on certain economies.

To conclude, the world crises, such as the Oil Crisis, COVID-19 Pandemic, Russia-Ukraine War, and Iran-Israel Conflict, have shown the different reactions of stock indices depending on the economic structure of the countries and their strengths in the sectors. The oil-exporting and energy-dependent countries experienced steeper drops, whereas the technology-driven economies and industries that are more sustainability-oriented, including clean energy and green bonds, were more resilient (Rehman et al., 2025). The COVID-19 Pandemic caused a global market recession, but the recovery was rapid in most industries, especially those that were in line with digital transformation and green recovery. Geopolitical developments such as the Russia-Ukraine War and the Iran-Israel Conflict brought temporary volatility, especially in the energy market, but also demonstrated the current global trends of energy diversification, technology, and sustainability.

The strength of diversified economies, especially those with robust technological bases, is still apparent, and commodity-exporting economies are more susceptible to price changes. The fact that clean energy and technology industries continue to expand despite geopolitical issues highlights the significance of diversification and flexibility in ensuring market stability. In the future, economies that are able to successfully overcome the obstacles of geopolitical instability, global energy transition, and the shift to sustainable technologies will probably demonstrate long-term stability and development.

1.16 Significance of Study

The analysis takes into account a number of peculiarities of the chosen asset classes. The energy markets are discussed in the context of their centrality to the global economy and their vulnerability to economic and geopolitical forces. Gold is examined in terms of its past performance as a hedge against market volatility. The technology industry is considered as a source of contemporary economic development and financial market performance. Green bonds are researched as an example of the emerging sustainable finance trend. APEC equity markets are also incorporated because they indicate the economic dynamism of the Asia-Pacific region. The study will focus on the interconnectedness between these various asset classes to give a complete picture of risk transmission channels and diversification opportunities in the face of growing financial market integration. The findings will be of special interest to institutional investors with multi-asset portfolios, and to regional policymakers interested in ensuring financial stability in a world of increasing cross-border capital flows and economic interdependence.

The ultimate goal of this research is to improve our knowledge of the interaction of various asset classes in the APEC financial market, which will lead to better investment decisions and policy making. The emphasis of the study on dynamic connectedness, hedging effectiveness, and co-movement patterns under different market conditions offers a strong platform to study financial market relationships in a region that is increasingly becoming more important in the global economy. The results will be of practical use in risk management practices and portfolio building, as well as contribute to the academic understanding of financial market integration in emerging economic blocs. With the growing complexity and interdependence of global financial markets, research such as this one is becoming a necessity in order to understand the challenges and opportunities that modern investment environments pose.

1.17 Problem Statement

As the world financial system becomes more interconnected, it has become critical to comprehend the dynamic interrelationships among various asset classes by investors, policymakers, and risk managers. Asia-Pacific Economic Cooperation (APEC) region, which constitutes a large share of the world economic production, is exposed to increased financial integration and susceptibility to external shocks. Against this background, energy commodities, gold, technology stocks, and green bonds are important assets that can be used as alternative or complementary investment opportunities. Nevertheless, their co-movement

patterns and interdependencies with APEC equity markets are under-researched, particularly during financial stress.

The COVID-19 pandemic, the Russia-Ukraine conflict, and the increasing uncertainties related to climate change are global crises that have severely shaken the traditional market dynamics, leading to structural breaks in correlations and volatility spillovers. Such shocks question the traditional portfolio diversification approaches and require more sophisticated approaches to measure dynamic connectedness and develop optimal hedging strategies that can respond to fast-evolving environments.

Although the literature on financial connectedness and risk management is increasing, there is little research that comprehensively examines the changing co-movement and hedging potential of major sustainable and traditional assets in the APEC region. Moreover, the consequences of global crises on the structure of interconnectedness and the efficiency of hedging strategies in various investment horizons are not studied well enough. Therefore, to bridge this gap by analysing the dynamic connectedness, optimal hedging strategies, and co-movement behaviours between energy commodities, gold, technology stocks, green bonds, and APEC equity markets, with emphasis on crisis-induced changes. The research will offer useful information on risk transmission processes, portfolio optimization, and policy implications in the face of global economic uncertainties.

1.17.1 Research Gap

Despite the growing body of literature on financial market connectedness, several critical gaps remain unaddressed, which this study seeks to bridge. Prior studies on dynamic connectedness predominantly focus on bilateral or tri-variate asset pairs (e.g., oil-equity or gold-bond). No study has jointly examined the connectedness of six asset classes Clean Energy, Crude Oil, Natural Gas, Gold, Technology, and Green Bonds with 19 APEC equity markets simultaneously within a unified TVP-VAR framework across a 10-year multi-crisis window (2015–2024). While green bonds have received growing attention in European and US markets, their role as diversifiers and hedging instruments within APEC economies remains largely unexplored. The distinctive regulatory environments, market maturities, and ESG adoption rates across APEC nations create a fundamentally different connectedness structure that existing literature does not capture. Most existing studies examine connectedness during a single crisis (typically COVID-19 or the 2008 GFC). This study

uniquely covers five distinct global crises the 2015–16 Oil Crisis, 2017 Climate Crisis, 2020 COVID-19 Pandemic, 2022 Russia-Ukraine War, and 2024 Iran-Israel Conflict enabling a comparative analysis of how crisis type and intensity reshape APEC market interconnectedness. No prior study integrates the Minimum Connectedness Portfolio (MCoP) framework with wavelet-based frequency-domain leadership evidence to guide adaptive allocation strategies across APEC markets during crisis periods. This integration offers a novel methodological contribution by aligning risk-minimization portfolio construction with time-frequency co-movement signals. This study addresses all four gaps and contributes both empirically and methodologically to the literature on international financial market integration, crisis-driven risk transmission, and sustainable asset allocation.

1.18 Chapter Plan

The chapter plan describes the structure of the study. The thesis is divided into five chapters, each of which covers one of the central points of the research:

Chapter 1: Introduction

This chapter provides the background of the study by addressing the significance of dynamic connectedness, optimal hedging strategies, and co-movement between Energy, Gold, Technology, Green Bonds, and APEC equity markets. It outlines the consequences of global financial crises and introduces the research objectives, questions, scope, and significance.

Chapter 2: Review of Literature

This chapter reviews the major theoretical and empirical literature on market integration, volatility spillovers, hedging strategies, and asset co-movements. It determines the research gaps, classifies previous studies according to asset classes and methodologies, and establishes the basis of the present study.

Chapter 3: Research Methodology

The third chapter describes the research design, data sources, and the time period chosen. It explains the models and methods used, including TVP-VAR, Hedge ratios and Wavelet Coherence, to examine dynamic connectedness and hedging performance. Rationales of methodological decisions are also given.

Chapter 4: Results and Data Analysis

This chapter provides the empirical results of the interconnectedness and co-movements of the chosen assets. It contains spillover, hedge ratio, and crisis-period behavior analysis, which is backed by tables, figures, and interpretations in line with the research objectives.

Chapter 5: Conclusion and Implications

The last chapter concludes the main findings, their theoretical and practical implications to investors and policymakers, and the contributions of the study. It also recognizes the limitations and gives future research directions in global asset allocation and financial risk management.

Chapter 2

2. Review of Literature

Section 2.1 discusses the Categorization of Past Literature on basis of Dynamic Connectedness, **Section 2.2.** on Hedging Strategies and **Section 2.3** on Co-movements. This is followed by **Section 2.4**, which describes the Bibliometric Analysis of the Past Literature on Equity markets spillovers . And then **Section 2.5** highlights the research gap based on the literature analyses, and **Section 2.6** brings the chapter to a conclusion.

2.1 Literature Review on Dynamic Connectedness among Financial Markets

Dynamic connectedness is the shock interdependence of financial assets and markets (volatility, returns, risk) through time. In contrast to the static correlations, which presuppose that there is a relationship over time, dynamic connectedness takes into account the dynamics of the changes in the linkages as a result of market events, structural changes, and policy changes. This is relevant to the study of systemic risk, portfolio diversification, and contagion processes across asset classes and geographical regions. That is, dynamic connectedness describes the dependence of various financial assets or markets over time, and it reflects the change in the relationship between them under different circumstances like economic recessions or crises (Diebold & Yilmaz, 2009).

Dynamic connectedness might be empirically observed (Barunik & Krehlik, 2018), but in the classical theory of finance, the concept is not well-defined (Barunik & Krehlik, 2018). In finance, what it would mean is that the movement in one market (e.g. energy price) does not happen in a vacuum, but would be strongly correlated with a movement in another market (equity market or green bonds) and would be more poorly behaved in stressed states.

The focus on the general risk and spillover effect across markets has also been an impressive contribution on the dynamic employed connectedness literature. Presence of the contribution to systemic risk The model suggested by Acharya et al. (2017) quantifies the contributions of the institutions in terms of an expected shortfall. Battiston et al. (2010) have highlighted the fact that the level of contagion and defaults in combination can be determined by the incorporated or dispersed clustering structures of the financial networks. Diebold and Yilmaz (2009) and Diebold and Yilmaz (2012) went a step further and generalized the forecast error variance decomposition (FEVD) to a vector autoregressions (VAR) that enabled one to build spillover measures that show market connectedness over time. Empirical DCC-GARCH models (Chiang et al., 2007; Mensi et al., 2022), Granger causality networks (Billio et al.,

2016), cointegration (Longin & Solnik, 1995), and network-based approaches (Xiao et al., 2020) are some of the frameworks used to study dynamic connectedness. The two methods give us an alternative perspective of looking at the correlation between the prices of oil, say, and other asset classes like technology stocks or even gold during a crisis.

Dynamic connectedness describes how geopolitical, economic, and financial shocks influence the volatility of oil prices in the oil markets and how volatility impacts the economy and related asset prices (Ferrer et al., 2018). As mentioned above, fluctuations in oil prices have significant implications on the stock market of renewable energy firms and the rate of technological advancement. Nevertheless, more recent evidence suggests that technology shocks are becoming more important in driving green energy markets in a manner that is independent of oil prices (Henriques & Sadorsky, 2008; Sadorsky, 2012). The development of green bonds as a financial tool promotes sustainable growth introduces new avenues of interconnectedness between investments of an environmental character and traditional financial markets, thus facilitating volatility spillovers between green finance and equity or bond markets (Gyamerah et al., 2022). In the Industry sector, the dynamic connectedness is manifested by the strong correlation with clean energy stocks that implies that green innovations and shocks related to them influence the valuation of green energy stocks and the movement of the whole stock market (Henriques & Sadorsky, 2008; Mensi et al., 2022). Gold has long been considered a safe haven asset, yet exhibits dynamic connectedness with energy and equity markets, serving as a hedge and contagion channel during market turmoil and volatility spillovers, which are modelled by DCC-GARCH and VAR techniques that capture spillovers (Bosch & Pradkhan, 2015). Lastly, Dynamic connectedness with return and spillover effects rose in times of financial crises and were influenced by external factors such as the Global Financial Crisis and the COVID-19 pandemic (Zhong & Liu, 2021; Zhang & Broadstock, 2020). The empirical evidence of the APEC region using VAR-based spillover indices, GARCH models, and network analysis shows that the level of interdependence in the APEC markets and between global commodities and financial markets is high and is relevant to systemic risk, contagion, and portfolio diversification strategies (Chen & Wang, 2021; Diebold & Yilmaz, 2012; Mensi et al., 2022).

2.1.1 Dynamic Connectedness between Energy and Equity Market

As the international markets move towards adopting clean, renewable and more diversified sources of energy, the interaction between the markets of the international markets,

particularly the clean energy natural gas and renewables market and the dirty energy crude oil market and the national equity markets has drawn the attention of both scholars and policymakers. Energy security is a prerequisite to fuel an economy. The combination of industries and services and energy consumption, particularly in the form of efficient expenditure, stimulates productivity and financial market performance (Cherp & Jewell, 2014; Yong et al., 2016). Recently, clean energy or low to zero emitting sources of electricity such as wind, solar, hydroelectric, nuclear, and even natural gas to some extent (Yao et al., 2019) has been increasing. Renewables grew at 5 percent per year compared to 1.7 percent in fossil fuels between 2009 and 2019 (Saeed et al., 2021). This has also led to a record-breaking milestone of global investments in renewables of \$358 billion in the first half of 2023 (Tiwari et al., 2023; Bloomberg, 2023). Nevertheless, the use of clean energy fossil fuels, especially crude oil, is excessively prevalent according to Lee et al., 2023. This underscores the necessity to examine the intricate interdependencies between the two sectors. In this respect, dynamic connectedness describes the changing relationships of various energy industries, and their interrelations with stock indices, with a specific focus on their returns and volatility spillovers. The substitution hypothesis advocated by Henriques and Sadorsky (2008), Sadorsky (2012), He et al. (2021) states that the rise in oil prices causes investors to shift to clean energy assets. Similarly, Kumar et al. (2012) and Reboredo (2015) argue that the volatility of oil prices and the increasing environmental concerns enhance the value of clean energy stocks, which implies a triangular relationship between dirty energy, clean energy, and the equities market.

Recent studies also use sophisticated econometric indicators, including Diebold-Yilmaz spillover index and DCC-GARCH models to measure time- and frequency-based methods in empirical studies and determine the dynamic relationship between energy and equity markets. To give an example, Naeem et al. (2021) indicate that the volatility spills between the energy markets and the equity indices are higher in the case of a financial distress. Dawar et al. (2021) show the decreasing reliance of the crude oil fund and the clean-energy fund that is an indication of the market segmentation under certain circumstances. Saeed et al. (2021) note that they find stronger tail-dependence and severe extreme spillovers, especially, in the crisis periods, as it happened during the COVID-19 pandemic. Both Foglia and Angelini (2020) and Corbet et al. (2020) observe that the volatility of clean energy stock is rather significantly influenced by the shocks in the crude oil market and even further state that the spillover effects of the sentiment extend to other sectors of the equity market. Other recent studies examine the relationship between the stocks in clean energy and the other markets of equity,

such as technology and commodities. As one example, Ferrer et al. (2018) analyze the relations between clean energy stocks and tech stocks and find that the pairwise connectedness between the two sets of stocks is too high in both the short-term and long-term investment horizons. On the other hand, Adekoya et al. (2025) disclose that the clean energy stocks are net shock transmitters to the conventional equity markets. This proves the need to track the changes in the relatedness to the system risk and considers the significance of building investment portfolios within the framework of energy transition and financial turbulence.

2.1.2 Dynamic Connectedness between Green Bonds and Equity Market

Green bonds are a significant kind of bond that contributes to resolving issues associated with the environment and society. Green bonds offer a chance to diversify a bond portfolio. In 2019, green bonds and loans were issued globally to the tune of USD 257.7 billion. This figure was expected to increase to USD 500 billion by 2021. Climate Bonds Initiative states that the bonds are specifically tailored to fund environmentally friendly projects in order to attain sustainable development objectives. The study by Ehlers and Packer (2017) demonstrates that green bonds are beneficial to both the issuers and investors because they finance projects that improve environmental protection. Pham (2016) in his research examined the interrelatedness of volatility between green and conventional bond market, and described volatility clustering, and spillover effects of conventional bonds to green bonds. Reboredo (2018) analysis revealed that there were significant dependencies between green bonds and the corporate and treasury fixed income market that places these bonds at a disadvantaged position regarding diversification of traditional fixed income portfolios. Conversely, the low co-movement of green bonds with stock or energy commodities implies that green bonds offer diversification to investors in these sectors. Reboredo and Ugolini (2020) also stated that green bonds are highly influenced by the fixed income market and have weak connections with the stock, energy, and corporate bond markets, which further supports the idea of diversification in the portfolio of an investor.

Pham (2021) noted that the dependency relationship between green bonds and green stocks intensifies in times of market distress, which demonstrates the volatility of the interdependence between the two. Kocaarslan (2021) found that the dynamic conditional correlation between green and traditional bond markets is enhanced by the rise in the value of

the US dollar, especially in times of crisis, and the correlation between green bonds and energy commodities or equity markets is reduced.

More recent empirical work further confirms the evolving role of green bonds in global financial networks. Seth and Singh (2025) investigated the connectedness among socially responsible investments across Asian markets, finding that ESG-oriented instruments exhibit lower but time-varying connectedness with conventional equity indices, especially during geopolitical shocks. Rehman et al. (2025) demonstrated that green bonds show significant resilience to oil price shocks during extreme events, reinforcing their role as defensive assets in energy-linked portfolios. Adekoya et al. (2025) further established that geopolitical risk is a significant predictor of green investment returns using a GARCH-based Mixed Data Sampling approach, underscoring the importance of including geopolitical crises in any comprehensive analysis of green bond market dynamics.

Recent studies are more concerned with the dynamic interrelationships between green bonds and equity markets through advanced econometric methods, which capture time-varying relationships. Yadav et al. (2023) examined the connectedness of green bonds to the financial markets of European OECD countries and discovered volatility in all frequency bands with certain stock exchanges being riskier markets. Ferrer et al. (2021) assessed the interdependence of green financial assets with major traditional financial assets through wavelet-based network analysis and found that green bonds are highly related to treasury and investment grade corporate bonds, whereas green stocks are more related to general stocks. The results of Yadav imply that the low correlation between green bonds and green stocks implies that they are distinct asset classes with distinct risks and returns. This difference highlights the importance of treating green bonds and green equities differently when designing portfolio strategies to manage risk effectively. Also, Zheng et al. (2024) created a multi-moment framework of connectedness networks that showed that connectedness in green bond and equity markets varies across statistical moments and that it reacts drastically to shifts in monetary policies. These green finance investment insights will help them make decisions in time as they seek to develop policies and plan investments in the green financial market.

2.1.3 Dynamic Connectedness among Technology and Equity Market

The interdependent relationship between the technology markets, clean energy firms, and the broader equity markets has been a topic of considerable academic attention, especially in the context of environmental demands and energy transition goals. Although the economic consequences of using clean energy are still negative, it is gaining value because of climate change and energy security concerns (Zhao, 2016; Bloomberg, 2017). Clean energy technologies investment has grown more than 600 percent between 2004 and 2016, but projections indicate that renewables will only make up 18 percent of energy mix globally by 2040, which is far below the 28 percent required to reduce environmental degradation (EIA 2018). Although traditional fossil fuels, such as crude oil, remain the main source of energy in the world, the high volatility of prices is opening up new investment opportunities in clean energy and technology (Arouri & Nguyen, 2010; Bondia et al., 2016). Return volatility spillover and transmission across these markets have been studied in many research works. As an illustration, Henriques and Sadorsky (2008) observed that the effect of technology shocks on returns to clean energy stocks was higher than the effect of oil price shocks. Sadorsky (2012) found that clean energy and technology stocks had stronger co-movements than oil prices using multivariate GARCH models. In the same way, when the clean energy market was assigned a dual role in an article by Ahmad (2017) and Dutta (2017), they briefly stated that technology companies are the net transmitters of volatility. Most recently, Maghyereh et al. (2016) who have been working on wavelet with multivariate GARCH models have found that there is a mutual spillover effect between clean energy stocks and technology stock, the effect is found to vary in strength over time, a sign of dynamic strong interdependence.

The latest events related to the tracking of dynamic connectedness among the financial markets support the dominance of the United States technology sector in the equity markets. Lu et al. (2023) provide an example of the development of the co-trading network models to study the stock co-movement and discovered that technology stocks are underrepresented in the higher level clusters which further increases the intersect or spillovers. Furthermore, Yue et al. (2020) with the help of transfer entropy, proved the paramount significance of the United States technology sector as a net recipient of information in the markets, which is a testament to its significance in terms of risk transmission. In addition, Attarzadeh and Balcilar (2022) addressed the vision of dynamic volatility spillovers between technology, oil, clean energy, and equity markets and disclosed that in addition to technology-oriented

companies, clean energy companies turn into net market shock transmitters. Their results are essential in terms of asset allocation and risk measurement in portfolios that seek to capture long-lived assets. Furthermore, Asl et al. (2024) examined the interconnection between AI, quantum computing, big data stocks, and renewable energy markets and identified complex interrelationships that can be used to supplement the older literature, which supports the idea that equity markets, especially technology equity are becoming more integrated into the new framework of financial and energy markets. The VAR, GARCH, copula functions, and network models all provide evidence of the complex but clear influence technology equities have on the rising or falling volatility in markets, especially in periods of market change or stress.

2.1.4 Dynamic Connectedness between Gold and equity market

The interest of investors in precious metals, especially gold, has grown tremendously in the pre- and post-2008 Global Financial Crisis (GFC) due to its rising popularity in the investment community and the financialization of commodity markets (Rehman et al., 2021). Gold has always been considered a strategic asset, which successfully protects investors against a wide range of market risks, including inflation, recession, currency depreciation, oil price fluctuations, and monetary policy uncertainties (Ciner et al., 2012; Lucey & Li, 2015). Gold, together with crude oil, is one of the most demanded portfolio diversifiers in times of financial turmoil due to the negative correlation between gold and equity markets (Kang, 2012; Singh et al., 2019; Alqaralleh & Canepa, 2022). These commodities sensitivity and responsiveness are reinforced by macroeconomic factors and geopolitics along with supply and demand distortions, which help them in portfolio construction (Shaik et al., 2023; Zheng et al., 2023). Gold and crude oil remain the focus of the diversification processes, with numerous researchers emphasizing the potential of the two assets to minimize the risks in the equity market (Maraqa & Bein, 2020; Singhal & Ghosh, 2016; Rehman & Vo, 2021). The volatility modeling and its communication across asset classes is the core of finance and risk management as it guides in the optimal asset allocation and hedging positions that are helpful in making informed decisions. These commodities are highly volatile in terms of spillover during the crisis periods (Dai et al., 2022; Attarzadeh & Balcilar, 2022b; Wang et al., 2023), and this fact proves the connection they have to the extended financial systems. In addition, the two-way volatility spillover between oil and clean energy assets (Attarzadeh & Balcilar, 2022a) and the increasing number of studies that address sustainable commodities (Sahoo &

Kumar, 2023; Zhang et al., 2022) indicate the changing trends in asset holdings in more environmentally friendly and resilient portfolios.

The dynamic interaction between the equity and gold markets is more relevant in the recent financial literature, particularly in the circumstances encountered during the crises, as offered by the COVID-19 pandemic. It is at such times that the safe-haven characteristics of gold are bound to increase due to the anticipated increased associations with the major stock markets of the world. The behavioural change outlined here indicates the increasing flitting of gold as a defensive asset between the times of equities decline. The width-in and cross-asset relationships which are manifested in certain studies that take into account more specific market dynamics such as asymmetric return spillover effects of gold futures and explicit sectoral Chinese stock indices have also assumed more extreme forms and evolve over time. The researchers have employed advanced econometric methods in order to explain these patterns. It is eminent that the VAR-BEKK-GARCH model revealed significant and time varying dependencies of the volatility spillovers between gold and oil and the European equity markets and the wavelet based time varying parameter VAR revealed that the interconnectedness is more during the times of economic turmoil (Wang et al., 2023). These results show the necessity to study the problem of gold- equity relations within the framework of dynamic models to manage risks and minimize losses.

This follows an analysis that was based on mixing of sustainable and conventional indices with diversified portfolios due to the overall strength that green indices demonstrated in terms of recovering during the recent crises (Makkar et al., 2023; Seth & Singh, 2023; Vilas et al., 2021). This suggests that additional development of the investment paradigm with a gold underpinning as the main element not only of classical defences, but also, with more advanced and comprehensive sustainable ones, of careful risk management aimed at maximizing returns in more uncertain global environments.

2.1.5 Dynamic Connectedness of APEC Equity Markets

Since the 1980s, economic integrations in the world regions have been on the rise due to the rise in trade and liberalization of financial markets (Oman, 1996; Yamazawa, 1992; Yeung, 2000). Along the same line, the Asia-Pacific Economic Cooperation (APEC) comprising 21 member economies such as the United States, China, Japan, Australia, South Korea, and others emerged as a significant regional bloc. APEC alone contributes over 60 percent of the

world GDP, about 47 percent of the world trade and 38 percent of the world population. APEC has been urging its members to foster cooperation, liberalize trade, and facilitate investments that have resulted in improved financial integration among its members, raising the degree of dynamic connectedness of equity markets in the region (Errunza, 2001; Ho et al., 2023). This increasing interdependence among various economies has a significant effect on cross-border portfolio diversification and financial contagion.

The increased globalization of economies has exposed them to systemic shocks such as the 2007 to 2009 Global Financial Crisis, the European sovereign debt crisis, the COVID-19 pandemic, and the ongoing Russia-Ukraine conflict. All these have resulted in acute volatility spillovers and made interconnected financial markets more fragile, and by extension, integrated economies (Baur, 2012; Akhtaruzzaman et al., 2021; Hassan et al., 2022; Bouri et al., 2023; Mnif et al., 2023). Such instances of contagion-related crises require the study of dynamic time-varying connectedness of APEC equity markets in the context of risk transmission to understand globalization.

Applied research has made greater effort to measure this dynamic interdependence with complex volatility spillover econometric methods that measure both temporal volatility and return spillover. Guimarães-Filho and Hong (2016) demonstrated that the inter-market connectedness of Asian markets increases in times of financial distress, whereas Joshi (2011) using a GARCH-BEKK model found that there were significant bidirectional spillovers in returns and volatility, highlighting the high financial interdependence of the APEC equity markets. A number of studies concentrated on the role of China as a regional risk transmitters, with Zhong and Liu (2021) showing that dynamic conditional correlations between China and the Southeast Asian stock markets existed and increased during crises. In addition, Chen and Wang (2021) identified asymmetric and time-varying spillover effects of China to the ASEAN-6 economies using dynamic copula-EVT-CoVaR and MES models. A study by Zhang and Broadstock (2020) demonstrated that over 50 percent of the forecast error variance of the eastern Asian markets is exogenous, which implies that the markets are highly interconnected.

The application of the Diebold and Yilmaz (2009, 2012) spillover index has been adopted as a methodological standard in the sense of measuring dynamic interconnections of volatility in measuring total and directional spillovers in an infratemporal and intraretinal way (Bessler and Yang, 2003; Forbes and Rigobon, 2002). Besides that, there is also the well-known

amplification of spillover effects generated by financial news, uncertainty, and geopolitical events, in returns and volatility (Bekaert et al., 2005; Zhang et al. 2020, Luk et al., 2020). The APEC economies that are underdeveloped are even more vulnerable due to their underdeveloped financial system (Habiba et al., 2021; Muharam et al., 2019). All these results demonstrate the topicality of dynamic connectedness to be investigated in the context of the APEC equity markets not only to reach the optimized investment and exposure to risks purposes but also to solve the issue of ensuring the financial instability of the region in the conditions of the constant economic crisis in the world.

A critical review of the above studies reveals important agreements and contradictions. While the majority of studies concur that crude oil is a significant net transmitter of volatility to equity markets particularly during the COVID-19 period (Olson et al., 2014; Cui et al., 2020; J. Li et al., 2023) findings diverge significantly regarding the direction and magnitude of spillovers across different methodologies. Studies using DCC-GARCH tend to underestimate connectedness during structural breaks, while TVP-VAR-based approaches more accurately capture time-varying shock transmission (Diebold & Yilmaz, 2012). Furthermore, the emerging evidence suggests that clean energy markets are gradually displacing crude oil as the primary source of price signals in technology-linked and ESG-sensitive portfolios (Tiwari et al., 2023; Yousaf et al., 2024), a dimension that most bilateral-pair studies fail to capture. The present study addresses this gap by incorporating all six asset classes simultaneously within a unified TVP-VAR framework applied specifically to 19 APEC markets across five crisis episodes.

2.1.6 The Spillover over APEC Equity Markets: The Influences of Regional Integration, Global Events, and Innovations in Finances

The equity markets in the Asia-Pacific Economic Cooperation (APEC) region are highly interconnected and are also influenced by the regional and global factors. According to Heaney and Hooper (1999), the markets of the APEC region can experience the impact of both regionalism and global market factors, with the emerging equity returns being more rationalistic, consultatively in ASEAN region to be exact and more covariable to the world market portfolios. This technical knowledge is cemented by the facts presented by Krivelevich (2019) who discusses the role of financial services in the economic integration of

the region, and notes that financial innovations, such as securitization, can enhance cross-border investments and enhance the interlinking of markets.

Furthermore, the additional integration of the stock markets on the regional level is disclosed as the significant market behavior driver in the APEC sphere (Valdes, Von Cramon-Taubadel, and Engler, 2016). Their research indicates that trade agreements not only in the APEC but in general have the impact of enhancing improved stock market linkages and as the studies by Li and Rose (2008, 2006) indicate the high cross movements of markets in terms of extremeness and systematic risk in APEC markets are not only influenced by regional market integration but also by global institutions. The interconnectedness of the region has also been enhanced by the integration of the capital market reforms in China, which has especially increased the risk linkages between China and other APEC economies (Sun et al., 2023).

Besides the two articles by Kakran et al. (2023) and Li and Rose (2006), the volatility transfers of major world events, such as the Global Financial Crisis (GFC), COVID-19, and Russia-Ukraine war, which have increased the vulnerability of cross-dependencies in the APEC stock markets, have been mentioned. This is seen in the fact that when there is an intervention in the economy of a large economy such as the US and Canada, it has a great implication in the transmission of the shock to the smaller economies in the APEC region, thus showing the spillover effects and how the risks are well managed during the process in the region. Moreover, Kakran et al. (2024) employ the fact that these spillover effects are time-moving and crisis-sensitive, which implies the dynamic and mixed nature of APEC market relations.

Therefore, the necessity to incorporate the economies of the region into a global township has brought to the fore the combination of the region economic policy, global financial events, and liberalizations of the capital market and in this regard, there has always been a complex network of interconnectedness among the region economies. Such a dynamic environment results in the need of full-scale risk management and coordination of policies that will assist in overcoming the challenges of the ever-integrated global market.

2.2 Best Hedging Strategy

One of the most significant financial risk management strategies in the energy dependent industries and the agitated markets in APEC is hedging. It is effective in hedging against

many types of risks (e.g., price risk, basis risk, credit risk, operational risk) to enable firms to remain solvent and profitable in challenging market environments. As an example, companies in the oil and gas sector employ hedging to deal with excessive volatility in energy prices. Empirically, Haushalter (2000) and Jin and Jorion (2006) demonstrate that highly leveraged firms are more likely to hedge a larger proportion of their output to reduce the volatility of cash flows. These companies are also more likely to have more assets that allow them to develop more advanced, organized hedging programs using derivatives like futures, forwards, options, and swaps (Hull, 2018). These financial instruments help in shifting the energy price risk to third parties in exchange of the potential revenue that would have been lost and in enhancing certainty of future cash flows. Moreover, energy derivatives markets have also been characterized by a growing separation between short hedgers (e.g., producers who do not want to see prices fall) and long hedgers (e.g., consumers who want to see prices rise), who are interested in opposite ends of the price risk spectrum (Knox, 2015; Ederington & Guan, 2005).

The Minimum Variance Hedge Ratio (MVHR) and the Expected Utility Maximization (EUM) approach have been the two approaches that have dominated the discussions in the academic world when trying to find a suitable hedge strategy. The MVHR is concerned with the portfolio variance by calculating hedge ratios that can effectively offset the price movements in the spot and futures markets (Khan et al., 2021). MVHR is the most acceptable methodology as it is simple and easy to apply as observed in the literature (Lien & Tse, 2002). Morgan and Sam (2020) claimed that the MVHR is based on risk aversion and zero expected return futures, which simplifies the real world, which may be a problem in real-life hedging behavior. This contrast enhances the utility-based approach that has the advantage of directly integrating the preferences and risk aversion of the investors into the hedging decision and produces more accurate aligned hedge ratios as compared to the real financial objectives (Cecchetti et al., 1988; Kroner & Sultan, 1993). Recent studies based on time-varying models, including DCC-GARCH and copula-based estimations, have demonstrated that optimal hedge ratios are not fixed or homogenous, but rather flexible to varying volatility regimes (Mensi et al., 2016; Al-Yahyaee et al., 2019). When these methodologies are applied to the highly integrated APEC markets, it is suggested that the best hedging would be proactive and not passive and would consider cross-market spillovers, investor sentiment, and macroeconomic shocks. As APEC economies continue to develop, there is a necessity to

strengthen and improve current sharp hedging techniques to achieve greater financial resilience to multi-dimensional energy challenges and transitions due to sustainability goals.

The interdependence of the risks of energy, green bonds, technology, and gold markets is a reason to develop effective hedging strategies to control risk in their interdependence. Hedging of the energy sector remains a major concern because of the volatility and the power of geopolitical forces and policy shifts on fuel prices, particularly on oil and gas (Al-Mulali & Ozturk, 2015). Moreover, with the global economies moving towards sustainable energy, green bonds have emerged not only as an investment opportunity but also as a carbon-intensive asset that offers smoother waters and ESG (Environmental, Social, and Governance) adherence. These bonds are regarded as possible hedging tools (Nguyen et al., 2022). Meanwhile, technology stocks, with their high sensitivity to macroeconomic shocks, innovation cycles, and general market sentiment, bring their own risk profile that necessitates dynamic hedge ratios, especially during market distress. To illustrate, gold is a good example of a safe haven asset that offers security during inflation, devaluation of a currency, and financial crisis. It has been demonstrated that optimal hedging strategies in these markets are built using time-varying models, including DCC-GARCH or wavelet coherence models, which consider dynamic correlations and volatility spillover (Reboredo, 2013; Umar et al., 2021). In these contexts, green bonds can be valuable as a risk diversifier when clean energy prices are low, and gold can be valuable as a robust hedge when there is volatility in the equity markets, so multi-asset class hedging strategies are essential to the long-term resilience of the portfolio during turbulent periods and during environmental transition.

2.2.1 Green Bond Spillover as a Hedge against Equity Market Risk

The role of low-carbon equities and green bonds in the financial markets of the world in general and risk mitigation role in respect to the volatility of the equity markets in particular have been of interest in the past few years especially in the areas of risk hedging against equity markets. As the world economy shifts towards sustainability, green bond and green assets such as green bonds have been viewed as a potential financial asset that can diversify portfolios, reduce risks and assist in the greening process. The most significant thing about green bonds is that they turn out to be a safe haven when the markets become volatile, particularly in extreme cases as witnessed in the recent past; one of them being the COVID-19 pandemic and the geopolitical crisis with Russia-Ukraine war. A study such as the one by Muhammad and Huang (2025) is remarkable since it demonstrates the 12 months' time

varying interconnectedness and portfolio management strategies between renewable energy tokens, sustainable investments and Stock market indices particularly in the Gulf Cooperation Council (GCC) region. Their conclusion suggests that the interconnectedness of green assets and traditional financial products is likely to be exaggerated in the extreme market environment, where green assets shock-absorb during the bullish market dynamics and the stock benchmarks shock-transfer during the bearish regime. Similarly, Wang and Qiao (2025) affirm that volatility spillover effects are high among green bonds, low-carbon equity, and crude oil price during extreme events hence making them a viable hedging tool. In their study, they also introduce new measures i.e. Connectedness Survival Rate (CSR) and Quantile Connectedness Survival Rate (QCSR) to measure the stability of the connectedness and provide it with the required quantitative tools to study the resilience of these markets during crises.

Ren et al. (2023) also address the application of a green bond as a hedging instrument by considering how the green bond can hedge equity markets and create portfolio diversification. They discovered that green bonds were effective hedges to the equity markets of many countries, especially prior to the COVID-19 pandemic. However, the crisis had a severe impact on their hedging abilities, other than them serving as safe havens to several nations. The study also examined the tail risk spill-overs between green bonds and international equities using a modern CAViaR-based TVP-VAR, showing that they increased dramatically when the first wave of COVID-19 emerged, and remained at the elevated level in subsequent periods. This underscores the evolving hedging ability of green bonds, particularly in the aftermath of international financial crises. In addition, Billah et al. (2023) examined the question of the interconnectedness of Sukuk (Islamic bonds) with green bonds and concluded that during periods of extreme volatility in the market environment, green bonds were more interconnected with other financial securities, particularly in reaction to the COVID-19 pandemic. In their analysis, they discovered that although there was weak spillover of returns between Lord and Sukuk and green bonds, the volatility dynamics showed that green bond had high hedging efficiency especially during uncertain periods.

The need to use green bonds and equities as risk mitigation tools can also be traced in the findings of Husain et al. (2022), who applied data and information on the green investments and climate policy uncertainty (CPU) in the United States. They found that the green financial investments and CPU had an asymmetric correlation with green equities and green bonds being more resilient and better returns on long-term basis during high uncertainty

periods. It has been asserted that green investments primarily in long-term capacity have a higher portfolio performance compared to conventional financial investments in the face of headwinds of high policy-related uncertainty that presents attractive hedging opportunities to investors who are ready to mitigate market risks according to their studies. Furthermore, Mezghani et al. (2025) and Pham (2021) provided even more information regarding the purpose of green bonds to enable portfolio dependencies to diffuse and utilize them as efficient hedge tools against crises in the short and long terms of time. Mezghani et al. (2025) used the findings of the high COVID-19 impact period and concluded that green bonds were pertinent vulnerable victims of the stock market shock and commodities, including gold, which acted as a net transmitter of volatility in the long term. They discovered that the green bonds had immense diversification benefits and an opportunity of hedging particularly when combined with other market assets such as gold. Similarly, Pham (2021) has also pointed out the time-frequency relationship between green bonds and green equities, which showed that green bonds and green equities were highly interconnected in extreme market movements, which encompassed the COVID-19 crises, meaning that they are likely to constitute a diversified asset class.

Finally, the significance of green bonds in terms of volatility and portfolio diversification was also confirmed by Pillai et al. (2024) and Do lkan et al. (2025). Pillai et al. (2024) examined the volatility spillovers and time-varying correlations between international green bonds and stock markets around the globe where green bonds were found to have both short and long volatility spillovers, which means that they are effective hedging instruments at the time when financial markets are in crisis. In their study they felt the need to mention that to reduce the financial risks, policymakers, researchers and investors worldwide must include green bonds in their portfolio diversification. Dojan et al. (2025) also investigated the asymmetric relationship between green investments and international stock markets because they determined the fact that green bonds were net receivers of shocks, but they also played the most important stabilization functions, eliminating volatility in portfolio global stock markets.

In summary, the application of green bonds and the low-carbon equity in the portfolio management strategies has a high probability of reducing risks especially in cases where turbulence occurs in the market. Combining these studies, the outcome indicates that green assets are changing and so far green bonds have been significant hedges as diversifiers and stabilizers in the equity market. The shock-absorbing ability, particularly when markets are

exposed to shock-filled conditions, such as the COVID-19 pandemic and geopolitical tensions, makes Green bonds an essential tool in the clearance of investors to safeguard their portfolio, and thus have sustainable returns financially. These studies provide useful data to investors, policy makers and financial institutions that want to know how the market risk works, and one that is sustainable in the dynamic world economy.

Comparing findings across the reviewed studies reveals a nuanced picture of green bond hedging effectiveness. Reboredo (2018) found weak co-movement between green bonds and equities, suggesting diversification benefits, whereas Pham (2021) demonstrated strong frequency-domain dependence, particularly at longer horizons, challenging the safe-haven characterisation. More recent evidence from Ren et al. (2023) and Rehman et al. (2025) confirms that green bonds exhibit asymmetric hedging properties effective in variance minimization but less reliable during extreme market downturns. Methodologically, studies relying on static correlation measures systematically overstate green bond independence. The present study advances this debate by evaluating green bond hedging through three dynamic portfolio frameworks (MVP, MCP, MCoP), providing a more rigorous test of their crisis-period effectiveness in the APEC context.

2.2.2 Best Hedging Strategy between Energy and Equity Markets

A shift towards cleaner sources of energy and increased focus on energy security around the world in recent years has also changed the optimal energy market-equity market hedging strategies. Previously, crude oil was regarded as a good hedge and an appropriate media of risk diversification in the equity market (Sadorsky, 1999; Babalos et al., 2015). This paradigm however changed with the global financial crisis that struck in 2008. As shown by Factors Silvennoinen and Thorp, (2013), the degree of connectedness between the oil and equities market rose to an enormous extent during the post-crisis period thus weakening the diversification power of oil. The non-obvious correlation between oil and equity is further complicated by the heterogeneity of industries; as hypothesized by Bohi (1989) and subsequently by Lee and Ni (2002), industries that consume more energy like petroleum refining and auto industry are more vulnerable to the volatility of the price of oil. In addition, Elyasiani et al. (2011) have reported high oil price sensitivities in nine of the thirteen sectors they examined. This necessitates the recent demand of multivariate GARCH models to learn more about the correlation between oil and equity markets and create sector-specific hedging strategies (Ahmad et al., 2018). The GARCH models (DCC, ADCC, GO-GARCH) with VIX

and oil show that oil does have some hedging value but only under specified regimes and should be used more sparingly.

Conversely, natural gas is regarded as a more significant and cleaner energy source, particularly to the US and China, the largest producers and consumers of natural gas in the world. The fluctuation in the prices of natural gas, which is a widely used resource in the industrial, commercial, and residential sectors, is a significant threat to equity markets. In their studies, Sadorsky (2001) and Boyer & Filion (2007) demonstrated that non-linear energy stocks are affected by gas prices, exchange rates, and market returns in different time periods. Moreover, Chkili et al. (2014) and Creti et al. (2013) claim that the correlation between the prices of natural gas and the returns on equities varies over time, and they use advanced modeling tools like DCC-FIAPARCH to describe the dynamic hedge ratios. Gatfaoui (2016) and Mensi et al. (2015) also discuss unstable co-movement patterns between Saudi Arabia and the US gas and equity markets, respectively. Asymmetric multivariate GARCH models significantly improve the effectiveness of hedging as a part of regime switching and long-memory volatility dynamics.

There is evidence of the further integration of natural gas into the Chinese economy (Higashi, 2009), although the literature on the hedging relationship between the natural gas and the equity markets in China is rather scarce. Because of the consideration of the increasing dependency, the integration of structural breaks, asymmetries, and regime shifts into transmission risk models ought to be sought after the best multi-market hedging models.

2.2.3 Best Hedging Strategy between Green Bonds and Equity Market

The interplay between the hedging of green bonds and the equity markets remains an area of financial research given the increased attention on sustainability and the volatility of international equity markets. Green bonds are issued with the express intent of funding climate-resilient projects and provide investors with a hybrid payoff of both environmental and financial returns. In contrast to conventional bonds, green bonds are intended to be less correlated with equity markets, thereby acting as possible hedges in economic downturns, times of increased environmental risk, and when the population is particularly sensitive to these risks (Reboredo, 2018; Nguyen et al., 2020). The studies by Reboredo, Ugolini, and Aiube (2020) and Hammoudeh et al. (2020) observed the low spillover of returns and price connectiveness, or the absence of it, between green bonds and equity markets, which

highlights their ability to diversify portfolios and hedge against downside risk. Green bonds were also mainstreamed by the Green Bond Principles, which were subscribed to by the International Capital Market Association in 2014, which in turn triggered the interest of ESG investors and traditional institutional investors.

According to the signalling theory, green bonds serve as a credible commitment to ecologically sustainable policies that increase market confidence and are likely to decrease risk premiums during turbulent periods (Engle et al., 2020; Pasta et al., 2021). These aspects allow green bonds to be effective hedging instruments in equity-intensive portfolios, particularly when the stock market volatility is caused by environmental, political, or geopolitical factors.

The current literature reviews the approaches to assess green bonds and their hedging performance against equities through different methods. GARCH type models such as DCC-GARCH, GO-GARCH, and ADCC-GARCH are used to compute time-varying hedge ratios and dynamic correlations. As demonstrated by Ahmad et al. (2018) and Sadorsky (2012), the conventional hedging assets like VIX and oil are indeed powerful hedging utilities, but green bonds are becoming more and more effective in mitigating portfolio risks, especially in a mixed green-brown asset environment. The hedging capacity of green bonds is further demonstrated by Kuang (2021a, b) and Ferrer et al. (2021) who demonstrate that green bonds and green stocks can be used to diversify risk against high-carbon or dirty energy stocks thus confirming their attractiveness to climate-conscious and risk-averse investors. Moreover, green bonds are less sensitive to macroeconomic shocks and geopolitical events, which makes them more appealing as hedges in the case of systemic crises (Park et al., 2020). Bondia et al. (2016) employ structural break models and Reboredo et al. (2017) wavelet coherence analysis, to demonstrate that the hedging relation between green bonds and equities is time-dependent and stronger in the short-term in case of financial turmoil or oil price spikes.

As investment in clean energy increases, the green bond market is maturing, becoming more liquid and regulated, enabling more certain hedging of equity exposures. In addition, the best hedging solutions using green bonds and equities are now complemented by multi-model integration, including advanced dynamic econometric modeling (GARCH/VAR), machine learning (e.g., reinforcement learning), and connectedness analysis, which are more resilient and flexible in managing financial risks in a fast-decarbonizing world.

2.2.4 Best Hedging Strategy between Technology and Equity Market

The new literature on the best hedging strategies between the technology sector and the equity markets presents the sharp changes that are typical in technology assets that require sophisticated combined actions to address unconventional volatility and innovation cycles. Conventional econometric models continue to provide basic methods, but others use multi-step hedging models, liquidity-based models, and regime-switching algorithms. As an example, Huang and Guo (2013) introduce the QRA (Quadratic Risk Adjustment) multi-step hedging strategy, which generalizes the static risk minimization models to incomplete markets through dynamic programming, and is demonstrated to be effective across different temporal horizons. Gao et al. (2019) emphasize the unifying nature of liquidity in option-based hedging when applying Bayesian reasoning by illustrating liquidity constraints, which show that the available cash influences key strike price decisions and Value-at-Risk (VaR) mitigation. In addition to this, François et al. (2012) advocate a dynamic regime-switching hedge that reacts to volatility fluctuations that is especially suitable to the volatile nature of the sector. These methods move beyond fixed hedge ratios to more dynamic ratios that include microstructure factors, macroeconomic volatility, and tail-risk shocks. These models force complex self-customization due to the pace of innovations in the market, the non-linear price paradigm of technology stocks, and calibrate complexity to the investors.

It is only in the recent past that some researchers have begun to use machine learning and deep reinforcement learning (DRL) to create complex and adaptive hedging strategies that can overcome the challenges presented by the high volatility and asymmetric risk of technology equities. According to Neagu et al. 2025; Cao et al. 2021, DRL algorithms such as Proximal Policy Optimization (PPO) and Monte Carlo Policy Gradient (MCPG) perform significantly better than classical methods when faced with high transaction costs and sparse rewards, which are common in deep-sea settings. These algorithms allow the regime-shift and informational shock portfolio recalibration of the tech market to strike-of price oscillations. Moreover, Bhaduri and Durai (2008) and Gok (2016) observed that GARCH-family models are efficient in long-horizon hedging, and they capture the time-varying volatility spillover between tech and long-range equity indices. Ebach et al. 2016 further the discussion by demonstrating that accounting models, particularly those subject to fair value regulations, are a powerful determinant of intensity and preference in hedging as companies strategically weigh earnings volatility against profit maximization. The model is vulnerable to contagion

or tech sell-off periods when combined with system-based ideas such as those proposed by Gao et al. (2015), who provided evidence of systematic interdependences to calculate hedge ratios. This is also advanced by Buehler et al. (2021) which shows how the incorporation of non-quadratic penalties in the DRL frameworks maximizes downside protection in long-term derivative hedging. Finally, the emerging literature is leaning towards a unified perspective of responding and adapting their hedging strategies at the nexus of technology and equity by combining machine learning with traditional econometric and accounting models.

2.2.5 Best Hedging Strategy between Gold and Equity Market

Gold has attracted a lot of research attention as a hedging and safe haven tool in the face of increasing financial volatility and contagion in the world equity markets. The differentiating study of Baur and Lucey (2010) establishes the context of three key functions of risk mitigation, namely hedge, diversifier, and safe haven, depending on the correlation between gold and other asset classes under different market conditions. Their study, which uses a GARCH-based regression model with daily stock, bond and gold price index data of the US, UK and Germany, concludes that gold is a hedge against stocks during normal times and a safe haven during crisis. This distinction is significant to portfolio managers who are concerned with reducing risks in extreme market conditions. However, this conduct is not uniform across the world. Their subsequent analysis with McDermott (2010) shows that gold does not serve as a safe haven in emerging economies such as Brazil, Russia, India and China (BRIC), which suggests that the hedging ability of gold can be influenced by market sophistication, investor sentiment, and domestic macroeconomic conditions. According to Capie et al. (2005), the exchange rates of the major currencies are inversely proportional to the gold returns when a linear ARDL model is applied. This observation confirms the hypothesis that gold can be used as a good hedge against currency risks especially when there is depreciation of the dollar. Similarly, Tully and Lucey (2007) presented the results using an APGARCH model. They affirmed the dominating role of the US dollar in the volatility of the gold prices, which reinforces the role of gold as a hedging asset in portfolios exposed to foreign exchange risks.

Moreover, the recent empirical literature has also focused more on time-varying spillover volatility and dynamic hedge ratios with advanced econometric models like VARMA-GARCH, DCC-GARCH, and causality-in-quantiles. An example is the study by Hammoudeh and others (2010) on volatility linkages of gold, silver, platinum and palladium and concludes

that despite the weakest short-run sensitivity, gold is highly sensitive to exchange rate fluctuations and geopolitical crisis, particularly the Iraq War in 2003. The authors also propose that gold is the most stable character of precious metals using multivariate GARCH frameworks and therefore the best hedging instrument in times of crisis. Mentis et al. (2013) use a VAR-GARCH model to examine volatility spillover of other major equity markets such as the S&P 500 to the commodities markets including gold during major crisis periods such as 9/11, the Iraq War and the 2007-08 Global Financial Crisis. Their findings describe the significance of the variable dependence of equity markets and the price of gold and attempts to dynamically change the respective hedge ratios. On the contrary, Maghyereh et al. (2017) oppose the relentless deport of gold dominance by stating that the application of a DCC-GARCH approach across the Gulf Cooperation Council (GCC) markets exhibits weak and inconsistent spillover connections between gold and equities arguing about the insignificance of gold as a hedge in small or oil-based economies.

Moreover, Naser (2017) and Balcilar et al. (2018) using Granger causality and nonparametric quantile-based methodology, respectively, indicate that the hedging capacity of gold is more active in the long-run and significantly reduces in the calm and highly turbulent periods. These conflicting results highlight a new trend in the literature that tries to evaluate the role of gold as an asset that is biased towards convergence, trying to explain that, although gold can be used to offer downside protection in certain situations, there is an over-reliance on it as a risk-minimizing asset that is bluntly stated without regard to market structure, regime shifts, and macro-financial interdependencies. Therefore, to attain a stable performance, an optimal hedging strategy using gold should be customized to the particular market and sensitive to temporal and structural changes.

2.2.6 Best Hedging Strategy between APEC Equity Markets

APEC with its 21 member economies was established with the objectives of promoting the emerging innovation, and sustainable economic growth and technological development in the region. In terms of rising environmental degradation in the world, APEC economies pledges itself to cleaner development such as the utilization and promotion of renewable energy, green technology, and resource conservation (APEC, 2020, 2021). Such environmental commitments, as well as many others, affect financial markets, particularly equity markets, as nations react to sustainability drivers in-shore and climate change risks. With the worsening ecosystems crisis, more and more serious pollution, climate change, and biological diversity

loss (Qiao et al., 2021; Le et al., 2017; Cui et al., 2015), the reduction of environmental and market risks has become extremely significant. Moreover, energy transition and environmental sustainability commitments are likely to lead to capital market instability because of policy changes, investor mood swings, and resource redistribution. Consequently, equity market investors in APEC are beginning to seek more effective ways of hedging their portfolios against these multiple layer risks.

Due to the rise in market uncertainty, geopolitical volatility, and global risk, the best hedging strategies in APEC equity markets are changing at a fast pace. Some empirical literature has been devoted to the intricate econometric models in these systems, including DCC-GARCH, BEKK-GARCH, and even wavelet-based models, which have found time-varying connectedness and dynamic estimation of hedge ratios across APEC stock indices (Al-Yahyaee et al., 2019; Reboredo & Ugolini, 2016). The 2008 financial crisis and even the COVID-19 pandemic demonstrated that precious metals, particularly gold and silver, have significant hedge asset value during crisis times (Bouri et al., 2020; Shahzad et al., 2019). Their low or negative correlation with equities in both short and long-term periods makes them more valuable in optimal portfolio constructions. The Exchange-Traded Funds (ETFs) tracking these commodities have been found to enhance the effectiveness of hedging in the Asia Pacific markets. Futures contracts on a country-specific basis, particularly the NFNE futures in Taiwan, have been found to reduce some of the risks in a sector by reducing the variance (Chuang et al., 2007). Other researchers like Mensi et al. (2016) and Chatziantoniou et al. (2021) claim that the effectiveness of hedges and asset connectedness vary across time horizons, which explains the importance of a multi-horizon hedging strategy. The results are especially applicable to APEC markets (which are heterogeneous due to the variations in the economic structure, regulatory framework and the reliance on energy that requires customized hedging). In general, the effectiveness of the hedging strategies can be improved against the dynamism of the APEC region economy and environmental issues through investments of the different asset classes such as energy commodities, green bonds as well as metals to dynamic modelling.

2.3 Co-movement

No wonder, co-movement phenomenon has been an issue of concern to the researchers of the financial and commodity markets since Pindyck and Rotemberg (1990) found out that

commodity prices whether they appear to be directly related or not, move together with each other over time. This led to debates as to whether such movements that occur concurrently are the result of fundamentals coming into line or market inefficiencies like the herd mentality or a liquidity crunch. Cashin et al. (1999) disproved this view by turning to the concordance measures and balanced this perception by coming up with minimal substantial evidence of irrational co-movement across commodities and introduced the voice of rationality. More recently, Lescaroux (2009) and Owusu et al. (2024), Huang et al. (2021) took the debate further by demonstrating that co-movement is more likely to be higher in short term cyclical components and is more accentuated in periods of market turbulence. Natanelov et al. (2011) also pointed out that the relationship varied over time, especially between crude oil and certain agricultural commodities, and that macroeconomic shocks, global crises, and inventory changes are essential.

The study has also evolved in terms of the study of commodity super-cycles longitudinal price trends over decades super cycles advert their turning points as a result of fundamental changes in international demand, usually triggered by the industrialization of emerging economies (Jerrett & Cuddington, 2008; Erten & Ocampo, 2013; Fernández et al., 2020). To an increasingly large extent, this literature is applying multiscale methods like wavelet analysis and cointegration - the analysis of time series, consisting of sine functions, exhibit super-imposed oscillatory motion - to the dynamics of co-movement phenomena which is revealed to be far more complex than a mere combination of correlational components, where it combines fundamental, cyclical, and speculative forces. Besides the commodities, co-movement has been playing a significant role in describing the connections between global equity markets, green bonds, technology-intensive industries, and safe-haven assets such as gold. The integration of the equity markets in the APEC economies has increased exponentially because of the financial liberalization, trade integration, and cross-border investments (Kuroda & Kawai, 2004; Chung & Li, 2024; Kamal & Bouri, 2025) The empirical evidence of volatility spillovers and contagion effects has been observed using sophisticated models like Copula-GARCH and wavelet coherence in the case of significant financial crises (Forbes & Rigobon, 2002; Yarovaya et al., 2022). Gold, historically viewed as a hedge and a safe haven asset, facilitates risk-averse investment strategies because it depicts negative co-movement with equities during periods of elevated stress (Baur & McDermott, 2010). Moreover, new financial products like green bonds and technology equities have been said to become more and more synchronic with the traditional stock

market due to changes in global policies and ESG investment policies (Wu, 2019; Wu et al., 2020; Dorfleitner & Zhang, 2024; Gyönyör & Horváth, 2024). The convergence of the Chinese capital markets, coupled with the rapid technological development of the region, reinforced the already established patterns of co-movement in the APEC countries in the reaction to external shocks (Sun et al., 2023; Sher et al., 2024). These diversifyer trends underscore the increasing literature base that emphasizes the necessity to examine co-movement of as many different classes of assets as possible in a multi-temporal framework with changing dependencies that consider systemic relationships. The contemplation of such a strategy offers great insights into how better to manage an investment portfolio on a global and strategic risk mitigation level.

2.3.1. Co-movement between Energy and Equity Market

The industrial and economic development of the world in the last two centuries has been largely dependent on the so-called dirty sources of energy like coal, natural gas, and crude oil. Meanwhile, the need to reduce greenhouse gas emissions has been persistent and this has prompted investors, institutions and even policy makers to consider clean energy alternatives. In this respect, the establishment of the Wilder Hill Clean Energy Index in 2004 was a good move towards gauging the performance of the market in terms of clean energy. Since then, investors began to move away towards renewable energy and technologies as opposed to fossil fuel-based investments. To illustrate, the world invested in clean energy increased by 300 percent to 363.3 billion dollars between 2009 and 2019 and even increased by 2 percent during the COVID-19 pandemic (Bloomberg New Energy Finance, 2019). Nevertheless, it is difficult to eliminate the reliance on conventional fossil fuels that allow cost benefit advantages, as well as infrastructure reliance. Due to this, natural gas remains a powerful energy source and will remain a bridge fuel because it has a cleaner carbon footprint than coal or oil.

The interconnections between clean and dirty energy markets are inherently interrelated and this offers outstanding implications in terms of price, diversification oversight, portfolio, and investment strategies. The literature has two dominant theoretical perspectives regarding the relationship between these markets. The substitution hypothesis assumes that the increasing oil prices will contribute to an increased transition to clean energy, which will improve renewables. This capital inflow enhances investor interest and tilts towards increased dependence on finance (Henriques & Sadorsky, 2008; Darnall et al., 2008; Sadorsky, 2012;

Song et al., 2019). Conversely, the decoupling hypothesis implies that clean and dirty energy are two distinct markets whose characteristics are costs, risk, and technology, which tend to work independently of one another (Ahmad, 2017). The evidence is more of a hybrid that fits into some kind of conditional and time varying co-movement as opposed to substitution or decoupling. As an example, the high cost of clean energy technologies, especially in the early stages, makes them very sensitive to changes in fossil fuel prices, which makes full uncoupling impossible both economically and structurally (Ferrer et al., 2018; J. Tian et al., 2021; Christophers, 2021) Thus, it is significant to note that investors and regulators should be aware of the shifts in dependence between these markets in the context of the energy transition to more robust frameworks in line with sustainable finance.

The COVID-19 pandemic was a natural experiment to test the resilience and interconnectedness of clean and dirty energy markets under conditions of extreme economic stress. The worldwide lockdown, along with travel bans, resulted in a decrease in the demand of fossil fuels by about 6 percent, with the U.S. and EU seeing a 9 percent and 6 percent decrease, respectively (IEA, 2021). This led to a record low in crude oil prices, as WTI futures briefly dropped below \$20 per barrel (Tang & Aruga, 2021; Tang et al., 2023). The clean energy sector was also affected by investment disruptions and project delays, but its price volatility was relatively lower, which suggests that diversification benefits may be achieved in times of crisis (Ghabri et al., 2021; Ghallabi et al., 2024). However, these advantages are not necessarily permanent; empirical research that includes time-varying models, including DCC-GARCH, wavelet coherence, and TVP-VAR, indicates that the consumption of clean and dirty energy rises during a crisis, thereby decreasing the effectiveness of diversification strategies (Reboredo, 2015; Bouri et al., 2022). Therefore, scholars and policymakers are increasingly interested in examining these changing relationships within the framework of post-pandemic recovery to enable transitions to cleaner energy systems and develop resilient energy policies. Moreover, the co-movement of clean and dirty energies is also significant in the formulation of the best hedging strategies. As uncertainty rises, investors, policymakers, and market stakeholders are increasingly resorting to tools that can help them mitigate risk to preserve value and stabilize financial systems, including the COVID-19 pandemic. Past research shows that the interaction between asset classes leads to stress that tends to increase systemic risk and reduce the overall hedging effectiveness (Chofreh et al., 2017; Kocaarslan & Soytaş, 2019; Chofreh et al., 2020). Since the energy markets remain vulnerable to economic cycles and geopolitical shocks, new

studies are aimed at establishing whether clean energy markets can be used to hedge against oil price volatility and vice versa. The extent and degree of such hedging relations are vital in the context of construction of diversified portfolios, strategies in line with climate goals, and achievement of post COP26 goals of energy transitions.

The wavelet-based co-movement literature reviewed above consistently identifies scale-dependence in energy-equity relationships: short-term co-movements are weak or negative, while medium-to-long-term correlations are strongly positive, particularly in commodity-dependent APEC economies such as Malaysia, Canada, and Russia (Cui et al., 2020; Choi et al., 2024). However, a key limitation across these studies is their geographic focus most are confined to G7 or BRICS countries, neglecting the heterogeneous economic structures of APEC nations. This study extends the wavelet coherence framework to all 19 APEC markets across five crisis windows, providing the most geographically comprehensive time-frequency co-movement analysis to date.

2.3.2 Green Bonds and Equity Market Co-movement

The issue of climate change and the necessity to transition to low carbon economy has made green bonds, capital raised to finance environmentally sustainable projects, popular in the global markets. Since the launch of the Green Bond Principles (GBP) by the International Capital Markets Association in 2014, the green bond market has experienced an enormous growth. Green bonds issuance reached its peak, increasing by 11 billion in 2013 to more than 81 billion in 2016 (Climate Bonds Initiative, 2017). A broad range of factors such as sovereigns, corporates, and supranational institutions now issue green bonds. The bonds support projects that are directed to renewable energy, energy efficiency, low-carbon transport, and sustainable water projects (European Commission, 2016). Although the use of green bonds has grown exponentially, they represent a tiny percentage of the total bond market. This implies that the fluctuation in value of the bonds will affect other investments and hence they are important to watch in regard to covering portfolios. According to researchers, the effort to comprehend how issuers of green bonds relate to equities, commodities, and fixed income segments is worthwhile since these investors seek to diversify and minimize risk (Reboredo, 2018). Unlike the ordinary bonds, green bonds consider the environmentally harmful factors that give insights on how investments on climate change are affected by various financial market conditions.

The relationship between green bonds and other assets is not fixed, and may vary significantly during some market regimes, especially during financial stress or macroeconomic shocks. As an example, in downturns or crises, e.g. the COVID-19 pandemic, a tendency to increase correlations between financial assets is observed, which reduces the benefits of diversification. Green bonds can be related to other bonds differently in those periods than in normal periods. In order to overcome this inability to capture, dynamic and static copula models have been used to examine the average and tail dependencies of green bonds and other financial assets (Reboredo et al., 2017). These models help to determine whether green bonds can be regarded as effective hedging tools or susceptible to volatility spillover in extreme market conditions. As an example, Pham (2016) examined the volatility of green bonds, whereas Flaherty et al. (2016) investigated the use of green bonds in financing climate mitigation. Moreover, the growing marketization of green bonds through dedicated sections on the Luxembourg, London, and Shanghai stock exchanges has enhanced their liquidity, transparency, and marketability. Nevertheless, despite such developments, the extent to which green bonds are decoupled or aligned with other financial markets is an empirical puzzle, especially with regard to asset managers who integrate ESG and sustainable finance into conventional portfolios. Understanding these types of interrelation will be central in realizing the real potential of green bonds in funding climate change and as an investment in times of financial hardship and in times of an environmental crisis.

2.3.3 Technology and Equity Market Co-movement

The technological and equity market connection has gained more importance to researchers due to the composition of technology companies in the global stock indices and their overweight influence on market volatility and returns. A significant change or technological advancements tend to lead to a similar change in the productivity of a firm, the competitiveness of an industry and the overall sentiment of the investors that influences the stock prices (Hall, 2001; Malkiel et al., 2003; Kumar & S, 2024). This means that stock markets start to anticipate technological advancement and take into account both real and speculative innovations. The boom in investment in technology stocks, particularly in the pandemic, and the digital acceleration, or the post COVID era, shows how powerful the influence of technology futurism is on the whole market ecosystem (Pástor & Veronesi, 2009). They, and many other researchers, also noted that technology indices and equity

markets are highly simultaneous in times of high uncertainty or times of technological disruption. As an example, consider the NASDAQ-100, which is dominated by technology stocks, and is likely to lead the entire market with tech-enhanced booms and busts (Phan & Narayan, 2020).

In addition, technology stocks and traditional equity markets exhibit co-movement that is time-varying and asymmetric, which means that their interdependencies are mutually determined by market conditions, risk appetite, and macroeconomic expectations. It was discovered that the technology sector returns are more sensitive than other sectors to global shocks and monetary policy changes (Baele, 2005; Chiang et al., 2007; Chiang & Zheng, 2010). In times of Crisis such as the Global Financial Crisis and COVID pandemic, tech stocks are more volatile in the short term, but rapidly stabilize due to high perceptions of their innovation potential. Moreover, the rapid spread of digital technologies in various industries has led to the increase in technology shocks across the equity market on a pervasive basis (Bloom et al., 2013). This reliance identifies the centrality of investigating the impact of innovation waves, R&D expenditures, and digitalization of markets on the stock market. As the world continues to digitize at an alarming rate, it is expected that the level of interdependence between technology and equity markets would rise, which would influence the diversification strategies, sector rotation strategies, and policy measures to enhance market stability.

2.3.4 Co-movement among Gold and Equity Market

Scholars have long examined the connection between gold markets and equity markets, largely because of the unique role of gold as a safe haven and hedge during times of financial market stress. The traditional definition of gold is that it is a zero-beta asset with better inflation-hedging capabilities. It has shown countercyclical nature to equities during partitions or crisis (Baur & McDermott, 2010; Baur & Lucey, 2010; Madani & Ftiti, 2021). This profile is further pronounced in the event of financial contagion and systemic risk where gold prices tend to rise as investors flee riskier equities in favor of a flight to quality. Numerous studies have also emphasized the risk management and diversification benefits of gold, arguing that its poor or negative correlation with equities increases portfolio efficiency (Capie et al., 2005; Hillier et al., 2006; Sakemoto, 2017). However, this correlation will be higher in times of extreme financial stress such as the Global Financial Crisis or COVID-19, where there is greater co-movement because of global investor sentiment and synchronized

macroeconomic shocks. This prompted a new line of research on the conditional and time-varying nature of the gold-stock relationship, especially in developed and emerging market economies where structural differences tend to affect asset integration and hedging relationships.

Going beyond mere correlation analysis, modern techniques tend to analyze the gold-equity synchronization in the time-frequency domain, such as wavelet transforms and multiple wavelet coherence (MWC). These methods demonstrate that the relationship between gold and stocks is not constant but changes with different time periods and economic cycles (Rua & Nunes, 2009; Vacha & Barunik, 2012). Multiscale empirical evidence suggests that the interactions between the gold and stock markets are frequency dependent, i.e. they interact more at certain time scales or during significant events such as geopolitical conflicts or inflationary shocks. In contrast to time-series models that only capture connections between economic phenomena at a single time point, joint time-frequency models are more likely to be flexible in terms of accommodating dynamic connections, both persistent and transient, reflecting the time-varying and structural changes of co-movement relationships. In addition, most of the past literature examines the gold-stock nexus in isolation, but recent studies favor a multivariate analysis that incorporates the interdependence of oil, gold, and stock markets at the same time (Zhang & Wei, 2010). This approach enhances the insight into the interdependence of asset markets, particularly in regions of Asia where the use of gold is culturally and economically significant. This study on the co-movement of spot prices of gold in China, India, and Vietnam as the leading consumers of gold in Asia can help in developing more holistic approaches to portfolio diversification and stability in international finance.

2.3.5 Co-movement of APEC Equity Markets

Equity market integration in the Asia-Pacific Economic Cooperation (APEC) region has been on the rise in the past decades as a result of a financial liberalization, international investments, and increased intra-regional cooperation (Kuroda & Kawai, 2004). As APEC members interact more, intra-regional diversification of stock markets has increased, providing opportunities or risks to investors worldwide (Anwer et al., 2022; Wu et al., 2020). This effect makes the APEC equity markets more amenable to the study of co-movement behaviors during shocks and crises. Empirical studies indicate that the market co-movements are more intense in the case of system-wide stress, thereby establishing contagious dynamics that are not characteristic of dynamic interdependence (Forbes & Rigobon, 2002; Yarovaya et

al., 2022). The volatility spillovers (VSs) that take place during such times are the allocation of uncertainty or sentiment among investors across nations (Luk et al., 2020; Sweidan, 2025)), which challenges risk decision making and diversification policies formulated by investors operating in the region.

The literature on contagion and spillovers is abundant and varied, but literature specifically on the APEC region remains very limited. Among the most prominent ones, Zhong and Liu (2021) and Chen and Wang (2023) depict the growing significance of the stock market in China; it is more interconnected with the economies of Southeast Asia even a few years ago. Previous studies such as C. L. Lin and Rajan (1999) and Bende-Nabende (2003) examined the extent of interdependence among the APEC member countries following the 1997 Thai baht crisis and foreign direct investment (FDI) inflow. The most recent research provides some insights into some of these relationships by characterizing them as changing, with Kakran et al. (2023) noting the growing effects of capital market liberalization in China on the capacity to external shocks. Moreover, intra-regional trade (Lee et al., 2012), and innovation-led convergence (Idrees & Sarwar, 2022), have been cited as factors that have led to higher financial co-movements. Thus, the APEC equity markets no longer move independently; rather, they display non-linear, dynamic interdependencies that necessitate sophisticated econometric modelling that encompasses TVP-VAR, and wavelet coherence to improve understanding of regional integration and systemic risk diffusion.

2.4 Bibliometric Analysis of Equity and Energy markets spill overs

2.4.1 Data Collection

In our bibliometric study of Equity and Energy markets nexus, we have used the Scopus database. Scopus is one of the most popular scientific databases that offer access to a wide selection of peer-reviewed academic journals, conference proceedings, and other scholarly publications, representing a wide range of disciplines, such as finance, economics, and energy. It is known to be very extensive and trustworthy, with high-quality academic material published by large international publishers like Elsevier, Springer, Taylor and Francis, and Wiley [61, 107].

The search query of this research was formulated to retrieve literature on energy and equity markets, with emphasis on spillover effects and hedging strategies. The search string was as follows: (energy market OR oil market OR natural gas market OR renewable energy market) AND (equity market OR stock market OR financial market) AND (spillover OR hedging OR

risk management OR volatility). This search was conducted in the title, abstract and keywords of the database. In order to guarantee the quality and relevance of the literature, only peer-reviewed journal articles published in English were used in the analysis. The topic area was restricted to economics, finance, and business management to make it consistent with the research topic.

The search query initially retrieved 1,230 documents. The titles and abstracts of these articles were then reviewed to determine relevance. Articles without necessary bibliometric information (e.g., abstract, keywords) or those that did not fit the inclusion criteria were not included in the study. This filtering procedure left a final dataset of 920 documents, which were then extracted in CSV format to be analysed with the bibliometric tool VOS viewer. VOS viewer is a free software that can be used to generate, visualize and analyze term maps and co-occurrence networks. It is commonly applied in bibliometric studies to create networks of keyword co-occurrences, citation analysis, and visualization of research trends [52].

The gathered and analysed data will be useful in terms of understanding the development of the research on the energy-equity market nexus, the most important research topics, the most influential authors, and their contributions to the field. It will also illuminate the new tendencies in hedging strategies and risk management methods, providing a general picture of the current research state and defining the possible gaps to be filled in the future.

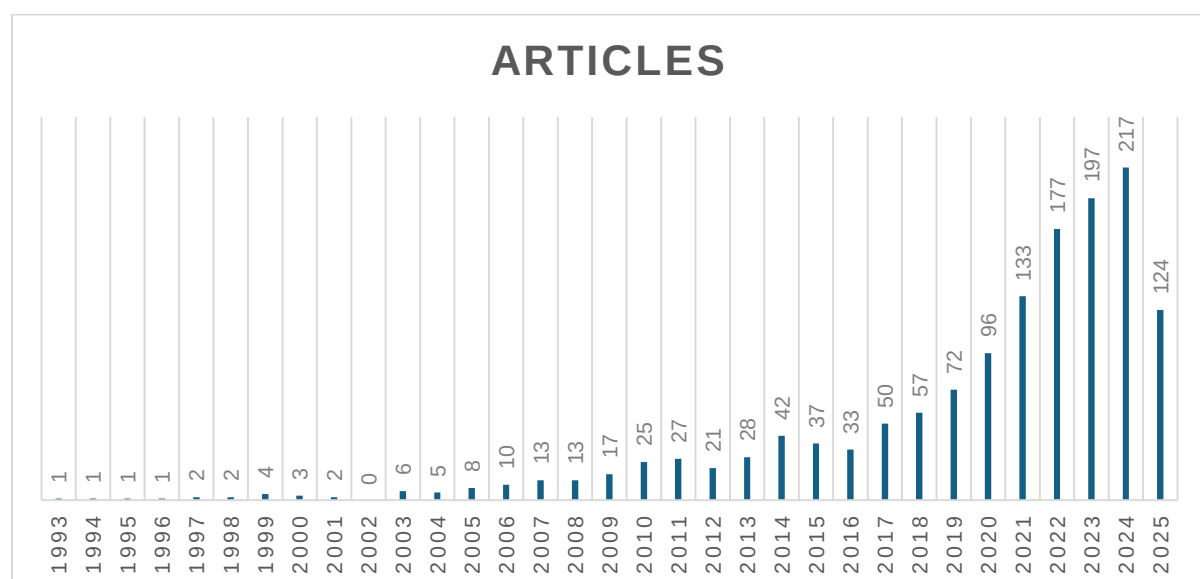


Fig. 2.1. Year-wise annual production of energy-equity market nexus research

2.4.2 Results of the descriptive analysis and discussion

2.4.2.1 Descriptive statistics

The Fig-2.1 data shows that there is a significant increase in the number of publications beginning in the year 2010. The first period (1993 to early 2000s) indicates that there is little activity in this research field with very few articles published annually. The number of articles is relatively low between 1993 and 2008, with the range between 0 to 10 articles per year. Nevertheless, since 2009, the number of articles per year increases significantly. This increase is particularly noticeable after 2014, when the number of articles exceeds 50 and increases sharply until 2024 and beyond 2025, with the forecast showing a sharp peak. This implies that there is a fast and increasing interest in the energy-equity market nexus study, especially in the recent years. The sudden increase in publications since 2014 is consistent with a wider academic interest in energy and equity markets, which has been fuelled by global trends such as energy transitions, sustainability, and socio-economic policies that have intersected energy, equity, and environmental concerns. This trend demonstrates the extent to which research in this area has become a topic of great interest because it is relevant to policy-making and the new global priorities of energy equity. This development indicates a wider academic concern with the intricate interdependencies between energy production, distribution, and social equity, which highlights the importance of this study in both academic and policy-making communities. The trend of the rise in publications in the direction of 2024 and further indicates the further development of this field of research, which will probably be devoted to the problems and solutions of energy equity as the global problems change.

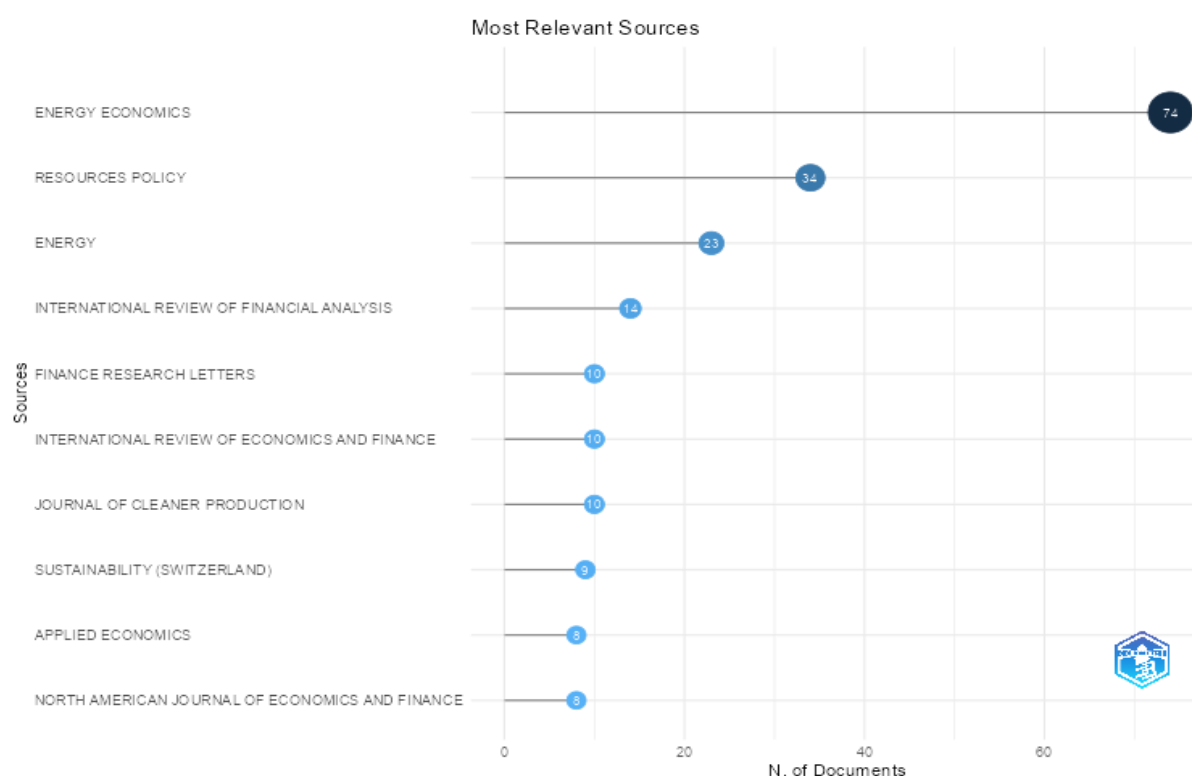


Fig. 2.2 shows top 10 most relevant journals

Table 2.1 and Fig-2.2, indicates that the number of published articles in 5 categories is as follows, Top Journals Energy Economics is the leading journal in the field of energy research with 74 articles. Resources Policy comes next with 34 articles and Energy with 23 articles, which indicates that these journals are important in publishing research on energy and market dynamics. Emerging Fields and Trends Journals such as International Review of Financial Analysis (14 articles) and Finance Research Letters (10 articles) are also notable in addressing the financial consequences of energy policies and market forces. According to Journal of Cleaner Production (10 articles) and Sustainability (Switzerland) (9 articles), sustainability and cleaner production processes are becoming more important in studies concerning the energy-equity nexus. Various Coverage The list is highly interdisciplinary, with such areas as economics, finance, environmental science, and energy studies being included. As an example, Applied Economics (3 articles), International Journal of Environmental Management (4 articles), and Environmental Science and Pollution Research (6 articles) demonstrate the increasing interest in the environmental consequences of energy policies. The diversity of journals in the field of finance, including Global Finance Journal (1 article) and Journal of Financial Economic Policy (1 article), indicates an increasing interest in the financial side of energy transitions and sustainability. Niche Research A number of specialized journals, including Energy Strategy Reviews (3 articles) and Technological

Forecasting and Social Change (2 articles), are devoted to the prediction of energy trends, technological progress, and their socio-economic consequences. The growing academic interest in quantitative modeling in energy and market nexus research is also evident in journals in applied economics and quantitative finance, including Quantitative Finance and Economics (2 articles). Other Notable Journals: The list is broad and contains a variety of journals, some of which are regionally or niche-specific in their coverage of the energy and finance relationship. As an example, the global and emerging market perspective on energy economics is reflected in North American Journal of Economics and Finance (3 articles) and International Journal of Emerging Markets (6 articles). The significance of renewable energy sources in the development of economic and financial systems is also highlighted in journals such as Energies (6 articles) and Renewable Energy (2 articles), as shown in this table, which demonstrates the popularity of the energy-equity market nexus among scholars, with many journals providing valuable information on energy policies, sustainability, finance, and environmental issues. The variety of journals and their contributions indicates the complexity and interdisciplinary character of research in this area.

Table 2.1: Top 20 most relevant journals

Journals	No. of Articles
Energy Economics	74
Resources Policy	34
Energy	23
International Review Of Financial Analysis	14
Finance Research Letters	10
International Review Of Economics And Finance	10
Journal Of Cleaner Production	10
Sustainability (Switzerland)	9
Applied Economics	8
North American Journal Of Economics And Finance	8
Research In International Business And Finance	8
Energies	6
Environmental Science And Pollution Research	6
International Journal Of Emerging Markets	6
Journal Of Risk And Financial Management	6
Economic Analysis And Policy	4

International Journal Of Finance And Economics	4
Journal Of Commodity Markets	4
Journal Of Environmental Management	4

Table 2.2: Top 20 most productive scholars.

Authors	Articles	Articles Fractionalized
Mensi W	17	4.03333333
Kang Sh	15	3.5
Tiwari Ak	13	3.53333333
Chen Y	10	3.11666667
Liu X	10	2.95
Vo Xv	9	2.18333333
An H	7	1.35
Hammoudeh S	7	1.86666667
Ji Q	7	1.83333333
Li Y	7	1.83333333
Wang X	7	3.03333333
Wang Y	7	2.41666667
Bouri E	6	2.2
Gao X	6	1.36666667
Li H	6	1.28333333
Pham L	6	4.25
Urom C	6	1.61666667
Ali S	5	1.33333333
Deng J	5	1.11666667
Guesmi K	5	1.36666667

Table 2.3: Institutions with more than 10 publications

Institution	Articles
China University Of Geosciences	41
Central South University	24
Beijing Forestry University	21
Pusan National University	19
Lebanese American University	15
Sultan Qaboos University	15
Beihang University	14

Capital University Of Economics And Business	14
China University Of Mining And Technology	14
University Of Economics Ho Chi Minh City	14
Changsha University Of Science And Technology	13
University Of Science And Technology Beijing	11
Zhongnan University Of Economics And Law	11
Kobe University	10
Xiamen University	10

2.4.2.2 Statistics of the influential authors, institutions, and countries

Table 2.2 shows the 20 most productive scholars in Dynamic Connectedness, Optimal Hedging Strategy and Co-movement amongst Energy, Gold, Technology, Green Bonds and APEC Equity Markets as found in the Scopus database and ranked according to their output in top journals.

Table 2.3 shows the 15 leading academic institutions that have made the most contributions to Dynamic Connectedness, Optimal Hedging Strategy and Co-movement amongst Energy, Gold, Technology, Green Bonds and APEC Equity Markets studies. The most published papers are affiliated to China University Of Geosciences with 41 publications, the Central South University with 24 publications and the Beijing Forestry University with 21 publications. In general, the top ten productive institutions list contains institutions in developing countries. Although the research activity on Dynamic Connectedness, Optimal Hedging Strategy and Co-movement amongst Energy, Gold, Technology, Green Bonds and APEC Equity Markets is spread all over the world, the low productivity of academic institutions located in developing countries can be partly attributed to the poor cooperation between countries, especially between authors of developing and developed countries.

Table 2.4 Top 20 contributing countries.

Countries	No of Articles	Percentage (%)
China	551	50.0909091
France	56	5.09090909
India	56	5.09090909
Usa	50	4.54545455
Turkey	40	3.63636364
Tunisia	34	3.09090909

Uk	34	3.09090909
Pakistan	33	3
Saudi Arabia	32	2.90909091
Australia	28	2.54545455
Japan	22	2
Brazil	19	1.72727273
South Korea	19	1.72727273
Germany	18	1.63636364
Spain	18	1.63636364
Lebanon	17	1.54545455
Romania	17	1.54545455
Iran	13	1.18181818
Nigeria	13	1.18181818
Italy	11	1

Table 2.5: Top 20 frequent keywords in the Dynamic Connectedness, Optimal Hedging Strategy and Co-movement research.

Keywords	Occurrences
stock market	164
spillover effect	144
commerce	131
financial markets	120
investments	109
energy market	102
crude oil	86
china	66
COVID-19	62
volatility spillovers	59
risk assessment	51
costs	39
united states	37
price dynamics	34
spillover effects	33
investment	31
natural gas	31
financial crisis	28

carbon

27

financial market

27

Table-2.4 depicts the respective countries' scientific output as published in Scopus. As can be seen, highest number of papers (551) originated in the China, followed by France (56), India (56), the USA (50), and Turkey (40). Research on Dynamic Connectedness, Optimal Hedging Strategy and Co-movement has been conducted worldwide, albeit there is a high concentration of academic research output in developed countries. South Asia and Europe made more contributions than others. While this may call for the strengthening of scientific collaboration, it should be noted that only publications in English language were considered for this study.

2.4.2.3 Statistics of keywords and citations

Table-2.6: Top 50 article globally cited

Articles	Total Citations	TC per Year	Normalized TC
REBOREDO JC, 2018, ENERGY ECON-A	494	61.75	6.33
Mensi W, 2013, Econ Model	436	33.54	2.77
Zhang Yf, 2023, Environ Sci Pollut Res	246	82.00	11.76
Umar M, 2022, Energy	242	60.50	6.00
Khalfaoui R, 2015, Energy Econ	229	20.82	2.45
Song Y, 2019, Energy Econ	219	31.29	2.61
Liu N, 2021, J Clean Prod	202	40.40	3.95
Ahmed Ad, 2021, Energy Econ	188	37.60	3.68
Pham L, 2021, Energy Econ	185	37.00	3.62
Du L, 2015, Energy Econ	181	16.45	1.93
Salisu Aa, 2015, Energy Econ	177	16.09	1.89
Ren B, 2022, Energy Econ	173	43.25	4.29
Lin B, 2014, Energy Econ	165	13.75	1.83
Wang X, 2019, Energy Econ	161	23.00	1.92
Mensi W, 2017, Energy Econ	161	17.89	3.78
Pham L, 2019, Energy Econ	158	22.57	1.88
Zhang H, 2021, Int Rev Financ Anal	139	27.80	2.72
Smales La, 2021, Q Rev Econ Financ	137	27.40	2.68
Elsayed Ah, 2020, Energy Econ	137	22.83	3.02

Jebabli I, 2022, Finan Res Lett	136	34.00	3.37
Dai Z, 2022, Energy Econ	135	33.75	3.35
Chang C-L, 2020, Renewable Sustainable Energy Rev	134	22.33	2.95
Lundgren Ai, 2018, Energy Econ	133	16.63	1.70
Ma Y-R, 2019, Energy Econ	132	18.86	1.57
Zhang Y-J, 2017, Energy Econ	125	13.89	2.93
Khalifaoui R, 2022, J Environ Manage	123	30.75	3.05
Jebabli I, 2014, Energy Econ	123	10.25	1.37
Khalifaoui R, 2022, Technol Forecast Soc Change	120	30.00	2.97
Yang K, 2021, J Clean Prod	120	24.00	2.35
Lin B, 2019, Energy	119	17.00	1.42
Sarwar S, 2020, Resour Policy	115	19.17	2.53
Khalifaoui R, 2019, Resour Policy	111	15.86	1.32
Al-Yahyaee Kh, 2019, Pac Basin Financ J	107	15.29	1.27
Lin Sx, 2001, Energy Econ	106	4.24	1.00
Kang W, 2015, Econ Transit	104	9.45	1.11
Jiménez-Rodríguez R, 2019, Energy Econ	102	14.57	1.21
Liu Z, 2020, Resour Policy	95	15.83	2.09
Olson E, 2014, Energy Econ	92	7.67	1.02
Zhang W, 2022, Int Rev Financ Anal	90	22.50	2.23
Dutta A, 2021, Energy	89	17.80	1.74
Cui J, 2021, Energy	85	17.00	1.66
Evrin Mandaci P, 2020, Resour Policy	83	13.83	1.83
Liu Z, 2021, Resour Policy	82	16.40	1.60
Reboredo Jc, 2018, Energy Econ	79	9.88	1.01
Pham L, 2021, Global Financ J	78	15.60	1.53
Quito B, 2023, Renewable Sustainable Energy Rev	76	25.33	3.63
Geng J-B, 2021, Energy Econ	76	15.20	1.49
Li J, 2023, Energy Econ	74	24.67	3.54
Karkowska R, 2023, J Int Financ Mark Inst Money	74	24.67	3.54
Asadi M, 2022, Energy Econ	73	18.25	1.81

Table 2.5: The 20 Most Common Keywords in the Dynamic Connectedness, Optimal Hedging Strategy, and Co-movement Study. This table shows the most common keywords in the studies of dynamic connectedness, optimal hedging strategy, and co-movement in

economic and financial research, especially in the energy market. The keyword stock market is the most frequent with 164 occurrences, which shows the focus of the stock market in the research that examines the interconnections of the markets, risks, and hedging strategies. Next is the so-called spillover effect (144 occurrences), which demonstrates the concern with how shocks in one market (e.g. energy) can spill over to other markets (e.g. finance or commodities). Other notable keywords are financial markets (120 times), investments (109 times), and energy market (102 times), which indicates that the studies in this field tend to associate the energy industry with the overall economic aspects of market volatility, investment patterns, and financial market dynamics. Such keywords as crude oil (86 times) and china (66 times) indicate the geopolitical and economic significance of the energy sector in the emerging markets, especially the global commodity markets and the role of the key players, including China. The fact that there are 59 instances of the term volatility spillovers and 51 instances of the term risk assessment shows that the focus is on the research of the volatility transmission across markets and the evaluation of risks, which are essential in the creation of hedging strategies. Lastly, such terms as COVID-19 (62 instances) reflect the influence of the pandemic on the financial and energy markets, which led to the recent increase in the number of studies that analyze the market reaction to such global events.

2.4.2.4 Top 50 most cited articles globally

Table-2.6 presents the list of 50 most cited articles worldwide according to the number of citations registered in Scopus and Google Scholar, which gives an idea of the most influential studies in the area of dynamic connectedness and optimal hedging strategy. The most cited article by Reboredo (2018) with 494 citations tops the list. The focal point in the article on energy economics and its application in the financial markets has resulted in it being a landmark article in the analysis of the relationship between energy and financial markets, particularly regarding risk management. The next two articles, the articles by Mensi et al. (2013) and Zhang Y F (2023) contain 436 and 246 citation respectively. Such publications have done significant contributions in the development of models to understand market interactions, hedging strategies and how they are used in the world energy and commodity markets. Still, other most cited works are Krrkinen (2023), Umar M (2022), and Khalfaoui R (2015) with 246 to 422 citations. The articles introduce practical models and evidence of the interrelatedness of the energy markets, the finance markets, and the macroeconomic environment and this indicates the awareness levels raising of articles. The number of citations of these articles shows how strongly they have become the foundation of the future

research and they are the articles, which one has to read at all cost to the scholars of energy economics, financial markets, and research of hedging strategy.

A more recent research has instead highlighted the inter-dependence between energy and equity markets more so in the aspects of volatility spillover, correlation of returns and hedging strategies. These are the most referred articles that form part of the top 50 articles in the literature of energy finance and assist in the understanding of the sensitivity of the market events such as financial crisis and adverse economic situations on the interactions between the markets. Reboredo (2018) focuses on the co-movement between the green bonds and the financial markets, namely, the stock and energy commodity markets. It points out that green bonds have weak diversification benefits relative to the stock and energy markets, which is valuable in knowing how the environment-based finance and the conventional markets relate to each other. Such dynamics play a pivotal role in development of hedging strategies that take into consideration potential impacts of green investments on the entire portfolios. Mensi et al. (2013) uses a VAR-GARCH model to test the volatility spill over amid the S&P 500 and commodity price indices, including the energy markets, one of which is oil. Their findings show that the flow of volatility between the stock markets and the energy commodities is high and therefore the matters of hedging in such volatile periods are also significant. The paper will assist in knowing how movement of stock indices can influence the commodity prices and the commodity prices the stock index and this is vital in portfolio management in equity and energy markets. Y. Zhang and Umair (2023) provide a detailed insight on the spark overflow between the green bonds performance, renewable energy stock, and carbon market. They demonstrate how green finance products are connected and may be utilized to provide portfolio diversity. Based on their research, these assets can be complementary, especially when it comes to the designing of hedging strategies that run long term and are hence sustainable. Umar et al. (2021) address the topic of volatility links between clean-energy shares and fossil fuel markets, particularly during the crises, e.g., the COVID-19 pandemic. The particular paper highlights the fact that the consequences of energy market contagion are more logical during the period of crisis and the intensity of volatility transmission is more notable within the short-term. Such information on interconnections networks can assist investors to come up with more effective hedging strategies. The article by Khalfaoui et al. (2015) studies the relationship between crude oil markets (Crude oil markets are referred to here as WTI) and stock markets of the G-7 countries using multivariate GARCH models and wavelet analysis. They discover that

volatility spillovers and time varying correlations between stock and oil markets are large indicating that investors need dynamic hedging that will be time-dependent to match changing correlation structure between the two financial markets over a span of time. Song et al. (2019) carry out a study of the directional spillover between fossil energy market and investor sentiment on renewable energy and renewable energy stocks. Their findings emphasize the potential impact of investor sentiment, more specifically toward renewable energy, on volatility and returns of renewable energy by indicating a new interconnectedness between the fossil and renewable energy sectors. This is particularly relevant where it comes to the formulation of strategies to hedge risks on volatility of both energy markets. N. Liu et al. (2020) examine the dynamic correlation between green bonds and clean energy markets, showing positive, time-varying dependence, and asymmetric risk spillover. They refer the spillover of the huge movements on prices on clean energy markets to green bond markets which explain why one should take such an interplay into account when managing the risks and when implementing hedging programmes. Ahmed and Huo (2020) apply a VAR-BEKK-GARCH model to examine the dynamic connections between the Chinese stock market, commodity markets, and international oil prices. The paper shows that there are large unidirectional spillover returns of the oil market to the stock market, which implies that the movements in the oil market affect the equity markets and that hedging strategies must be sensitive to the spillover effects, especially during volatile market periods. Pham (2021) is devoted to the interrelatedness of green bond and green equity markets, examining spillovers in various frequency bands. The paper concludes that green bonds and green equities are not related in stable market environments, but the relationship between the two is enhanced in extreme market movements, which can be used to develop hedging strategies that consider the possibility of extreme market events in green finance. Du and He (2015) analyze the spillovers of extreme risks between crude oil and stock markets through Value at Risk (VaR) and kernel-based tests. The findings indicate that there are high risk spillovers, where the stock market has positive spillover to the crude oil market prior to the financial crisis and two-way spillover after the crisis. The paper also points out asymmetric correlations in risk spillovers, which are important in hedging strategies, particularly during extreme market volatility. Salisu and Oloko (2015) use the VARMA-AGARCH model to examine the spillover effects between oil prices (WTI and Brent) and the US stock market (S&P 500). The paper identifies a positive stock market to oil market spillover of returns, and two-way shock spillovers. The findings also indicate that structural breaks, especially following the global economic slowdown, influence the effectiveness of hedging. This paper highlights the

importance of considering such breaks in the development of hedging strategies since failure to do so can skew risk management decisions. Ren and Lucey (2022) investigate the safe haven characteristics of clean energy indices relative to cryptocurrencies and analyze spillover dynamics in energy, cryptocurrency, stock, and gold markets. Although clean energy is not a direct hedge against cryptocurrencies, it is a weak safe haven in times of extreme market crashes. This paper proposes that clean energy may provide diversification to cryptocurrency investors, especially during periods of increased uncertainty. B. Lin et al. (2014) examine the volatility spillover between oil and stock markets in Ghana and Nigeria, employing sophisticated multivariate models such as VAR-GARCH and DCC-GARCH. The analysis reveals that there is a high volatility spillover especially between oil and stock markets in Ghana. The study points out that oil markets are important in portfolio diversification of stock investors in the region and emphasizes the need to understand the dynamics of volatility in managing portfolios with oil exposure. X. Wang and Wang (2019), discuss volatility spillover frequency dynamics between crude oil and the Chinese stock markets via spectral representation framework. The studies establish short run volatility spills particularly due to oil market volatility and longer run were negative in the situation of the 2015 financial crisis in China. The results demonstrate the importance of setting conditional spillover effects when managing risks and portfolio creation especially during periods when financial markets are turbulent. In light of the above, Mensi et al. (2017) analyze time-varying equi-correlations and risk spillovers among crude oil, gold, and stock markets, by using the DECO-FIAPARCH model. Based on the analysis, it emerges that both oil and the gold markets are infrequently exposed to risk spillovers especially during an economic downturn such as the post-2008 financial crisis. The article is incisive regarding the benefits of possession of a diversified portfolio of gold that is used to hedge against volatility in the energy market. Pham (2019) explores the relationship between clean energy stocks and oil prices paying attention to the sub-sectors in the clean energy market. The study has concluded that there exists a difference in the importance of oil prices and clean energy stocks depending on the sub-sector with biofuels and energy management stocks as most connected to oil prices. The implication of this difference is that disaggregate clean energy portfolio is vital towards better hedging and diversification that has both policy and investment implication. In order to determine the effect of the COVID-19 pandemic on the energy and stock markets, H. Zhang et al. (2021) combine time-varying parameter VAR models and a spillover index. The study concludes that, COVID-19 pandemic significantly influenced the spillover effect between these markets and the spillover risk between the stock

market and energy market intensified after the pandemic. The research provides insightful pieces of advice on the way to overcome them, recalculation of hedge ratios when market dynamic conditions alter under crisis. In Table 2.1, the dynamic conditional correlation (DCC) model is used by Smales (2021) to determine the impact of geopolitical events on oil price and stock market volatility. The results show that geopolitical risks have stronger effects on oil prices than on stock markets, and oil futures has the potential of playing the role of a hedge instrument against the geopolitical risks to stock market investors. The article reveals the value of considering geopolitical event when investors formulate ways of hedging, particularly when volatility in oil prices is high due to disruption in supply. Elsayed et al. (2020) consider the spillover volatility of the energy market with the major global financial markets that include clean energy, stock markets, and the US economic policy index. The paper concludes that oil price shocks are exogenous and have little contribution to the global financial markets. Nevertheless, the volatility of the oil market affects clean energy stocks, especially in the case of financial crises, which is why it is necessary to change the weights of the portfolio and the hedge ratio depending on the market situation.

Jebabli et al. (2022) examine volatility spillover between energy and stock markets during the COVID-19 pandemic and compare it with the volatility spillover during the 2008 global financial crisis. Their results indicate that volatility spillovers between stock and energy markets were much higher in the COVID-19 crisis than in the global financial crisis. The paper also finds that natural gas is more effective in hedging than crude oil on average, which is important in terms of energy-based portfolio management and risk mitigation strategies. Dai et al. (2022) investigate the volatility spillover effects and dynamic correlations between WTI crude oil, gold, and Chinese stock markets in such industries as new energy vehicles and environmental protection. The analysis reveals that there is a high interdependence between these markets with WTI crude oil and gold being net recipients of systemic shocks. It finds that a portfolio with WTI crude oil and stock markets has high hedging effectiveness, implying that crude oil is an effective hedging instrument. Chang et al. (2020) discusses herding behavior in renewable energy markets in the context of extreme events, such as the Global Financial Crisis (GFC), SARS, and COVID-19. The paper points out that in such crises, particularly the COVID-19 pandemic, herding in renewable energy markets is caused by extreme oil returns. The findings also show that there are high cross-sector herding spillover effects, especially between the U.S. fossil fuel energy market and renewable energy markets, which provides information on how investors behave collectively in times of

uncertainty. Lundgren et al. (2018) study the returns of renewable energy stocks in comparison to other significant investment assets such as stocks, currency, U.S. Treasury bonds, and oil using nonlinear causality and connectedness network analysis. The research concludes that the European stock market is highly dependent on the renewable energy stock prices, and the uncertainties in the GFC and the European sovereign debt crisis have a significant effect on the returns and volatility of energy investments. These results indicate that renewable energy investments are susceptible to the wider economic uncertainties. Ma et al. (2019) examine the correlation between WTI oil prices and the stock returns of the U.S. energy sector, separating the systemic and idiosyncratic factors. The analysis shows that the U.S. energy industry is a net contributor to the WTI price dynamics, with industrial-level common information being the primary driver, whereas individual energy stock returns react to oil price dynamics. These results emphasize the need to consider both systemic and idiosyncratic factors in the management of energy market portfolios. Y. Zhang et al. (2017) use a Volatility Threshold Dynamic Conditional Correlation (VT-DCC) model to examine the spillover impact of stock market volatility on crude oil and natural gas markets. The research concludes that the volatility of the stock market has a significant impact on the crude oil and natural gas markets, especially following the 2008 financial crisis and the 2014 oil price crash. The study also finds that there are typical co-movements between the stock and energy markets, which highlights the importance of dynamic hedging strategies when there are market shocks. Khalfaoui, Jabeur, et al. (2022) examine shock spillover networks in green markets, such as energy, solar, wind, and water markets, and Bitcoins and uncertainty, especially in extreme market conditions. The research concludes that green energy markets and global carbon indexes are important sources of spillovers in bearish market conditions, which provides important information on portfolio management strategies that target environmental markets in bearish market conditions. Jebabli et al. (2014) examine the transmission of shocks across international food, energy, and financial markets, especially during the financial crisis. The paper finds that stock markets and crude oil markets were net exporters of volatility, whereas food markets were severely affected by immediate effects of crude oil and MSCI market shocks. The paper highlights the need to diversify portfolios to incorporate energy investments such as oil and stocks, which can enhance risk-adjusted returns, particularly in times of financial crisis. Khalfaoui et al. (2022) reconsider the U.S. stock market returns dependence on climate change-related risks (CCRR). The paper employs spillover and connectedness network analysis to evaluate the effects of green index, carbon price, and climate uncertainty on the U.S. stock returns. The findings indicate that the risks of

climate change are important in the transmission of spillovers, especially in extreme market conditions, and the need to incorporate such factors in portfolio diversification strategies by environmental investors. Yang et al. (2020) examine the risk spillover of geopolitical risks to renewable energy stock markets. The analysis reveals that there are large spillovers of geopolitical risk to these markets, and the magnitude of spillovers varies across market conditions. The geopolitical risk affects the renewable energy stock market in China in the short term, but in other markets, the spillover is higher in the long term. This paper recommends that geopolitical risk must be keenly observed in the development of hedging strategies in renewable energy investments.

B. Lin and Chen (2019) examine the spillover effect between the carbon emission trading (CET) market in China, the coal market, and the stock market of new energy companies (NEC). The analysis shows that there are strong time-varying correlations and long-run persistence of shocks across these markets, and that there are bi-directional spillover effects between the coal market and the NEC stock market. The paper concludes that the optimal hedge ratio of coal is almost 50 percent, and that of new energy stocks is approximately 17 percent. These results indicate that coal and renewable energy stock investments should be balanced to hedge effectively in the energy transition in China. Sarwar et al. (2020) analyze volatility spillover between oil and stock markets in Karachi, Shanghai, and Bombay. The paper finds that there are bidirectional spillovers in Karachi, unidirectional spillovers in Shanghai, and mixed spillovers in Bombay. Interestingly, the findings indicate that there is no significant difference in volatility spillovers between the pre-crisis and post-crisis periods, and the spillovers differ depending on the frequency of data (daily, weekly, and monthly). This paper highlights the significance of the economic environment and frequency of data in the analysis of market spillover in risk management. Khalfaoui et al. (2019) examine volatility spillover between the oil market and the stock markets of oil-importing and oil-exporting nations. The paper concludes that lagged oil price shocks have a more adverse impact on oil-importing nations. The findings also indicate the asymmetry of the effect of positive and negative oil price shocks, where the negative shocks are more significant. In the case of oil-exporting nations, the study recommends that they should have more oil assets in their portfolios to hedge against them, which implies that sector-specific investments are important in portfolio management. Al-Yahyaee et al. (2019) investigate dynamic spillover of returns and risks between commodity futures (energy and precious metals) and the Gulf Cooperation Council (GCC) stock markets. The analysis reveals that there are substantial

spillovers especially in the 2008 global financial crisis where silver, platinum and energy futures are net transmitters of returns and risk to the GCC stock markets. The results highlight that the commodity and GCC equities combination offers diversification potential, and precious metals are more effective hedges than energy markets in GCC nations. Lin and Tamvakis (2001) study the price discovery in crude oil and refined oil products with emphasis on spillover effects between the NYMEX and IPE markets. The paper finds significant spillover effects among these markets, where the IPE morning prices are affected by the NYMEX closing prices of the previous day. The paper provides useful information on the mechanism of information transmission in energy markets, and the importance of market interdependence in price determination. Kang and Ratti (2015) investigate the relationship between the policy uncertainty in China, the global oil market, and the Chinese stock market returns. The paper concludes that economic policy uncertainty shocks in China have a lagged adverse impact on world oil production, oil prices, and stock returns. This paper brings out the growing interdependence of these markets particularly since 2003 when the influence of China in the global oil market has been on the rise. The results indicate that policy uncertainty is an important factor to monitor in energy market forecasting. Jiménez-Rodríguez (2019) examines the correlation between stock markets and EU allowances (EUAs) prices, showing that the stock market volatility affects EUA prices. The paper demonstrates causality in the direction of stock markets to the European Climate Exchange market, particularly because economic activity influences energy demand and carbon emissions. The paper has significant implications in terms of how financial markets affect carbon emission trading and the interdependence between financial markets and environmental policy instruments. Z. Liu et al. (2020) examine the dynamic correlation and risk transmission between the oil market and the U.S. stock market based on implied volatility indices. The analysis shows that there is a strong positive relationship between oil and stock volatility returns, particularly in the global financial crisis. The two-way volatility spillover between these markets indicates that the interdependence between oil and stock markets can be influenced by both energy and monetary policy changes, which can be used to understand how to manage portfolio risk in such situations. Olson et al. (2014) analyze the connection between the energy and equity markets based on volatility impulse response functions of a multivariate BEKK model. The research concludes that low returns in S&P 500 cause volatility in the energy index, but the opposite is not true. The dynamic hedge ratio analysis shows that the energy index is not a good hedging tool to equity markets. This observation implies that investors should critically evaluate the hedging performance of

energy assets in their portfolios. W. Zhang et al. (2022b) investigate the dynamic relationship between the ESG stock index, renewable energy stock index, green bond stock index, sustainability stock index, and carbon emission futures. The research concludes that the main volatility transmitter is carbon emission futures, and the volatility receiver is green bonds. The study reveals that the long position in carbon emission futures and short position in renewable energy stocks have the greatest hedging effect. The paper has emphasized the need to incorporate sustainability-oriented assets in risk management approaches to environmentally-sensitive investors.

(Dutta et al., 2021) examine how news-based equity market volatility (EMV) trackers affect crude oil volatility. The analysis reveals that EMV trackers are very influential in times of high oil volatility but the influence is insignificant in times of low oil volatility. The study notes that EMV trackers are more effective than the VIX, economic policy uncertainty (EPU), and geopolitical risk (GPR) indexes in forecasting oil volatility, indicating that asset pricing and risk management strategies may be improved by incorporating EMV trackers. Cui et al. (2020) investigate the time-frequency dependence and risk connectedness between oil and stock markets in oil-importing and oil-exporting nations. The paper employs wavelet coherence and BK frequency connectedness to determine the dynamics of risk spillovers across different time horizons. It concludes that long-term risk spillovers are more pronounced, and oil markets are more exposed to spillovers by stock markets in countries such as the US, EU, Canada, and Russia. The findings indicate that investors ought to consider such spillovers when rebalancing portfolios, particularly in the event of a global crisis such as the COVID-19 pandemic. Mandacı et al. (2020) examine volatility spillover between global commodity futures, equity markets, the US bond market, and the US Dollar index. The study employs a dynamic connectedness methodology to identify a moderate volatility relationship that reached its peak in the 2007/08 global financial crisis. The paper determines that the most effective hedging can be attained by investors in the equity and bond markets by shorting energy futures (e.g., natural gas) and metal futures (e.g., gold). This study is a valuable piece of advice to portfolio managers regarding risk management in commodity markets. Z. Liu et al. (2021) examine the tail risk spillover between crude oil and stock markets in oil-importing and oil-exporting countries through a quantile spillover index method. The paper finds that structural reversals in risk spillovers occur during extreme events, and that spillovers are larger in the tails of the volatility distribution. The results

highlight that policymakers and market regulators ought to keep track of these extreme risks and cushion their shocks to stabilize the market.

Reboredo and Ugolini (2018) examine how Twitter sentiment and sentiment divergence affect renewable energy stocks. The findings indicate that Twitter sentiment has no significant impact on stock returns, volatility, or trading volumes, but sentiment divergence creates feedback effects on volatility and trading volumes. This study indicates that although the sentiment of social media does not necessarily affect the stock prices, it can affect the market behavior in times of uncertainty, which can be used by traders and investors in renewable energy stocks. Pham and Nguyen (2021) investigate the tail-dependence of green bonds with other asset classes including energy, stock markets, and conventional bonds. The study uses the cross-quantilogram approach to determine that spillovers between green bonds and other assets are not constant across quantiles, which implies that the hedging advantages of green bonds are not the same in extreme and normal market conditions. This underscores the opportunity of green bonds as a diversifying asset class, particularly in times of financial stress. Quito et al. (2023) examine the connection between energy efficiency, renewable energy, and financial development in 43 European countries. The research concludes that renewable energies encourage energy efficiency (EE), and the adoption of renewable energies in neighbouring countries has a positive influence on national EE. The paper indicates that policymakers can use these spillover effects to improve energy efficiency and promote sustainable economic growth, and green energy policies are critical in regional development. Geng et al. (2021) investigate the dynamic information relatedness among natural gas markets, uncertainties, and stock markets in North America and Europe. The analysis reveals that the high-frequency band (1-12 weeks) is the main contributor to total return and volatility spillovers, and the low-frequency band (12 weeks or more) has weaker spillovers. This study shows that investors and policymakers should be aware of both short-term and long-term connectedness in natural gas markets. J. Li et al. (2023) examine the spillover effects of returns and volatility between the crude oil futures market in China and seven green energy stock markets. The analysis shows that green energy stocks are the most influential in the price dynamics of the crude oil futures market, particularly in the COVID-19 outbreak. The findings indicate that the green energy market is a key factor in determining the volatility of crude oil futures, which is a useful piece of information in understanding the interdependence of energy and green markets in times of crisis. Karkowska R. and Urjasz S. (2023) examine volatility spillover between dirty and clean energy markets and international stock indices in

reaction to the increase in geopolitical risk, especially following the Russian invasion of Ukraine. The research concludes that clean energy indices are less risky than global equities, and the cost of hedging in renewable energy assets is more expensive than non-renewable energy indices. This study indicates that although renewable energy is less volatile, its increased cost of hedging should be taken into account when developing portfolio diversification strategies.

The literature reviewed highlights the intricate interconnections between energy and equity markets, especially in terms of volatility spillover and risk transmission, especially in times of global crises and extreme events such as the COVID-19 pandemic and geopolitical shocks. One of the main lessons of these studies is that volatility is highly transmitted between oil and stock markets, particularly in times of financial instability or economic recession. Such spillovers are not fixed and need constant rebalancing of investor portfolios, as the interdependencies between the two markets change over time. The importance of clean energy markets in offering diversification opportunities is noted, especially in certain sub-sectors like biofuels. In addition, gold and other commodities are also recognized as good hedging tools, which can be used to counter the volatility in the energy market. The studies all emphasize the need to come up with dynamic, adaptive hedging strategies that can effectively react to the changing market conditions that are created by such crises.

The studies also point to the influence of structural breaks, including the global financial crisis of 2008 or the COVID-19 pandemic, on the market dynamics. These structural shifts modify the interdependence between energy and equity markets, where volatility spillovers are more evident in times of crisis. As an example, natural gas and gold are more effective hedging instruments than crude oil during market crises, which implies that investors need to diversify their portfolios by investing in various commodities and sectors. Moreover, geopolitical risks, especially those associated with oil price shocks, are also important in fuelling volatility. The geopolitical events, like the 2022 Russia-Ukraine war, have a more direct effect on oil prices than on the stock markets, which is why it is important to use oil futures as a hedge in periods of increased geopolitical risk. The studies also highlight that the interplay between market volatility and crises needs a profound knowledge of the market conditions involved.

Also, these studies highlight the dynamic aspect of volatility spillovers, which have different impacts on market conditions and time periods. Spillovers between energy and equity

markets are more likely to increase during crises, such as the COVID-19 pandemic or the 2008 financial crisis. Gold and natural gas have been shown to be more effective hedging instruments in such periods than crude oil, which underscores the importance of customized hedging strategies that respond to the specifics of each crisis. The other key lesson is that cross-sector herding behavior should be considered, especially between fossil fuel energy and renewable energy markets in extreme market events. Such behavior can have a significant impact on market volatility, implying that investor sentiment and mass behavior are critical factors in market dynamics, particularly in times of uncertainty.

The common keywords and the most cited articles in these areas indicate the general tendencies and the increasing interest in the interdependence of financial and energy markets, especially in the hedging strategies, risk management, and economic spillover effects. These tables give an overview of the most important subjects in the current research, indicating the most influential studies and the changing areas of interest in the interface between energy economics and financial market analysis.

2.5 Results of network analysis and discussion

2.5.1 Analysis of keyword co-occurrence network

Keyword co-occurrences are a fundamental relational bibliometric indicator that can be used to identify the underlying research trends and knowledge structures in a scientific discipline [139,172]. This analytical tool plays a significant role in the identification of clusters that assist researchers in having a wider perspective of different research foci and the relationship between important concepts in a particular field of study. In the present study, the keyword co-occurrence network was analysed by first extracting keywords in each of the relevant articles. These keywords were then narrowed down to make them consistent, especially by changing the full-length phrases (e.g., dynamic connectedness, optimal hedging, and financial markets) to their common acronyms or shortened versions. Keywords that are often used in the same articles are likely to have a more significant co-occurrence relationship in the network.

The data were entered into VOS viewer to create the keyword co-occurrence network. The full counting approach was then used to generate the network by applying a density-based spatial clustering method [91]. Since a perfect network must contain 200-500 keywords [58],

the frequency of keywords inclusion was set to 3 times. This produced a network with six different clusters, each of which was assigned a different colour (see Fig. 2.2). Here, the nodes are keywords, and the size of the node is proportional to the number of co-occurrences. The proximity of the nodes is an indication of the density of co-occurrence of the nodes, and the closer the nodes, the stronger the relationship between the keywords. To further improve the analysis, we analysed the ten most common keywords in each cluster (see 2.7). The clusters were then labelled according to the keywords that dominated the cluster and the themes that emerged to define the cluster. This comprehensive methodology enabled us to identify the major areas of interest in the study of dynamic connectedness, optimal hedging strategy, and co-movement, and to comprehend the interrelation of various factors, including market interdependence, risk management strategies, and financial dynamics.

Table 2.7: Words Cluster

Node	Cluster	Betweenness	Closeness	PageRank
stock market	1	408.267483	0.01515152	0.13901615
spillover	1	20.2723273	0.01136364	0.03054564
risk spillover	1	0	0.00943396	0.00800257
oil prices	1	78	0.00990099	0.03238986
volatility	1	2.76774194	0.01	0.02826822
spillover effects	1	0	0.00952381	0.0121251
oil market	1	0	0.01	0.01585482
var	1	1.21911854	0.01086957	0.01856004
energy market	1	0	0.00943396	0.0153878
carbon market	1	0	0.00952381	0.0121251
connectedness	2	98.8860856	0.01282051	0.05079913
renewable energy	2	37.0376324	0.01282051	0.03844266
spillover effect	2	0	0.00990099	0.01313836
tvp-var	2	40.7024229	0.01136364	0.0290061
connectedness network	2	0	0.00990099	0.00963755
spillover index	2	18.352297	0.01136364	0.01936983
hedging	2	0.29512516	0.00869565	0.01031441
portfolio diversification	2	0	0.00892857	0.00976769
dynamic connectedness	2	0	0.0078125	0.00685879

dcc-garch	3	40	0.00917431	0.01665502
china	3	0	0.00671141	0.00829035
COVID-19	4	171.731804	0.01351351	0.07342895
stock markets	4	173.962815	0.01282051	0.07481354
volatility spillovers	4	3.05998012	0.01030928	0.02991574
spillovers	4	54.3714801	0.01098901	0.04231397
crude oil	4	47.46012	0.01234568	0.03605494
clean energy	4	0	0.00990099	0.0147286
green bonds	4	0	0.00847458	0.00683253
energy markets	4	0	0.00847458	0.00683253
oil	4	0	0.01010101	0.01307437
energy	4	1.39739994	0.00952381	0.0098871
financial markets	4	0	0.00763359	0.00684114
commodities	4	1.65395079	0.00952381	0.01331744
natural gas	4	0.64335664	0.00990099	0.02095193
financial crisis	4	16.4854342	0.01111111	0.02080421
quantile connectedness	4	0	0.00877193	0.00802961
volatility spillover	5	76.4334257	0.01219512	0.04024837
commodity markets	5	0	0.00952381	0.01025364
COVID-19 pandemic	5	0	0.00819672	0.00699254
oil price	5	0	0.01	0.01165719
covar	6	0	0.00714286	0.01519721
systemic risk	6	0	0.00714286	0.01326923

Fig. 2.3: Keyword co-occurrence network analysis

The keyword co-occurrence network presented in Fig. 2.3 and the related analysis in Table 2.7 provide an in-depth exploration of the main themes and trends in the study of dynamic connectedness, optimal hedging strategies, and co-movement, especially in the energy markets and financial markets. The network visualizes the frequency of the co-occurrence of some keywords in the literature, and the clusters found in this network assist in classifying the research foci and showing the interconnectedness of the keywords.

This cluster, which is centred on the terms stock market, spillover effects, oil prices, and volatility, is concerned with the financial side of the research, especially the connection between stock markets and other economic and commodity markets. The keywords like stock market, oil prices, spillover effects, and energy market indicate a strong interest in the way volatility in one market, especially energy, spills over to affect the behavior of financial markets. This cluster brings to the fore an emerging literature that focuses on the dynamics of risk transmission across various markets and the financial consequences of such interactions. The interconnectedness of energy and financial markets is based on risk spillovers and volatility, especially when determining the best hedging strategies to reduce the risks.

The cluster is defined by keywords such as connectedness, spillover effect, and dynamic connectedness, which implies that the interdependence of different markets and assets is the focus. Dynamic connectedness is an important area of study to determine the spread of market shocks across interconnected networks. The phrases spills over, energy market, volatility spillovers, and financial markets also confirm the notion that this cluster is concerned with the systemic risk and the quantification of connectedness between various financial and commodity markets across time. This cluster is core to the application of co-movement research in the analysis of market correlations and how the movement of one market can affect another.

Some of the terms in this cluster are renewable energy, hedging, and portfolio diversification. It is a study of the application of hedging strategies in the energy market, especially renewable energy. The emphasis on the concepts of portfolio diversification and hedging suggests an interest in the methods that companies and investors employ to hedge against the risks of changes in energy prices. The fact that there are terms such as renewable energy and carbon markets also indicates that this cluster is considering the incorporation of sustainable energy solutions and the impact of such innovations on hedging strategies in the financial markets.

The keywords in this cluster such as energy market, oil market, and oil price are the research that is specifically concerned with the dynamics of the energy sector and the volatility associated with it. This cluster indicates that a lot of the research is on the commodities market, particularly oil, and its great importance in the stability of the global economy. The discussion of the oil prices in terms of the market volatility and spillover effects is essential to comprehend the impact of the energy prices changes on the energy market and the financial system as a whole.

The terms that are important in this cluster are COVID-19, stock market, and financial markets, which indicates the influence of the pandemic on the global markets. The fact that this cluster contains the terms of financial crisis, commodity markets, and energy shows that the study is concerned with the impact of the COVID-19 pandemic on market volatility, asset prices, and risk spillovers. The pandemic caused major shocks to the global economy, and the literature reflects the way in which these shocks caused market dislocations and changes in the connectedness of global markets.

The last cluster, which is marked by the words china, systemic risk, and financial risk, examines the effects of emerging markets, especially China, on the global financial markets. The analysis of the concept of systemic risk in the context of these markets indicates the role of interconnected economies, especially in the light of the emergence of China, in the stability or instability of the global financial systems. The word covar shows that there is an interest in co-movement models and covariance analysis to know how these emerging markets relate with the more developed markets.

The word clusters analysis, which is presented in Table 2.7, gives additional information about the relationships between the nodes in the keyword co-occurrence network, their centrality and influence in the field. The node of the stock market is a very powerful keyword with the maximum betweenness value, which means that it is a central hub in the network. It also possesses a high value of closeness, which implies that it is closely related to other keywords within the network. This supports the notion that the study of stock markets is central to dynamic connectedness and co-movement analysis. The nodes volatility and risk spillover also have high betweenness scores, which means that they play central roles in the interpretation of how market shocks spread across financial markets. Their interrelatedness with oil market and stock market implies that they are more concerned with volatility analysis and risk management. The node of the connectedness network in Cluster 2 has a moderate betweenness score, which highlights its significance in the study of the systemic risk and

dynamic interrelations between markets. It is closely related to other important keywords like spillover effect, renewable energy, and financial markets. China has a lower betweenness and higher closeness, which means that it is significant in some niche areas, especially in the context of systemic risk and emerging markets. The emphasis on the concept of systemic risk and financial risk in the case of China is an indication of the current research on the geopolitical impact of emerging markets on the global financial systems. The word cluster analysis and the keyword co-occurrence network give a good idea of the changing nature of the research on dynamic connectedness, optimal hedging strategies, and co-movement. The findings indicate the main areas of interest, such as the impact of energy markets, the role of risk spillovers, the significance of stock markets, and the new importance of COVID-19 and financial crises. The interdependence of these themes demonstrates the complexity of the modern financial systems and the increased interest in using IoT technologies, blockchain, and big data to overcome the challenges of volatility and market disruptions. The results also show how renewable energy and emerging markets are important in determining the future research directions. Future research needs to investigate the practical implications of these technologies, and the consequences of systemic risks, to offer practical information to industry stakeholders.

2.6 Bibliometric Review: Green Bonds and Equity Market Spillovers

2.6.1 Data Collection

In our bibliometric study of the relationship between Green Bonds and Equity Markets, we have used the Scopus database. Scopus is a major scientific tool that is characterized by the availability of a wide range of peer-reviewed academic journals, conference proceedings, and scholarly publications in different fields, such as finance, economics, and environmental studies. It is well-known due to its extensive and trustworthy content of leading global publishers like Elsevier, Springer, Taylor & Francis, and Wiley. The search query used in this study was aimed at retrieving literature that was relevant to the relationship between green bonds and equity markets, especially spillover effects, connectedness, and the implication of green bonds on financial markets. The search string was as follows: ("green bonds" OR "green bond market" OR "sustainable bonds") AND ("equity market" OR "stock market" OR "financial market") AND ("spillover" OR "connectedness" OR "market nexus" OR "risk management" OR "volatility"). This search was done in the title, abstract and keywords of the database. We included only peer-reviewed journal articles published in English to guarantee

high-quality and relevant literature. The topic area was limited to economics, finance, and environmental economics to match the research topic.

The search initially yielded 1,500 documents. The screening of these articles was done by reading the titles and abstracts to determine their relevance to our study. Articles that did not contain the necessary bibliometric data (e.g., abstract, keywords) or did not correspond to the inclusion criteria were not considered further. This filtering process left a final dataset of 1,120 documents, which were subsequently extracted in CSV format to be analysed with the bibliometric tool VOS viewer. VOS viewer is a free software that allows the creation, visualization, and analysis of term maps and co-occurrence networks. It is commonly applied in bibliometric studies to create keyword co-occurrence networks, citation analysis, and research trend visualization.

The information gathered and processed will be useful in understanding the development of the research on the green bonds-equity market nexus, the most important research topics, the most influential authors, and their contributions to the research. It will also point out the new trends in green bonds spillover effects, their interrelation with equity markets, and their use in risk management strategies. This ex 2.4.1. Data Collection tensive review of the existing body of knowledge will assist in determining the possible gaps and provide guidance on future research in this emerging field of finance and sustainable investment.

Table 2.8: Average citation per year

Year	MeanTCperArt	N	MeanTCperYear	CitableYears
1993	216	1	6.55	33
1994	26	1	0.81	32
1995	450	1	14.52	31
1996	112	1	3.73	30
1997	114.5	2	3.95	29
1998	55	2	1.96	28
1999	38.5	4	1.43	27
2000	38.67	3	1.49	26
2001	101	2	4.04	25
2003	23.33	6	1.01	23
2004	43.4	5	1.97	22
2005	24.5	8	1.17	21
2006	30.3	10	1.52	20

2007	42.77	13	2.25	19
2008	33.08	13	1.84	18
2009	27	17	1.59	17
2010	37.88	25	2.37	16
2011	27.33	27	1.82	15
2012	15.86	21	1.13	14
2013	59.11	28	4.55	13
2014	17.86	42	1.49	12
2015	43.7	37	3.97	11
2016	54.52	33	5.45	10
2017	41.1	50	4.57	9
2018	31.23	57	3.9	8
2019	32.07	72	4.58	7
2020	36.1	96	6.02	6
2021	43.19	133	8.64	5
2022	26.61	177	6.65	4
2023	14.72	197	4.91	3
2024	4.89	217	2.44	2
2025	1.1	124	1.1	1

2.6.2 Average number citation per year

Table 2.8 shows the average number of citations per year of a series of publications between 1993 and 2025. The citation pattern shows a number of trends in the influence of these publications in the field. The citations during this period are quite high in the early years with the first year, 1993, having 216 citations and an average citation per year of 6.55. This implies that the early years work was influential academically, especially since 1993 recorded the highest average citation per year. The citations decreased in the following years, but the influence was steady with an average of 1.43 in 1999 and 1.49 in 2000. The citation rates were moderate between 2000 and 2009. During this time, the average citation per year was lower in 2005 (1.17) than in 2007 (2.25) and 2009 (1.59). This era reflects a growth in scientific production but a fairly constant citation impact across the years. Since 2010, the number of citations has increased significantly, with the highest number of citations in 2016 (54.52 citations) and the highest average citation per year in 2016 (5.45). The post-2010 years are characterized by an overall increase in citation rates, which indicates the increasing awareness and impact in the smart learning environment domain. It is worth noting that 2015

(3.97 citations) and 2016 were the years of great contribution to the field. The citations begin to grow considerably in 2020 and 2021, with 2020 having an extremely high number of citations (36.1), and a steep rise in the number of publications and citations in 2021. Interestingly, the 2023 data indicates a significant rise in citations (197), which is still indicative of the increasing interest and impact over the past years. The values of the Mean TC per Year indicate an overall increasing trend beyond the year 2010, which indicates an increasing impact in the green bonds. The column of Citable Years indicates that the impact of these publications has been spread over a number of years, and the number of citable years has reduced slightly over the years.

Table 2.9: Top 20 global most cited articles

Article	Total Citations	TC per Year	Normalized TC
Reboredo Jc, 2018, Energy Econ	494	61.75	15.8191011
Koutmos G, 1995, J Int Money Financ	450	14.516129	1
Mensi W, 2013, Econ Model	436	33.5384615	7.37643505
Hameed A, 2010, J Financ	367	22.9375	9.68848997
Reboredo Jc, 2020, Econ Model	341	56.8333333	9.44489325
Baruník J, 2016, J Financ Mark	335	33.5	6.1450806
Arouri Meh, 2011, Econ Model	302	20.1333333	11.0487805
Le Tn-L, 2021, Technol Forecast Soc Change	301	60.2	6.96953343
Mensi W, 2017, J Bank Financ	299	33.2222222	7.27493917
Tiwari Ak, 2022, Global Financ J	298	74.5	11.1987261
Awartani B, 2013, Energy Econ	290	22.3076923	4.90634441
Zhang W, 2021, Int Rev Financ Anal	267	53.4	6.18227716
Zhang Yf, 2023, Environ Sci Pollut Res	246	82	16.7167989
Reboredo Jc, 2020, Energy Econ	239	39.8333333	6.61973456
Pham L, 2016, Journal Of Sustain Finance Invest	236	23.6	4.32907171
Khalifaoui R, 2015, Energy Econ	229	20.8181818	5.23995053
Song Y, 2019, Energy Econ	219	31.2857143	6.82893027
Theodossiou P, 1993, J Financ Res	216	6.54545455	1
Kang W, 2015, J Int Financ Mark Inst Money	204	18.5454545	4.66790353
Liu N, 2021, J Clean Prod	202	40.4	4.67722841

2.6.3 Top 20 Global Most Cited Articles

Table-2.9 shows the performance of articles in terms of citations in different metrics. The article by Reberedo JC in 2018 is the most cited in this table with a total of 494 citations and a high citation rate of 61.75 per year, which makes its normalized TC (Total Citations) 15.8191011, meaning that this article remains highly influential in its field. Next in line is the article by Koutmos G in 1995 with 450 total citations, 14.52 citations per year, and a normalized TC of 1. Such normal measurement is likely to imply that this article will always continue being an important source of reference, and this citation behavior is more or less constant. Next is Mensi et al. (2013) with its total citations amounting to 436 and higher citation rate of 33.54 citations per year which yields a normalized TC of 7.37643505. The significance of the research topic is shown by the fact that there is still a high amount of citations per year. The works by (Reboredo & Ugolini, 2020) are other prominent articles with steady citation rate of 341 total citations and high citation rate at 56.83 entries/year, and this means that the ratio is high over a short period. Among the topics covered by the articles listed, one can find energy economics (e.g. W. Zhang et al. (2021) and finance and environmental investigations (e.g. Zhang XF, 2023). According to the statistics regarding citations, researchers on such themes as energy economics continue to attract much interest, which can be observed through articles such as Pham (2016) and Khalfaoui et al. (2015) that uses the most citations. Other achievements of the table of articles with the low total citation and high normalized citations are combined by the articles of Tiwari et al. (2022) and Zhang W. (2021) which illustrate the progress of the global literature on such areas. The column of Normalized TC is informative in particular because it shows the relative effect of a particular article as a function of the number of citations per year, with some of the articles reaching extreme values in the normalized variant, such as Reboredo (2018) and B. Zhang et al. (2023) This means how topical the articles are and how fast they are disseminated in the community of scholars. this table reflects the impact of the most influential articles in time with the focus on the citation rates and the continuity of the research. It provides an estimate of how fast some topics of research are gaining popularity, and in the case, it is concentrated around such works, that are related to energy economics, finance, and sustainability, which are very much cited in the past years.

Here is a review of 20 articles of major studies analysing interconnectedness, volatility spillover and portfolio management between green bonds and equity market: Reboredo (2018) analyzes the co-movement of green bonds and the rest of financial markets. The

analysis shows that green bonds are very correlated with corporate and treasury bonds and not co-moved with stock and energy commodity markets. The results show that green bonds can be relevant sources of major diversification to stock and energy market investors, whereas such investors in corporate and treasury bonds are not affected. In addition to this, the price spillover of the corporate and treasury markets play a crucial role in influencing the rate of the green bonds but the price volatility of the stock and energy markets has minor impact on the rate of the green bonds. Koutmos and Booth (1995) evaluate on the price and volatility between the three largest stock markets of New York, Tokyo and London. In their analysis, they observed that volatility spillovers are more pronounced when the news concerning the end market in which a national stock market operates is unfavourable, a fact that underlines how national stock markets are becoming more and more interworking with each other. Even though they do not directly deal with green bonds, their findings can be applied on the basis of how volatility is normally transmitted across markets, which can also be employed to green bonds in a similar way. Mensi et al. (2013) apply a VAR- GARCH model to investigate the volatility and returns transmission between S&P 500 and commodity prices index in the United States. Although green bonds were actually not scrutinized, their findings can as well be applied to give a helpful information on the likelihood of how green bond markets can be interrelated with the equities, especially when it comes to managing the portfolio contents and risk elimination. Hameed et al. (2010) focus on the liquidity and volatility spillover effects to the stock market showing that negative market returns decrease liquidity especially when they are in the scenario of market tightness. Though this does not have any direct correlation with the green bonds, its findings with respect to liquidity spill can be employed to elucidate on the potential liquidity effects of green bond markets on equity markets during financial crises. Reboredo J.C. & Ugolini A. (2020) investigate the extent of price links between green bonds and economic markets via structure VAR device. These findings show that, green bonds correlate strongly with fixed-income and currency markets, face large price spillovers of these markets, as well as large reverse spillovers. They can also establish that the green bond market is loosely related to stock, energy and high-yield corporate bond market as this directly implies on portfolio management and risk management of green bond investors. Baruník and Hlínková (2016) examine asymmetric volatility spillover in U.S. stocks. Their results of asymmetric spillovers give a wider picture of how volatility may be passed across markets, which is essential in the dynamics between green bonds and equity markets, particularly in the event of market shocks. Arouri (2011) analyze volatility and transmission of returns between oil and stock markets in the GCC

countries, through a VAR-GARCH model. Although it is not specifically about green bonds, this research offers some information on the impact of commodities such as oil on equity markets, which may be relevant to the potential interaction of green bonds with stock markets, especially in the context of sustainable investment. Le et al. (2021) discuss the spillovers between Fintech, green bonds, and cryptocurrencies. The paper concludes that green bonds are net recipients of volatility shocks and are loosely linked to stock markets. It also implies that green bonds are better hedging tools against equity market risks than other assets, particularly in the long run. Mensi et al. (2017) integrate the VMD approach with copula functions to investigate the dependence relationship between oil prices and stock markets. Though green bonds were not directly examined, their results on risk spillovers provide valuable information on how the green bond market may interact with equity markets, especially in the management of oil price risk. Tiwari et al. (2022) examine the volatility transmission and the pattern of returns between green bonds, carbon prices, and renewable energy stocks. They discover that clean energy markets are the primary net transmitters of shocks in the network, whereas green bonds and renewable energy stocks are the primary recipients of shocks. The paper indicates that green bonds have a small contribution to risk diversification when used alone but can be used to minimize portfolio risk when used together with other green assets. Awartani and Maghyreh (2013) examine the oil and equity markets in the Gulf Cooperation Council countries and conclude that oil market volatility is spilled over to stock markets. Even though green bonds were not included in this research, their results on asymmetric spillovers between commodities and stocks can provide some information on how green bonds may perform in turbulent markets. W. Zhang et al. (2022) analyze the spillover between the COVID-19 pandemic, crude oil, and stock markets. Their research highlights the significance of risk management during market shocks, which is also applicable to the study of how green bonds can react to global crises and how they can help to reduce financial risks. Zhang and Umair (2023) examine the dynamic spillover between green bonds, renewable energy stocks, and carbon markets. Their findings indicate that there are high dynamic spillover effects between green bonds and renewable energy stocks, which implies a complementary relationship. The paper offers important information on the application of green bonds in a green finance ecosystem and the synergies between the assets. Reboredo and Ugolini (2020) determine the network connectedness between green bonds and other asset classes. They discover that green bonds are closely related to treasury and corporate bonds but loosely related to high-yield corporate bonds, stocks, and energy assets. These results show that a green bond is primarily a fixed-income security and it does

not make much contact with equity markets, and this matters in portfolio management and risk management. In a work by Pham L. (2016), the volatility of the green bond market gets discussed in accordance with S&P Green Bond indices. The paper ends up by stating that the occurrence of the conventional bond market shocks are likely to spill further to green bond market, thereby appealing to the fact that green bonds will be dependent on other fixed-income markets. This observation implies that green bonds are vulnerable to the overall market situations and this point could as well be applicable to the investors who might desire to utilize the green bonds as a hedge against the risks in the equity markets. The study by Khalfaoui R. et al. (2015) focuses on crude oil markets and stock markets and has revealed that volatility spillover was quite strong. The discussion would help in understanding the overall impact that commodity markets including green assets with reference to green bond issuance scheduled in energy bonds may have on the equity market. Song et al. (2019) study the spillover effect between fossil energy market and renewable energy and the volatility spillover between the fossil energy market and the renewable energy stock market is substantial, especially between fossil energy market, especially crude oil, and the renewable energy stock markets. Such correlation has the potential to provide an impression of how green bonds related to the energy sector interact with equity markets. Theodossiou P. & Lee U. (1993) discuss the fact that the U.S., Japanese and European stock markets are dependent on one another. Even though they do not look into green bonds, their findings on volatility spillovers can be exploited to understand the risk of spill-over between green bonds and the world equity markets particularly in global portfolio management. Kang W. et al. (2015) consider the effects of oil shock prices on the U.S. stock market returns and volatility. The article provides an insight on how price shocks in energy markets may affect green bonds specifically green bonds relating to energy production by highlighting the importance of market shocks in risk communication. Liu N. et al. (2021) examine green bonds and clean energy-related copula dependence. Their findings show that green bonds and clean energy stocks have positive, time-varying dependence, and the spillover is asymmetric in both directions. This paper indicates that green bonds and clean energy stocks are highly correlated, and green bonds can be used to hedge downside risk in clean energy investments.

These papers offer valuable information on the intricate connection between green bonds and equity markets. Green bonds have significant spillover effects on fixed-income markets but poor interactions with stock and energy markets. Although green bonds do not provide significant diversification to equity investors in isolation, they are important in mitigating risk

when used in conjunction with other green assets, such as renewable energy stocks. In addition, green bonds are subject to market shocks, especially those of fixed-income markets, and can be used as a complementary tool in the wider green finance ecosystem, improving portfolio resilience and aligning with sustainable investment objectives.

Table 2.10: Top 20 Globally Collaborated Countries

From	To	Frequency
CHINA	USA	25
CHINA	UNITED KINGDOM	21
CHINA	PAKISTAN	17
CHINA	AUSTRALIA	15
FRANCE	PAKISTAN	12
FRANCE	SAUDI ARABIA	11
TUNISIA	SAUDI ARABIA	11
CHINA	LEBANON	10
USA	TURKEY	10
KOREA	OMAN	9
PAKISTAN	SAUDI ARABIA	9
TUNISIA	FRANCE	9
INDIA	SAUDI ARABIA	8
TUNISIA	KOREA	8
CHINA	CANADA	7
CHINA	FRANCE	7
CHINA	KOREA	7
PAKISTAN	LEBANON	7
UNITED KINGDOM	AUSTRALIA	7
USA	KOREA	7

2.6.4 Top 20 Globally Collaborated Countries

The table-2.10 provides the list of different countries and their collaborations in the green bonds and securities market research, indicating the frequency of country collaboration. China is the leading actor in this market, and some of its partnerships include the USA (25 partnerships), United Kingdom (21), Pakistan (17), and Australia (15). France is next in the

list with key partnerships, particularly with Saudi Arabia (11), and Tunisia also has a key partnership, especially with Saudi Arabia and France. Other nations such as USA, Pakistan, Korea and India also enjoy regular and significant partnerships especially with Saudi Arabia, Lebanon and other major markets. This table indicates the high international connectivity among countries, which is essential in promoting green finance and sustainable development projects in the bonds and securities sector.

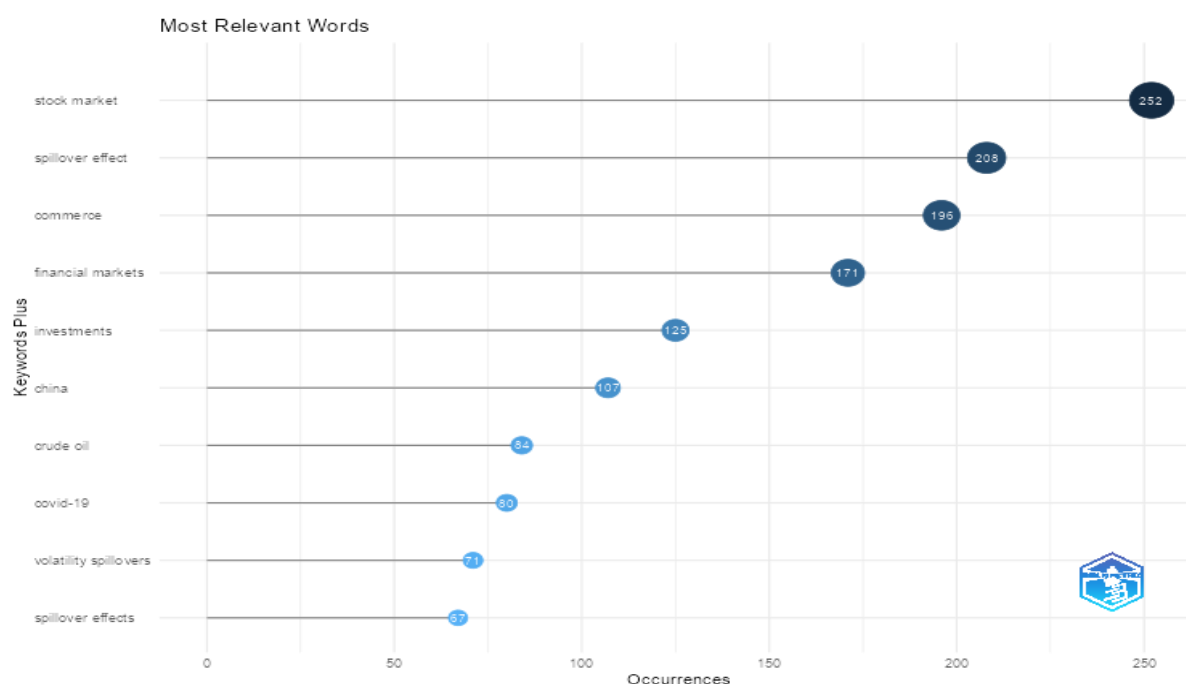


Fig. 2.4: Top 10 most relevant words

Table 2.11: Top-20 Most Frequent Keywords

Words	Occurrences
stock market	252
spillover effect	208
commerce	196
financial markets	171
investments	125
china	107
crude oil	84

COVID-19	80
volatility spillovers	71
spillover effects	67
risk assessment	61
united states	60
financial crisis	59
investment	52
energy market	50
financial market	42
price dynamics	34
costs	32
value engineering	32
gold	28

2.6.5 Top-20 Most Frequent Keywords

Table 2.11 shows the 20 most common words in the financial markets, and it is evident that the most important areas are the stock market, spillover effects, and investments. The term stock market (252) is the most common one, which highlights its importance in the context of financial dynamics. The stock market is one of the fundamental aspects of financial research, and it is necessary to comprehend the changes in the market and the overall economic effect. The second most frequently used term is the spillover effect, (208) which is the impact that an event or a market can have on another. The term plays a pivotal role in research on the interdependence of various financial markets and the economy, especially during crises or volatility. The word commerce, which is the third word with 196 instances, indicates the importance of trade and business activities in the operation of financial markets. It emphasizes the business transactions that determine the investment flows and market dynamics. The term "financial markets" itself is also important, with 171 occurrences, highlighting the broad variety of market platforms, including stock, bond, and commodity markets, that make up the global financial system. The 125 occurrences of the word "Investments" also indicate the interest of the financial sector in capital allocation, asset management, and risk. Investments play a key role in assessing the performance of markets and economic growth. Other words like China, crude oil, COVID-19, and volatility spillovers indicate major global factors and occurrences that impact financial markets. The reference to

China (107 times) indicates its significance as a world economic force, and its markets tend to have extensive effects on the world financial system. Next is the term "crude oil" (84 occurrences), which demonstrates the influence of commodity markets on the trends in the financial markets. The term "COVID-19" (80 instances) shows the long-term economic impact of the pandemic, which transformed the financial environment in the world. The term "volatility spillovers" (71 occurrences) refers to the fact that financial markets are interconnected, and instability in one region can be transmitted and impact other regions. The phrase risk assessment (61 times) emphasizes the necessity of the evaluation of financial risks, which is a crucial part of investment and economic analysis, especially when evaluating market uncertainties. Other words like United States, financial crisis and energy market also help in the comprehension of global financial impacts, which are both historical and current issues in the market. These keywords show how financial research is highly concerned with how to comprehend and maneuver market forces, international risks, and how significant events impact financial stability. The prevalence of the terms connected with the market behavior, crisis management, and investment strategies demonstrates the necessity to learn and adjust to the evolving financial environment.

Fig. 2.5: Word cloud

As shown in Fig-2.5 on word cloud, there is a strong emphasis on the dynamics of the stock market, particularly volatility spillover. Such important terms as stock market (163 mentions) and volatility spillover (142 mentions) are also present, which means that these notions are the focus of the analysis. The word COVID-19 (113 mentions) shows the great influence of the pandemic on the financial markets of the world, which affects volatility and spillover effects. The term volatility itself is also a key concept, appearing 89 times, since it quantifies the changes in asset prices, which are fundamental in the study of market risk. Other

prominent terms such as green bonds (72 mentions) imply the increasing interest in sustainable financial instruments and their spillover effects, which means the changing environment of finance, where environmental issues are gaining more power. The term "emerging markets" (30 mentions) refers to the particular dynamics of developing markets, which tend to have a different dynamic than developed economies, particularly in the context of a crisis. The methodological nature of the research, which aims at predicting and comprehending market risks, is reflected in the use of GARCH (35 mentions) models, a common statistical technique applied in financial analysis to model volatility. A number of terms associated with financial crises and risk spillovers, including financial crisis (32 mentions), systemic risk (20 mentions), and contagion (27 mentions) indicate that the dataset also addresses the issue of how economic shocks can spread across markets, causing widespread instability. The words oil, crude oil, and oil prices (26 times) highlight the importance of commodities, especially oil, in determining market volatility and spillovers. The impact of big economies, especially the "China" and its "stock market" (24 mentions) shows that the study focuses on the global interconnectedness of markets, where shocks in one region may impact others. The fact that there is a mention of the term "bitcoin" (22 times) indicates that the influence of cryptocurrencies on the traditional financial system is also a topic of interest. The term "economic policy uncertainty" (34 mentions) refers to the influence of governmental decisions and the uncertainty of these decisions, which may have a significant impact on the stability of the market and the confidence of investors. In general, the word cloud creates an Fig of a study aimed at comprehending the interdependence of financial markets, the influence of different economic and policy drivers, and the way volatility and risks in a single market can spread throughout the global financial system.

one of the clusters, which shows its centrality in the literature. The terms are allocated to a cluster, which is a group of related terms that are similar or associated with each other. As an example, Cluster 1 includes the terms associated with the concept of information spillover, Cluster 2 is devoted to the concept of risk spillover, and Cluster 3 is devoted to the terms associated with COVID-19. Cluster 4 contains terms associated with the stock market, and Cluster 6 contains terms associated with oil. The column of "Cluster Label" gives a name to each cluster, e.g. information spillover or stock market, which can be used to determine the main themes of the study. The centrality measures such as Betweenness Centrality, Closeness Centrality, and PageRank Centrality indicate the importance or influence of each term in the entire network of terms. Betweenness Centrality shows the extent to which a term acts as a connector between other terms, Closeness Centrality shows how close a term is to all other terms, and PageRank Centrality shows the overall influence of the term. As an example, the concept of risk spillover has a high Betweenness Centrality (507.69), which means that it is central to the connection between different research areas. Likewise, the betweenness centrality of COVID-19 is very high (2047.73), indicating its extensive influence on various clusters, especially in the pandemic. The terms such as stock market and COVID-19 are both common and central, which implies that they are the main subjects of the literature. Conversely, the terms like information spillover and risk spillover might not be as widely discussed but play a significant role in connecting different fields of study, as their centrality is high. The thematic map identifies the main areas of interest, including stock market dynamics, volatility spillovers, and the impact of COVID-19 on global markets. Risk contagion, financial crisis, and market interconnectedness are other significant themes, which are reflected in such terms as contagion, spillover effects, and economic policy uncertainty. This analysis provides a detailed picture of the interrelation of these themes and determines the most important concepts and relations in the research area.

2.6.6 Factorial Analysis Overview:

Factorial analysis is commonly used in bibliometric studies to understand the relationships between different terms, topics, and their co-occurrence patterns within research articles. In your case, this analysis is done through Multiple Correspondence Analysis (MCA), which is suitable for categorical data, such as the presence or absence of keywords in different documents.

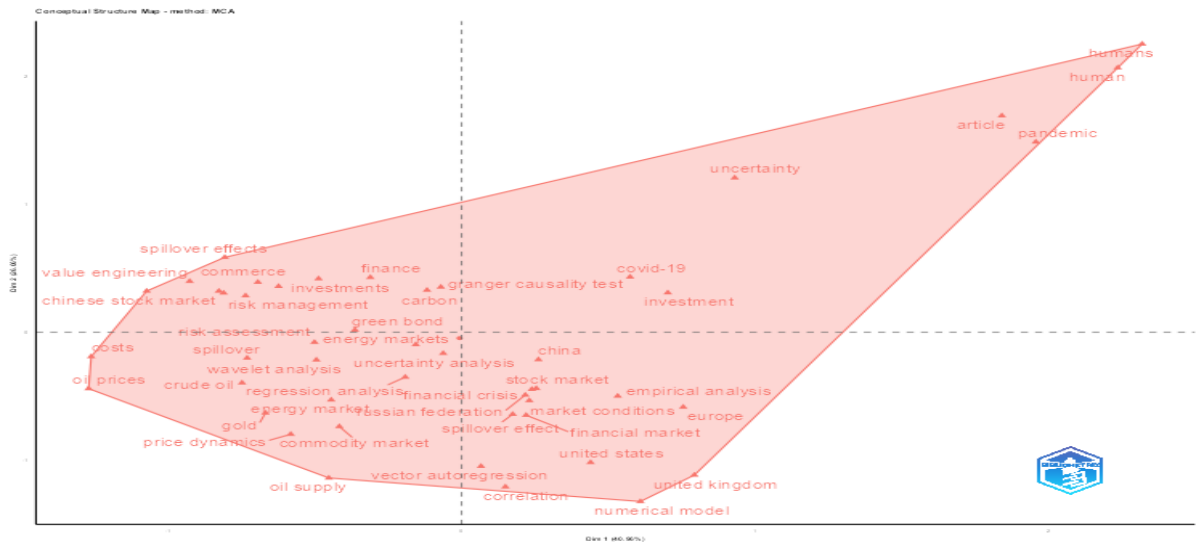


Fig. 2.8 Factorial Analysis overall structure of the data keywords clusters

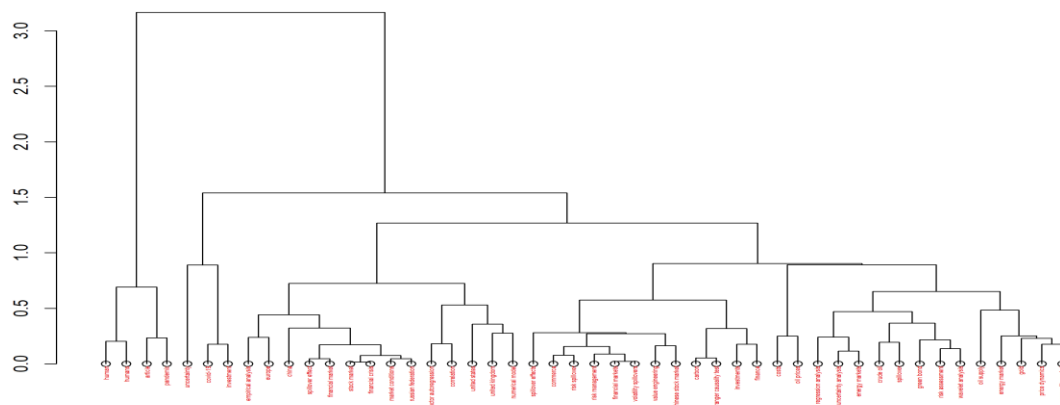


Fig. 2.9: (Hierarchical Clustering), hierarchical relationships diagram

Dim1 and Dim2 are the axes or principal components of the MCA. These dimensions represent the greatest variation in the data. The values of these dimensions of each word indicate the relationship between the terms and how they contribute to the overall structure of the data. Clusters are sets of terms (or research articles) that have similar co-occurrence patterns. All terms in your data are in one cluster (Cluster 1). This implies that the subjects under analysis are highly similar in terms of co-occurrence, which may indicate the main themes of the collection of articles. The analysis seems to be dominated by keywords like stock market, spillover effect, financial markets, COVID-19, energy market, and financial crisis. These are probably the key terms in the research topics discussed in the data. The

lower the Dim1 value, the closer to 0 or negative, the more the keyword contributes to the variability along this dimension, e.g. the keyword stock market has a Dim1 value of -0.44 and spillover effects has a Dim1 value of 0.64. Conversely, words such as human (2.23) and pandemic (1.96) are highly affected by Dim2, indicating an interest in human-related or social problems in the context of economics and finance.

In the dendrogram (Hierarchical Clustering), we can see hierarchical relationships between the keywords, which means how closely they are related in terms of co-occurrence: The human-related terms (e.g., "humans," "human," "article") are grouped with strong positive dimensional values. This may be a study that focuses on human behavior or social effects, perhaps in connection with the pandemic or COVID-19. Another group of terms, including oil prices and commodity market, is characterized by negative dimensional values, which emphasize the energy and financial markets. The fact that such terms as spillover effects and financial market co-occur indicates that certain notions in economic modeling (e.g., risk spillovers) are closely interrelated.

Through Dim1 and Dim2 values of each term, we are able to examine the extent to which each dimension explains the variance of the data. Dim1 keywords such as value engineering (-0.93), costs (-1.26), and gold (-0.67) have strong negative values in Dim1, which indicates that these topics can be related to economic models that are concerned with risk assessment, pricing, and commodities. Dim2 keywords such as humans (2.32), uncertainty (0.93), and pandemic (1.96) have high positive values on Dim2, which can be interpreted as an emphasis on social, economic, and environmental uncertainty, particularly in human behavior during a crisis such as the pandemic.

The data set inform us of the contribution of each term to the overall structure of the data. They are founded on the frequency of the term in comparison to others and its importance in each of the main components (Dim1, Dim2). The fact that all the words belong to one cluster indicates that the topics under analysis are closely interrelated. This may suggest that the academic articles under consideration tend to address various concepts (such as finance, energy markets, risk management) simultaneously, particularly in the light of the global pandemic. The paper reveals the interconnection of various dimensions, including economic (stock markets, oil prices) and social (human impact, pandemic). The high co-occurrence of the terms associated with uncertainty, risk management, and financial crisis indicates the

increasing interest in the study of the impact of crises (e.g., COVID-19) on financial markets and human behavior.

2.7 Bibliometric Review: Technology Markets and Equity Market Spillovers

Following the Fourth Industrial Revolution, technology-based financial assets, including FinTech, cryptocurrencies, AI, and clean energy markets, have become more integrated with traditional equity markets. This has resulted in new understanding of the way these technology markets pass volatility to equity markets and vice versa how equity markets can use hedging by investing in technology assets.

2.7.1 Data Collection

In our bibliometric study of the Technology Markets and Equity Market Nexus, we used the Scopus database. Scopus is a major scientific database that provides extensive access to peer-reviewed academic journals, conference proceedings, and scholarly publications across a broad range of fields, such as finance, economics, business, and technology. It is widely renowned through its extensive scope and high quality material and books printed by leading global publishing houses such as Elsevier, Springer, Taylor and Francis and Wiley. The search tool employed in the research was specifically customized with respect to retrieving the literatures concerning technology markets and equity markets, and specifically, to do with spillover effects, connectedness, and market interactions. The search string employed was as follows, (technology market or tech market or information technology market or digital economy) and (equity market or stock market or financial market) and (spillover or connectedness or nexus or correlation). This quest was carried out in the title, abstract and keywords of the database. To ensure quality and relevance of the literature only peer-reviewed journal articles written in English were used in the analysis. To accommodate the scope of the study, the scope of the topic area was restricted to the area of economics, finance, business management and technology.

The initial search query brought out 1,350 documents. These articles were then checked based on the titles and the abstract with regard to the relevancy of the research. Articles which did not exhibit the inclusion criteria such as articles that did not contain the required bibliometric information e.g. abstract, keywords or the ones which did not contain the

relationship between the technology markets and the equity markets, were excluded. After such filtration, the resulting final file produced 1,050 documents, which were later piped in the CSV format to be further analysed in the bibliometric tool VOS viewer. VOS viewer is a free program most often used in bibliometric analysis to design and visualize term maps, co-occurrence networks and citation patterns, which may be utilized to determine tendencies and relationships in the literature.

The retrieved and analysed data will prove highly beneficial to the development of the research on the technology-equity market nexus because it will constitute the most significant research topics, the most significant researchers, and their works in the field. The spill-over effects and relatedness across technology markets and equity markets will also be analysed and an in-depth review of the current body of research and the gaps that can be bridged through further research is also to be done. The proposed bibliometric study will bring relevant knowledge to the existing body of ideas in the changing interdependence of technology and financial markets, with regard to how volatility in technology markets impacts on markets in circle, and vice versa.

Table-2.12: Top 15 Globally Most Cited Article

Paper	Total Citations	TC per Year
Le Tn-L, 2021, Technol Forecast Soc Change	301	60.2
Bouri E, 2020, Appl Econ	41	8.2
Kogan S, 2023, Rev Financ	25	8.33333333
Shahzad U, 2023, Int Rev Econ Financ	20	6.66666667
Foglia M, 2024, Res Int Bus Financ	17	8.5
Ali S, 2024, Resour Policy	16	8
Gharbi O, 2023, China Finance Rev Int	14	4.66666667
Ziadat Sa, 2024, Energy Econ	11	5.5
Manahov V, 2024, Ann Tour Res	8	4
Tian M, 2024, Eur J Financ	6	3
Yousaf I, 2024, Energy Econ	2	1
Gubareva M, 2025, Energy Econ	2	2
Hung Nt, 2024, Polit Ekon	2	1
Muhammad S, 2025, Singap Econ Rev	1	1
Shah Wu, 2025, Renew Energy	1	1

2.7.2 Top 15 Globally Most Cited Article

Table 2.12 shows the 15 most cited articles in the area of dynamic connectedness and optimal hedging strategies and spillover as indicated by the number of citations in sources like Scopus and Google Scholar. The article by Le TN-L (2021) is at the top of this list, having 301 total citations, which makes it a very influential article. The paper on green bonds and economics and its use in financial markets has been very important in the understanding of the relationship between green bonds and technology and financial markets especially in risk management and market forecasting. Next come the papers by Bour E (2020) and Kogan S (2023) with 41 and 25 citations respectively. These are more recent works that have helped to increase the body of knowledge on the role of financial strategies and market dynamics in green and technology and commodity markets. Although they have a relatively low number of citations compared to older works, their influence is felt, especially in new fields of finance. The other articles with significant citations are Shahzad U (2023), Fogli M (2024), and Ali S (2024) with 20, 17, and 16 citations respectively. These papers provide empirical evidence and sophisticated models of market connectedness, risk management, and hedging strategies in energy markets and the financial world in general. The rising number of citations to these papers is an indication of their rising significance as background readings to future studies. The more recent contributions, including Gharbi O (2023) and Ziadat SA (2024), are also very relevant, providing articles with 14 and 11 citations, respectively. These articles offer new insights into the changing nature of the connection between energy economics and financial strategies. Although the rest of the papers on the list, including those by Manahov V (2024), Tian M (2024), and Yousaf I (2024), are less cited, they address new and emerging issues in energy and economic systems, which makes them increasingly relevant to future studies in energy economics, financial markets, and hedging strategies. The fact that some of these articles have relatively lower citation counts is an indication of their more recent publication dates. Nevertheless, the growing number of citations per year, e.g., 60.2 citations per year in the case of Le TN-L (2021), demonstrates a high academic impact, which implies that these articles are becoming increasingly recognized in the academic community. These widely referenced articles highlight the increasing significance of the interrelatedness of energy markets and financial markets, and the need to optimize hedging strategies in this dynamic world.

The most cited articles on Spillover Dynamics Between Technology Markets and Equity Markets have been discussed as follows: Le et al. (2020) investigate the volatility

connectedness among FinTech, green bonds, and cryptocurrencies and find that technology markets are highly interconnected with traditional equities. Their results show that technology assets such as FinTech are not appropriate to hedge in the same portfolio, although they do contribute to volatility. They indicate that conventional assets, such as gold and oil, are more stable hedging tools, and volatility spillovers are minimal. Bouri et al. (2021) examine the spillover of returns and volatility between clean energy, rare earth stocks, and equity markets during the COVID-19 pandemic. Their findings indicate that clean energy assets convey greater volatility during crisis times, which influences the dynamics of the wider market. It is important to note that the clean energy index was a net transmitter of volatility to other sectors during the pandemic, which indicates its interdependence with equity markets. Kogan et al. (2022) and Kogan et al. (2023) investigate the effects of fraudulent news manipulated on social media platforms on retail trading and prices. Their results indicate that the manipulation of financial news can have a substantial impact on the equity market, which is an indirect but deep impact of technology platforms on market behavior. This shows how digital technology and social media platforms can spill over and affect equity market volatility. Shahzad et al. (2023) explore the spillover between Blockchain-based platforms (AIB, TIX, and BCDN) and ESG indexes. They discover that Blockchain-enabled technologies are more coherent with ESG investments, especially in normal and bullish market environments. This implies that technology markets have the potential to affect the dynamics of equity markets, particularly in industries that prioritize sustainability. Foglia et al. (2024) concentrate on fan tokens and stock markets and conclude that the volatility spillovers between digital assets (such as fan tokens) and traditional equity markets are long-run persistent. The paper highlights the increasing interconnectedness between new digital assets and conventional stock markets, providing an understanding of how digital asset markets may influence the behavior of equity markets. Ali et al. (2024) investigate the spillover relationship between energy cryptocurrencies and GCC stock markets and find that cryptocurrencies are net recipients of return spillovers, whereas stock markets are net senders. Their results indicate that energy cryptocurrencies may be used to reduce risk and maximize portfolio returns, particularly in times of increased uncertainty such as the COVID-19 pandemic. Gharbi et al. (2023) examine volatility spillovers in the U.S. FinTech stock market pre- and during the COVID-19 pandemic. They discover that investor biases (such as overconfidence) were net transmitters of volatility in the pandemic, whereas conventional risk factors, such as value at risk (VaR), were net receivers. This underscores the importance of FinTech as a transmitter and receiver of market volatility, particularly

during crisis times. Ziadat et al. (2024) analyze the spillover between clean energy markets and global stock markets. In their research, they point out that clean energy and renewable energy indexes are powerful hedges against equity market volatility in busting market conditions, and these assets are stable in times of extreme market uncertainty. Manahov and Li (2023) examine how five well-known cryptocurrency heists affected the cryptocurrency and tourism token markets, finding that they resulted in a decline in market quality. The paper highlights the importance of AI in monitoring crypto wallets to reduce systemic risks in the market, which highlights the increasing interdependence between cryptocurrency markets and equity markets. Tian et al. (2024) investigate the risk transmission between FinTech and sub-industries in the Chinese financial sector and find that FinTech has a substantial risk spillover. Their results also point out that the risk spillover of FinTech to Chinese sub-industries varies considerably across risk levels, which emphasizes the importance of technological assets in reducing equity market risks. Yousaf et al. (2024) and Yousaf et al. (2023) examine the returns and volatility connectivity between the electricity and AI-based markets, demonstrating that AI stocks can be used as safer investments in times of high market risk. According to their research, some AI stocks are net transmitters of risk to conventional equity markets, particularly in times of market crises like the COVID-19 pandemic and the Russia-Ukraine conflict. Gubareva et al. (2025) examine the dynamics of risk transmission between oil, AI, clean technology, and traditional markets. They discover that technology markets, especially AI and clean technology, are more prone to risk spillover transfers than conventional markets such as oil and U.S. government debt. Their analysis highlights the possibility of oil and the U.S. dollar serving as a hedge against extreme risk spillovers in AI and clean technology industries. Hung (2024) analyses the interaction between DeFi (decentralized finance) and CEE (Central and Eastern Europe) stock markets in the context of the COVID-19 outbreak and the Russo-Ukrainian conflict. His analysis indicates that DeFi assets provide more diversification advantages to CEE stock markets, particularly in the long-term investment horizon, and serve as net recipients of volatility spillovers. Muhammad & Huang (2025) investigate the tail risk spillover between FinTech, sustainability investments, and SME stock indices in the COVID-19 pandemic and the Russia-Ukraine war. They discover that sustainability-based assets, such as ESG and green bonds, are effective hedges in a crisis, whereas FinTech has limited risk mitigation in extreme situations. This paper emphasizes the crisis-contingent nature of technology assets as hedging instruments. Shah et al. (2025) examine the volatility spillover between renewable energy, FinTech, and European real estate markets in the context of the COVID-19 and Russia-

Ukraine crises. Their results indicate that renewable energy and real estate markets are the main net recipients of volatility, whereas FinTech markets convey more risk. This implies that technology markets such as FinTech can be employed strategically to hedge against volatility in the real estate market. Elbayar et al. (2025) examine how Fear and Greed Indices (FGIs) affect stock markets and green technology assets in times of financial crisis. Their analysis shows that green bonds and green fintech are safe-haven assets, which can be used to hedge against equity market volatility, particularly in post-2020 market stress. Missaoui et al. (2025) concentrate on the impact of FinTech and technological innovation on African stock markets in times of crisis. They demonstrate that FinTech has a substantial impact on stock market returns during the COVID-19 pandemic and the Russia-Ukraine conflict, and FinTech is a risk transmitter and receiver in African markets. Wang et al. (2025) discuss the economic consequences of the circular economy (CE) on companies and their supply chains. Their analysis indicates that firms that adopt CE practices, especially those in the technology industry, have better financial performance and risk resilience, which may be transferred to their partners, including those in equity markets. Zaman et al. (2024) discuss the regulatory opportunities and challenges of Blockchain technology in emerging Muslim markets. Their results indicate that Islamic crypto assets, including Shariah-compliant DeFi tokens, can serve as safe havens in times of market stress, and can hedge against equity market risks (Billah et al., 2024). 2018 Conference Proceedings contain a number of papers on the spillover effects in the Asia-Pacific technology stock markets and innovation-driven financial products. In one study, the spillover between FinTech and stock market returns is examined, and it is stated that the growing use of FinTech innovations may lead to market volatility spillover, especially in uncertain economic times (Liu et al., 2025).

Table-2.13: Yearly Frequency of Topics (Keywords)

Year	RISK ASSESS	FINAN CIAL	FINAN CIAL	ENERG Y	COVID-19	ARTIFI CIAL	INVEST MENTS	FINAN CIAL	STOCK MARK	SPILLO VER
2021	0	0	1	0	1	0	0	1	2	1
2022	0	0	1	0	1	0	0	1	2	1
2023	0	1	1	0	1	0	0	1	2	1
2024	1	3	3	2	2	1	3	2	6	5
2025	3	3	3	3	3	3	4	4	7	7

2.7.3 Yearly Frequency of Topics (Keywords)

Table-2.13 indicates observation of years, the frequency of topics is evidently changed. Stock Market and Financial Markets are always important, and new subjects such as Artificial Intelligence, Energy Market, and Risk Assessment are becoming more and more important, particularly in recent years. The high increase in the keywords Investments, Energy Market, and Artificial Intelligence shows the new trends and issues in these fields. The prevalence of COVID-19 and Spillover Effects indicates that the influence of the pandemic remains a topic of discussion, but its popularity decreases slightly with time. The general tendency is the growing diversification of the research focus, especially the tendency to concentrate on the emerging technologies and energy markets.

Table 2.14: **Most Relevant Keywords/ Most Frequent Words**

Words	Occurrences
Fintech	9
COVID-19	6
Blockchain	4
Bitcoin	2
Portfolio Diversification	2
Risk Spillovers	2
Spillover	2
Spillover Effects	2
Spillovers	2
African Stock Markets	1
Ai-Based Stocks	1
And Tvp-Var Framework	1
Arma-Egarch	1
Arma-Garch	1
Artificial Intelligence (Ai)	1
Asian Pacific Region	1
Bayesian Tvc Var Model	1
Cee Regions	1

China	1
Circular Economy	1

2.7.4 Most Relevant Keywords/ Most Frequent Words

Table-2.14 indicates most frequent words where Fintech is the most frequent word with 9 occurrences. This shows how financial technology is important in modern research. Fintech includes mobile payments, digital banking, blockchain, and AI-based financial services. Its popularity highlights the revolutionary impact of technology on the finance industry and indicates an increased interest in the way these technologies are changing financial markets, investments, and services. The word COVID-19 is mentioned 6 times, which indicates its continued influence on financial markets, economic stability, and risk management strategies. The long-term economic and financial impacts of the pandemic are still being researched, such as the way markets responded to health crises, governmental responses, and the global economic downturn caused by the pandemic. The term is still topical because the world is still recovering its consequences, and it is one of the areas of interest. The term blockchain appears 4 times, which shows its growing significance in financial and economic studies. The technology that underlies cryptocurrencies such as Bitcoin, blockchain, has a great potential to disrupt the traditional finance by increasing transparency, security, and lowering the cost of transactions. It has uses outside of cryptocurrencies, such as supply chain management, digital contracts, and decentralized finance (DeFi). Bitcoin is mentioned twice, and this is an indication of its popularity as the most popular cryptocurrency. Bitcoin has significantly impacted the financial markets and the evolution of blockchain technology, and numerous studies have been conducted on its volatility, effects on the traditional financial system, and its use as an alternative investment. The concept of portfolio diversification is also mentioned 2 times, which indicates its significance in the financial risk management strategies. The concept of diversification is important to investors, who seek to minimize the risk of their portfolio by owning a range of assets. The high frequency of this term indicates that the optimization of portfolios is one of the key topics of the modern research, particularly in the framework of risk management and financial market analysis. Risk Spillovers is an applicable term that is used 2 times and is essential in the interpretation of how risk is transmitted across various financial markets, regions, or assets. This term implies that the study is dealing with the spread of shocks or financial crises in one market to other markets. It is especially applicable in the analysis of global interconnectedness, market stability, and

the spread of systemic risk. The word spillover is used twice and is connected to the concept of risk spillovers. It also implies the wider idea of how shocks or changes in one sector can impact other sectors. The prevalence of this term reflects a focus on the interdependence of markets, especially in international finance, where shocks in one economy or asset class can propagate around the world. The one-time appearance of AI-based stocks indicates the increasing overlap between artificial intelligence (AI) and stock market analysis. This term probably means the stocks of companies that are taking advantage of AI technology or employing AI to fuel investment strategies. It demonstrates the impact of AI on the behavior of the stock market and investment patterns. Another very relevant term is Artificial Intelligence (AI), which is mentioned once in the dataset. The growing role of AI in financial markets is transforming the way risk is measured, trading algorithms are created, and data is interpreted. It emphasizes the importance of machine learning and AI technologies in improving financial decision-making and forecasting. Circular economy is referred to once and is a new field of interest. A circular economy is an idea that aims at minimizing waste and encouraging the reuse of resources. Within the financial context, it may refer to sustainable investing, green bonds, and corporate initiatives to respond to environmental and social governance (ESG) considerations. African Stock Markets (1 occurrence) this term implies that the research involves geographical research, especially in emerging markets such as those in Africa, and may refer to the regional behavior of stock markets as the focus of the research. ARMA-EGARCH & ARMA-GARCH (1 each) these are statistical models applied in the analysis of financial time series data. Volatility in financial markets is modelled using ARMA (Autoregressive Moving Average) models and EGARCH (Exponential Generalized Autoregressive Conditional Heteroskedasticity) models. Their reference indicates an interest in econometric models to study market risks and dynamics. Bayesian Time-Varying Coefficient Vector Autoregressive (TVC-VAR) model is a sophisticated econometric model that is applied in the analysis of the dynamic relationship between variables over time. Its inclusion implies an emphasis on advanced quantitative methods in the study of financial and economic data. The mention of China implies the targeting of one of the biggest and most powerful financial markets globally. The position of China in the world financial systems, trade, and its market reforms are the reasons why it is a major research topic. The most common and topical words in this data set indicate the increasing role of fintech, blockchain, and artificial intelligence in the financial sector, and the continued impact of COVID-19 on the world markets. The study also focuses on portfolio diversification, risk spillover, and spillover effects, which means that much attention is paid to risk management and the

increasing interest in the shift towards cleaner energy sources and the economic consequences of energy markets. Risk Assessment suggests an increased emphasis on financial and market risk assessment and management, and the existence of United States suggests a geographic focus or area of interest in some of the studies. Alternative Energy, Clean Energy, Clean Technologies, Costs, Crude Oil, Currency, Equity, Financial Data Processing, Fintech, Power Markets, and Renewable Energies are mentioned twice. These words denote new issues concerning sustainability (alternative and clean energy, renewable energies), finance (fintech, equity, financial data processing), and energy markets (crude oil, power markets). The growing attention to fintech and financial data processing indicates the significance of technological progress in the development of financial services and market activities. The term AI-based Stock is mentioned only once, which indicates that it is a more specific subject in the data set, dealing with AI-based stock analysis or trading models. This underscores a new and niche interest in the overlap between artificial intelligence and stock market dynamics.

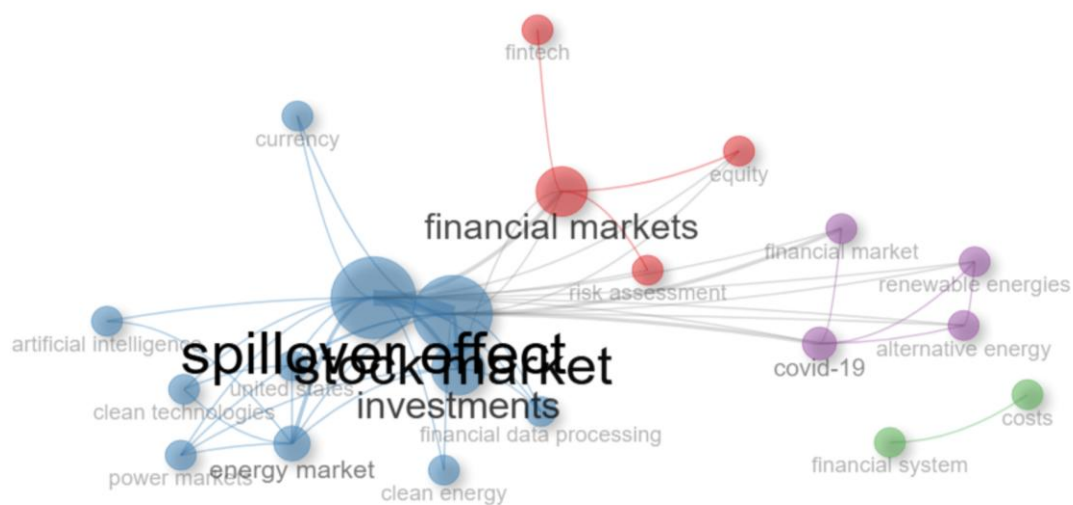


Fig. 2.11: Keywords occurrence Network Cluster

2.7.5 Keywords occurrence Network Cluster

Fig-2.11 shows the network where the terms like financial markets, spillover effect, stock market, and risk assessment are represented along with their cluster and centrality measures. These terms are closely interrelated, particularly in groups of the "financial markets," the "energy market," and the "renewable energies." Cluster 1 includes such nodes as financial markets, risk assessment, equity, and fintech. These are the focus of the analysis, and the terms such as spillover effect and stock market have high betweenness centrality. Cluster 2 contains such terms as energy market, investments, artificial intelligence, and united states, which are more technical and geographical in nature. Cluster 3 includes words connected with the concepts of costs and financial system, which may be oriented on economic aspects. Cluster 4 is concerned with energy-related words, such as alternative energy and renewable energies. Betweenness shows the position of a term as a bridge in the network. As an example, the term spillover effect has high betweenness, linking different clusters. Closeness is the measure of the proximity of a term to other terms in the network. Most other terms are close to terms such as stock market and financial markets.

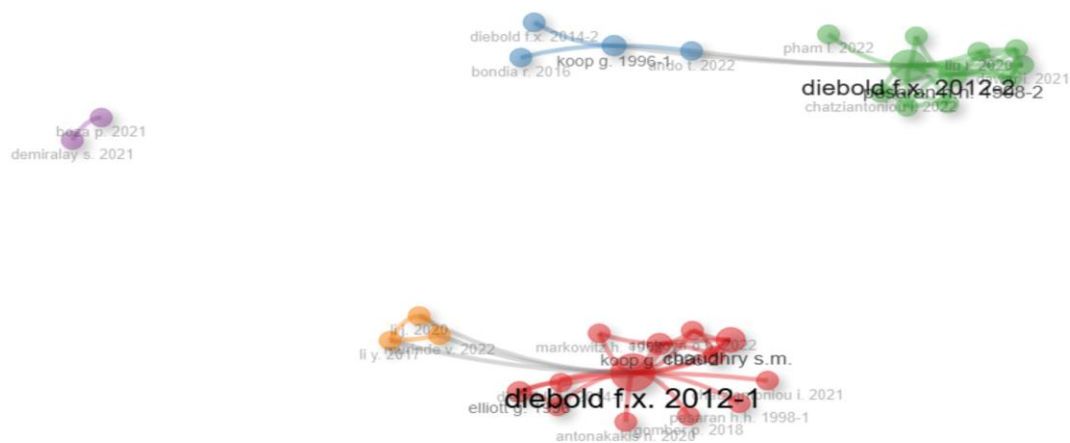


Fig-2.12: The network visualization of co-citation cluster

Fig-2.12 indicates the clustering of various authors or papers according to their co-citation patterns. Each cluster is a set of authors or works that are often cited together, which means that they have a thematic or methodological similarity. • The blue cluster and green cluster are closely connected, which indicates that these authors/papers are in the same research area. The focus of these clusters is Diebold F.X. (2012). The size of nodes represents the significance or centrality of authors/papers. The nodes with higher centrality are larger nodes like Diebold F.X. (2012) which are important in the network. The red cluster at the bottom-right appears to be another cluster of authors such as Chaudhry S.M. (2022) and Pesaran H. (1998-2). Orange and Purple Clusters: These are smaller groups, including Boza P. (2021), Demiralay et al. (2021) and Lij. J. (2020). The nodes are sized according to the importance or centrality of the authors/papers in the network. The bigger the node, the more central the figure in the network, i.e. these authors or works are very influential and are often cited by other works in the field. Diebold F.X. (2012), which seems to be one of the largest nodes, indicates that the works of this author are basic or influential in the field. The edges between nodes are citation relationships. The density or thickness of the lines can be used to show stronger or more frequent citation ties between the nodes that are connected. The connectivity implies that some papers or authors are central to citation networks, linking various research groups or fields.

2.7.6 Factorial Analysis

Fig-2.13 and Fig-2.14 show factorial analysis where Dim1 and Dim2 are the main components of the Multiple Correspondence Analysis (MCA) that reflects the largest variation in the data. These dimensions assist us in comprehending the distribution and relationship of the terms with each other. The Dim1 and Dim2 values indicate the contribution of each term to the overall structure of the data. In the analysis, all the terms are under one cluster (Cluster 1), which indicates that the topics analysed are very similar. This grouping shows that the research articles have similar themes, which are probably focused on economics, financial markets, energy, and social impact. The most significant terms that are used in the analysis include stock market, spillover effect, financial markets, COVID-19, energy market, and financial crisis. These are the key terms of the research topics, which indicates the orientation on the global financial trends and economic crises. The Dim1 and Dim2 values of these terms indicate their impact on the structure of the dataset. As an illustration, the words stock market (-0.44) and spillover effect (0.64) are moderate on Dim1, indicating their applicability in the study of economic phenomena and financial processes.

Conversely, words like human (2.23) and pandemic (1.96) have high positive scores on Dim2, indicating a high social aspect of the study, probably on human-related issues like the social effects of the pandemic. The dendrogram (hierarchical clustering) also shows the connections between these terms. It indicates the degree of relatedness of the terms in terms of co-occurrence. The words that refer to human behavior or societal effects, including humans, pandemic, and social impact, constitute a cluster with high positive values on Dim2. This implies that the research should be based on the relationship between the human behavior and societal changes and the economic situation. On the other hand, the terms such as oil prices and commodity market, which constitute a separate cluster in the dendrogram with negative values on Dim1, indicate the studies of energy markets and their economic consequences. The words like spillover effects and financial market are placed next to each other, which means that there is a close connection between such concepts as risk management and economic modeling. This implies that the study is specifically interested in the way risks, e.g. financial crisis or market fluctuations, spread within the system. The high negative scores of keywords such as value engineering (-0.93), costs (-1.26), and gold (-0.67) along Dim1 indicate that these words are associated with economic models that deal with risk assessment, pricing strategies, and commodities, which are important in the study of the global economy. Dim2 also reflects social, economic, and environmental uncertainty, especially human behavior and crisis. Such keywords as uncertainty (0.93) and pandemic (1.96) show that the research is focused on the effects of uncertainty, particularly on human behavior in the context of global disruptions, like the COVID-19 pandemic. The high positive scores on Dim2 indicate that these words are the focus of the debate on societal resilience and adaptation to crises. The values of contributions give additional information on the contribution of each term to the total structure of the analysis. These contributions indicate how often and how important each term is in the context of Dim1 and Dim2, which assists in comprehending what concepts are behind the overall structure of the data. The fact that all the terms belong to one cluster indicates a high level of interconnectedness between the topics, which indicates a complex interrelation between finance, energy, risk management, and social issues, particularly in the pandemic context. On the whole, this factorial analysis demonstrates the interconnection of different dimensions, including economic (financial markets, energy markets, and pricing strategies) and social (human impact, uncertainty, and the pandemic). It points to the increased attention to the question of how global crises such as COVID-19 affect financial markets, risk management, and human behavior. The fact that the

terms associated with uncertainty, risk spillovers, and financial crises co-occur also highlights the significance of these issues in the contemporary academic literature.

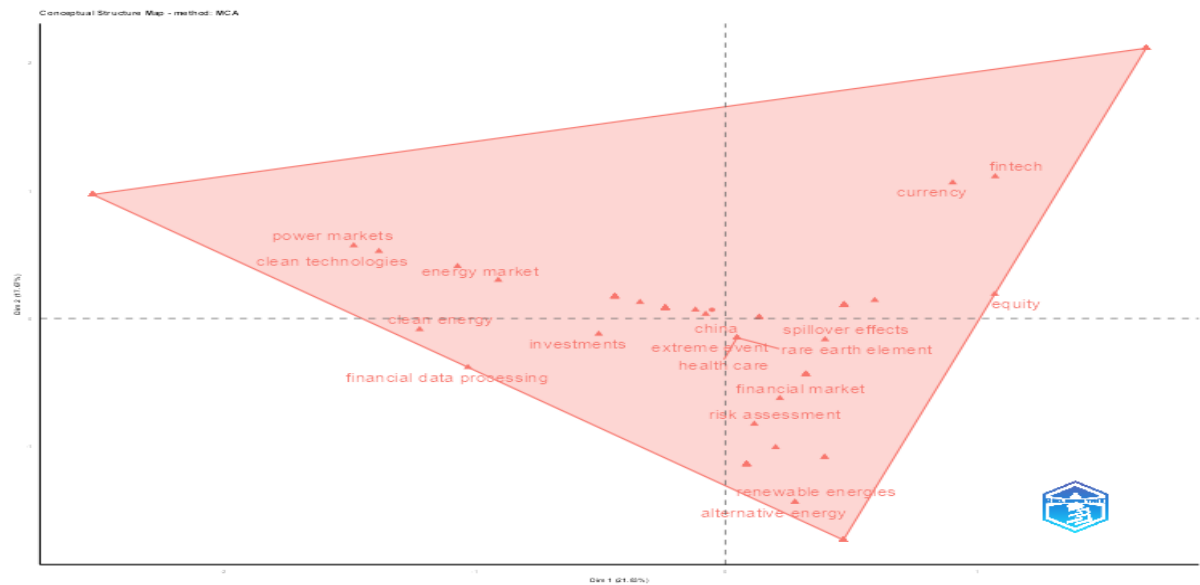


Fig. 2.13: Factorial Analysis overall structure of the data keywords clusters

paper also points out that more advanced, time-varying econometric models are required to quantify spillovers and risk transmission, especially in the light of the changing and interdependent financial markets. The study will help in the knowledge of portfolio management and risk mitigation in the APEC region, which will be of great help to institutional investors and policymakers who have to deal with the dynamics of global market fluctuations.

CHAPTER 3

3. Research Methodology

The methodology of the research and the frameworks used to investigate the dynamic relationships and complex nature of all asset classes to be chosen is described in this chapter. It relies on the literature reviewed in Chapter 2 and plugs the research gaps in the research by attributing to the explanations on how they are conducted to understand the co-movement patterns, lead-lag pairing, and potential hedging opportunities in financial markets. One studied model, presented and explained in the chapter, is the Time-Varying Parameter Vector Autoregressive (TVP-VAR), Connectedness Approach understanding suggested by Koop and Korobilis (2014) and representing the generalization of a well-known Diebold and Yilmaz (2012) approach of connectedness. The model is presented as an instrument in quantitatively measuring the directional, time-varying spillover between asset classes yielding information on market integration, systemic risks and the role of individual asset in price discovery. As supplementary to the econometric method, wavelet-based methods are also described in the chapter, including the Wavelet Power Spectrum, Cross Wavelet Transform and Wavelet Coherence. These tools are covered in terms of the applicability in terms of capturing co-movements in a diverse number of time scales as it creates the opportunity to determine the structural breaks, short-run fluctuations and long-run synchronization in market behaviour. Besides connectedness and wavelet methods, the chapter describes several portfolio optimization models, i.e., Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectivity Portfolio (MCoP). These models are described as possible instruments to assess the benefits of diversification and to develop hedging strategies in various interrelated market conditions. In general, the chapter is aimed at defining and justifying the research design, clarifying the theoretical and methodological instruments to be applied to answer the objectives of the study. It preconditions the empirical implementation in the following chapters and shows how the selected methods help to fill the gaps in the financial literature concerning market interdependence and risk management.

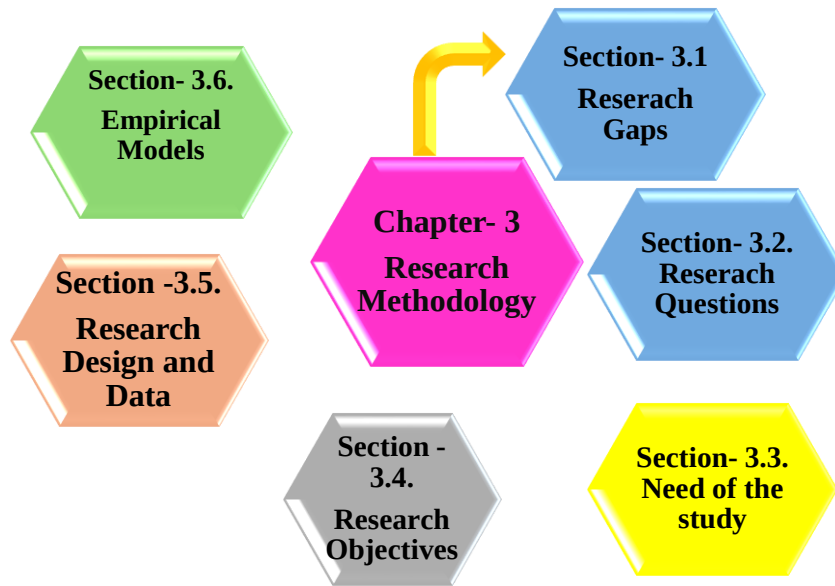


Fig. 3.1 Bird Eye view of Research Methodology

3.1 Research Gap

The literature on financial spillovers in APEC nations has primarily focused on the analysis of cross-country equity returns. (Kakran S. et al., 2023; Sun G. et al., 2023) Nevertheless, there is a notable research gap in understanding the cross-border spillover effects in commodity markets and sustainable financing instruments, specifically:

- ✓ An investigation can be conducted to analyze the impact of energy price fluctuations on the economic indices of APEC nations. Exploring the relationship between energy prices and their influence on APEC capital markets could be a promising area for research. Research could investigate the repercussions of prices in the conventional (dirty) energy industry on economic stability.
- ✓ Gold's role as a financial instrument is commonly examined as a secure investment, but its impact on the financial systems of APEC countries during periods of economic instability has not been well investigated.
- ✓ Despite the increasing popularity of green bonds, the current research lacks information on the spillover effects of green bonds on financial markets and sustainable development initiatives across APEC nations.

3.2 Research Questions??

- How do fluctuations in global fossil fuel energy prices influence the stock markets and economic stability of APEC countries?
- What role do clean energy investments play in shaping capital markets within APEC economies?
- How can advancements in technology, particularly in energy and market analytics, be used to hedge risks in the APEC stock markets?
- Can gold price volatility be linked to financial stability or instability within the APEC region, and how?
- What are the implications of green bond issuances and their performance for financial market dynamics in APEC countries?

3.3 Need of the Study

- ❖ This study will help to understand the dynamic interconnections between several global markets.
- ❖ The identification of appropriate hedging methods in the face of multiple global crises helps to reduce risks in interconnected markets, providing advantages for investors and financial institutions.
- ❖ The findings will suggest that which assets are suitable for diversifying portfolios. This information is crucial for investors who aim to create well-balanced and resilient portfolios.
- ❖ This study innovatively incorporates the Technology, stock, and commodity markets into an integrated framework to model the return and volatility spillovers.

3.4 Research Objectives

The objectives of this research are:

- 1) To investigate Dynamic Connectedness amongst select asset classes.
- 2) To discover co- movement amongst select asset classes.
- 3) To identify hedging options amongst select asset classes.

3.5 Research Design and Data

The research design serves as a comprehensive roadmap guiding the overall framework of the study, including the research approach, structure, and processes aligned with its objectives. This study employs a quantitative research approach using time series data to explore key financial relationships. The design is both exploratory and descriptive, aiming to investigate the Dynamic Connectedness, Optimal Hedging Strategy, and Co-movement among various asset classes such as Energy, Gold, Technology, Green Bonds, and APEC Equity Markets. Selected APEC countries are presented in Fig 3.2. For empirical analysis, the study utilizes daily log prices covering the period from January 2015 to December 2024, with data extracted from the Bloomberg Terminal. The selected variables and their tickers have been presented in Table 3.1. The time period covers varied crisis as mentioned in Table 3.2.



Fig. 3.2: APEC Member Economies.

Fig Source: Word Press at <https://cofda.wordpress.com/tag/asia-pacific-economic-cooperation/>

Table-3.1: List of variables APEC Countries and Green Bonds, Energy, Commodity and technology

S.No	Category	Name of the Country	Name of the Variable	Symbol
1	Green Bond	Global Index	S&P Green Bond Index	SPGRBND
2	19 Developed and Emerging APEC Countries	Philippines	PSEi	SBBCPHU
		Canada	TSX	SBBCCAU
		Australia	ASX 200	SBBCAUU
		Chile	CLX IPSA	SBBCCHL
		Singapore	STI	SBBCSIU
		Hong Kong	HK50	SBBCHKU
		Taiwan	TWSE	SBBCTAU
		Indonesia	JCI	SBBCIDU
		Thailand	SET Index	SBBCTLU
		Russia	MOEX	IMOEX
		USA	S&P 500	USSPX
		Japan	NIKKEI 225	SPJ500
		South Korea	KOSPI	KR30
		Vietnam	VNI	IDFPVNPD
		Malaysia	KLCI	FBMKLCI
		China	SHCOMP Index	SPC500CP
		New Zealand	NZSE50	SBPCNZU
		Mexico	BMV	TT0000
		Peru	BVL	SBPCPEU
3	Dirty Energy	Global Indices	S&P GSCI Crude Oil	SPGSCL
			S&P GSCI Natural Gas	SPGSNG
4	Clean Energy	Global Index	S&P Global Clean Energy Select Index	SPGTCSUP
5	Gold	Global Index	S&P GSCI Gold	SPGSGC
6	Technology	Global Index	Dow Jones Global Technology Index	W1TEC

Type of Events	Time-line
Oil Crisis	2015-16
Climate Crisis	2017
COVID -19	2020-2021
Russia Ukraine War	2022-2023
Iran-Israel war	2024

Table-3.2.: Events Covered under this study

This diverse selection of variables allows for a comprehensive analysis of interlinkages and risk transmission across both conventional and sustainable financial markets. When applying time-varying connectedness models to time series data, it is essential that the dataset possesses certain key characteristics to ensure the accuracy and effectiveness of the analysis. The first one is stationarity which means that the statistical characteristics of the data, e.g., mean, variances, and autocorrelation, are time-invariant. The notion of stationarity is also a prerequisite when it comes to utilizing the GARCH and the VAR-based spillover models. Secondly, data is obligatory; the notion of consistency with data implies a similar format, sampling periods, data collection and quality verification throughout the research period. The reliability, comparability and the precision of results are improved by consistent data.

Completeness is another essential characteristic, i.e. the dataset should represent the whole period under study without any missing data, because these gaps may undermine the validity of the reporting and insert bias. Granularity equally matters which refers to the amount of detail, or timeliness that data points will be captured. On a finer level (e.g. data gathered within every second or every minute), it is possible to use fine granularity to analyze in detail in the short term, but coarse granularity (e.g. daily or monthly data) is more appropriate in pattern recognition of long-term indicators. Keeping high-frequency data however can demand a large amount of storage and processing resource.

Another critical aspect is that of relevance meaning the data shall be intimately linked with the goals of the study. It should have all the variables needed, time lines and circumstances to enable a thoughtful and correct analysis. Relevant information generally exhibit large signal to noise ratios i.e. the meaningful information is much more than the random noise. Time is also the issue as real-time or near-real-time decision-making environments are involved. It must also be current as well as accessible.

Lastly, validity refers to how accurately the data reflects the actual phenomenon or process being studied. Ensuring validity requires stringent quality controls, accurate measurement techniques, and consistency with theoretical expectations. Valid data forms the foundation for sound analyses, reliable models, and effective decision-making. Together, these features ensure that time series data is fit for rigorous empirical modelling, particularly when analysing dynamic financial relationships.

3.5.1 Robustness Checks:

To ensure the reliability of the empirical findings, three robustness checks were performed. First, the TVP-VAR model was re-estimated using alternative lag orders ($p = 2$) identified through the Akaike Information Criterion (AIC), yielding directionally consistent connectedness rankings with only marginal changes in magnitude. Second, sub-sample analyses were conducted for each of the five identified crisis windows Oil Crisis (2015–16), Climate Crisis (2017), COVID-19 (2020–21), Russia-Ukraine War (2022–23), and Iran-Israel Conflict (2024) confirming that the crisis-period intensification of the Total Connectedness Index (TCI) is statistically robust and not an artefact of the full-sample estimation. Third, portfolio performance metrics (Sharpe Ratios, Hedge Effectiveness) were recalculated using a 500-day rolling window instead of 250 days; results remained qualitatively unchanged, confirming that findings are not sensitive to the choice of estimation window length.

3.6 Empirical Models

This section describes the modelling framework used in the study (see Fig.3.3). As mentioned in the introduction, the general analysis is divided into four major steps; but to simplify the analysis, these are summarized into two major stages of methodological analysis. The initial step is econometric modelling, in which we estimate and interpret different measures of connectedness to learn about the dynamic relationships between chosen financial assets. The second step is the construction of optimal portfolios, and then the co-movement and performance analysis. This systematic methodology enables a thorough analysis of market interdependencies, risk transmission, and the consequences to portfolio diversification and hedging strategies.

For objective wise achievement methodology, please refer to Fig 3.3.

Fig-3.3.: Empirical Framework Graphical Representation of Study Methodology and Variables and Major Crisis (Events)

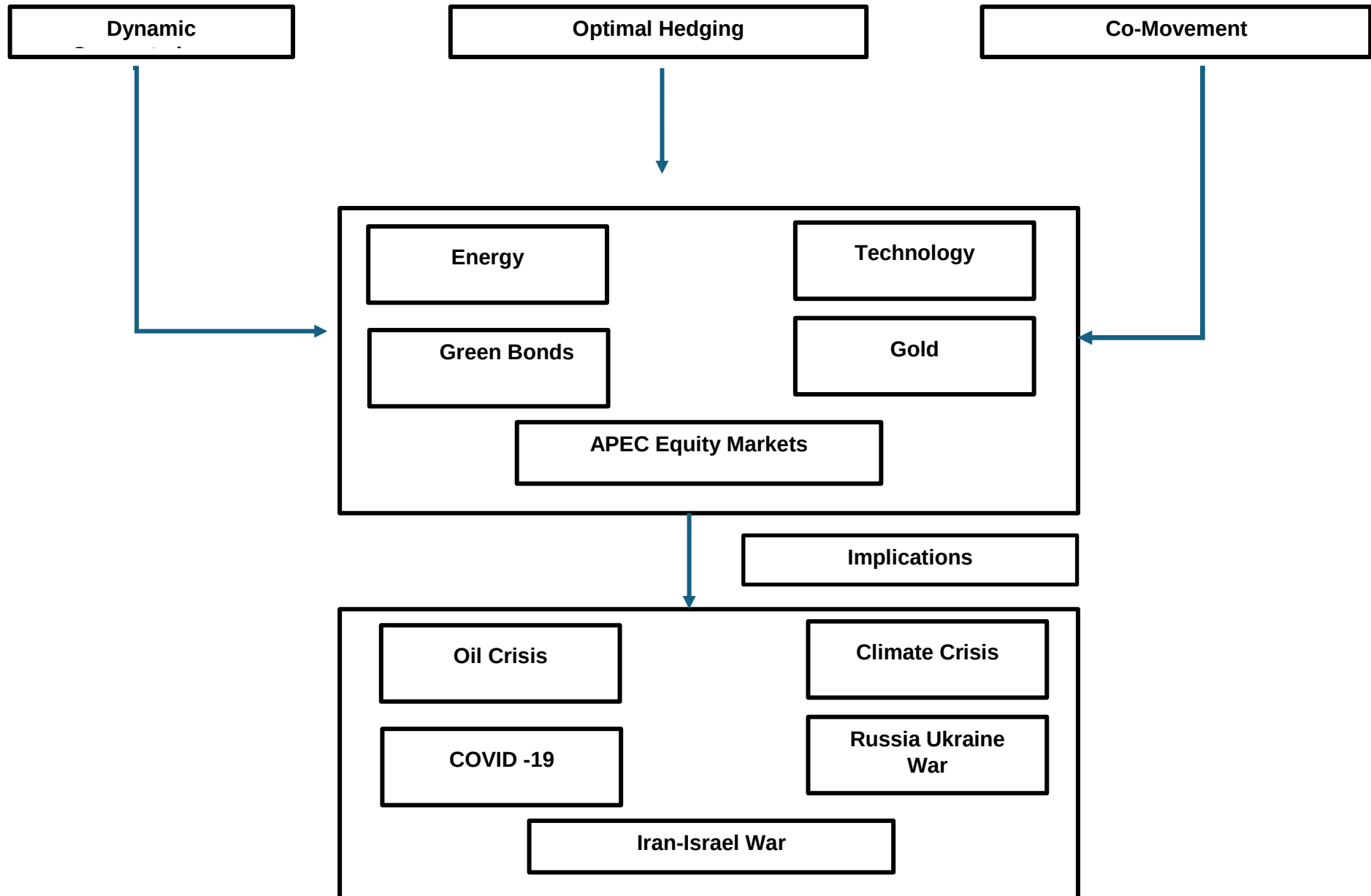
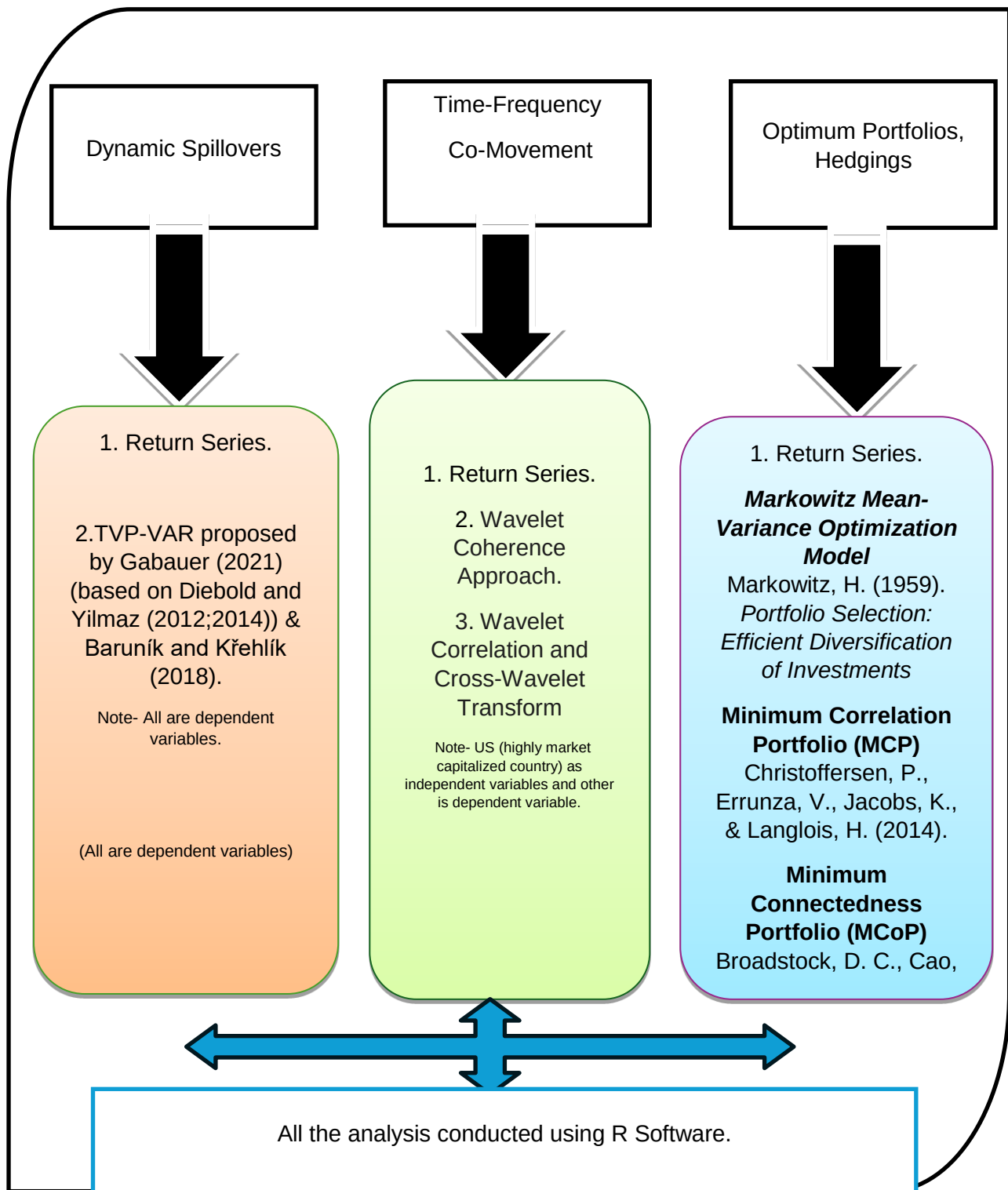


Table 3.3: Objective-wise Methodology (Models for achieving objectives)

Objectives	Methodology
To investigate Dynamic Connectedness amongst select asset classes.	Descriptive Statistics Diebold-Yilmaz Model (2012) (TVP-VAR Connectedness Approach)
To discover co- movement amongst select asset classes.	Wavelet Analysis Wavelet Coherence Partial Wavelet Coherence Wavelet Correlation
To identify hedging options amongst select asset classes.	Portfolio Weights Hedge Ratio and Hedge Effectiveness Multivariate Portfolio construction Sharpe Index

The tables-3.3 shows, research uses a three-pronged methodological approach. First, dynamic connectedness between asset classes is measured by the Time-Varying Parameter VAR (TVP-VAR) model, which captures the directional spillovers and systemic connections over time. This strategy is flexible to structural changes and changing market conditions. Second, the study describes how to use wavelet methods to analyze time-frequency co-movement, including the Wavelet Power Spectrum, Cross Wavelet Transform, and Wavelet Coherence. These tools give information on short-run and long-run dependencies between asset classes. Third, to assess portfolio optimization, the chapter describes the creation of three portfolios: Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP). Sharpe ratios are used to evaluate each portfolio to determine the most effective risk-adjusted return strategy in different interconnectedness scenarios. This holistic framework (see Fig 3.4.) improves the knowledge of market behavior, co-movement structures, and optimal asset allocation strategies.

Fig. 3.4: Graphical re-presentation of models used in the study on R studio.



3.6.1 TVP-VAR based connectedness approach

The DY method proposed by Diebold and Yilmaz (2014) has been extensively used in previous studies to examine directional volatility spillovers and volatility transmission between markets. This method usually uses a rolling-window method, which is effective but limited. In particular, the selection of the rolling window size may cause methodological issues, including the omission of some observations, as Dai and Zhu (2022) note. As a solution to these issues, Antonakakis et al. (2020) proposed one more model, a time-varying parameter vector autoregressive (TVP-VAR) model. Unlike the conventional practice of rolling-window methods, TVP-VAR can be estimated using flexible windows without any losses of observations, which enables more comprehensive estimation process (Mishra and Ghate, 2022). The current paper builds on the works of Antonakakis et al. (2020) by applying a TVP-VAR (1) model selected via the Bayesian Information Criterion (BIC), and inspect the co-relatedness of asset returns across asset classes. This model can be mathematically represented as follows:

$$\lambda_t = B_{t\lambda_t} - 1 + \varepsilon_t, \varepsilon_t \sim N(0, S_t) \quad 1$$

$$\text{vec}(B_t) = \text{vec}(B_{t-1}) + u_t, u_t \sim N(0, R_t) \quad 2$$

Where λ_t, λ_{t-1} and the error term ε_t are specified as $k \times 1$ dimensional vectors. $\text{vec}(B_t)$ Represents the vectorized form of B_t , and S_t and R_t represent the variance– covariance matrices. Note that B_t and S_t are $k \times k$ dimensional matrices. U_t is a $k2 \times 1$ dimensional vector, and R_t is specified by a $k2 \times k2$ dimensional matrix.

The H-sim suitability analysis is performed by the scale of the Generalized Forecast Error Variance Decomposition (GFEVD) described by Diebold and Yilmaz (2014) by aggregating the forecast of the H-step. Under the method, it is easier to compute directional connectedness and net connectedness of asset returns which give information about the complex relationships between various markets. Its methodology uses an n-variable formulation that can be represented by $(\lambda_t = \lambda_{t,1} \dots \lambda_{t,n})$ where the nt is expressed by a multidimensional covariance-stationary Vector Autoregressive (VAR) of p. This process reflects the dynamic nature of the relationships between the variables with time, producing a solid depiction of how market shocks emanating in one market spread to others.

$$\lambda_t = \sum_{s=1}^p \vartheta_h \lambda_{t-s} + \varepsilon_t \quad 3$$

Within this model, Θ_h is an $n \times n$ p -order lag polynomial of order P and represents a set of white noise disturbances, having a non-diagonal error covariance. The error terms in this structure takes place so as to capture aspects of interdependence of variables which occur due to the fact that there is a correlation between variables. The Vector Autoregressive (VAR(p)) process is further extended in terms of representation of its moving average (MA). This is essential since it enables examining the time variant relations between the variables in terms of the new expressing them as the works of both current and previous actions. Particularly, a VAR (p) model is rearranged as a Vector Moving Average (VMA) process that is vital to estimating clusters of forecast error variances and measures of connectivity. The TVP-VAR approach is a modification of the classical VAR approach to allow a broader incorporation of the time variability of the dynamics of the system through time-varying coefficients. These coefficients are changing and take into account the variations in relations between variables. The TVP-VAR is then converted into the time-varying Vector Moving Average (TV-VMA) specification, that can be written as in Eq. (4).

$$Z_t = B_t Z_t + \varepsilon_t = \sum_{j=0}^{\infty} A_{jt} \varepsilon_{t-j} \quad 4$$

Given that A_{jt} denotes the square matrix of coefficients, the generalized forecast error variance decomposition (GFEVD) of the H -step forecast of the j -th asset return in response to shocks from the i -th asset return is expressed through the equation (often Eq. (5)) as follows:

$$\phi_{ij}^g(H) = \frac{\sigma_{jj}^{-1} \sum_{h=0}^{H-1} (e_i' A_{t+h} \Sigma e_j^2)}{\sum_{h=0}^{H-1} (e_i' A_{t+h} \Sigma e_j)} \quad 5$$

When $\phi_{ij}^g(H)$ is normalized, the spillover index can be represented as follows:

$$\Theta_{ij,t}^g(H) = \frac{\phi_{ij}^g(H)}{\sum_{j=1, i=1}^N \phi_{ij}^g(H)} \quad 6$$

Where e_j is a vector that has 1 on the place of the j th asset return, and $\sum_{j=1}^N \Theta_{ij}^g(H) = 1$ and $\sum_{i,j=1}^N \Theta_{ij}^g(H) = N \cdot \sigma_{jj}^{-1}$ represents The standard deviation of the error term serves as a key measure of variability in the model's residuals, capturing the extent of unexplained deviations in the system. From this framework, several connectivity metrics were derived to analyze the interrelations among variables: the Total Connectedness Index (TCI), "FROM" connectedness, "TO" connectedness, net directional connectedness, and net pairwise directional connectedness. These indices, calculated based on the connectivity measures outlined in Equations (7) and (11), respectively, provide a comprehensive view of how shocks propagate within the system:

Total connectedness index (TCI):

$$TCI_t^g(H) = \frac{\sum_{i,j=1, i \neq 1}^N \Theta_{ij,t}^g(H)}{\sum_{i,j=1}^N \Theta_{ij,t}^g(H)} = \frac{\sum_{i,j=1, i \neq 1}^N \Theta_{ij,t}^g(H)}{N} * 100 \quad 7$$

FROM AND TO connectedness Index

$$TD_{i-j}(H) = \frac{\sum_{i=1, i \neq 1}^N \Theta_{ji,t}^g(H)}{\sum_{j=1, i \neq j}^N \Theta_{ji,t}^g(H)} * 100 \quad 8$$

$$TD_{j-i}(H) = \frac{\sum_{i=1, i \neq 1}^N \Theta_{ij,t}^g(H)}{\sum_{i=1, i \neq j}^N \Theta_{ij,t}^g(H)} * 100 \quad 9$$

Net directional connectedness index (NDC):

$$CI_{i,t}^g(H) = TD_{i-j}(H) - TD_{i-j}(H) \quad 10$$

Net pairwise directional connectedness index

$$NPDC_{i,j}(H) = \left(\Theta_{ji,t}^g(H) - \Theta_{ij,t}^g(H) \right) * 100 \quad 11$$

Estimation process of the model involves the following steps that are mainly involved. The first one is the data preparation process whereby it deals with ensuring the right time series information is gathered, and the missing values are correctly handled in such a way that they can render the data complete and precise. The second procedure is model specification that implies the identification of the optimum lag order and appropriate variables that should be selected as factors and entered into the Time-Varying Parameter Vector Autoregressive (TVP-VAR) model. The third process called parameter estimation involves estimating the model time-varying coefficients, as well as error variances with either Bayesian or state-space approaches. Lastly, the connectedness analysis is performed by estimating measures of connectedness relying on the estimated parameters, and this enables a close investigation of time-varying correlations between variables, which form the subject of interest.

3.6.2 Portfolio Back-Testing

In order to assess the financial significance of our results, we conduct a historical back-testing of the chosen portfolio strategies. The exercise is based on the assumption that the investors have direct access to investable instruments that track the respective indices, are bond-oriented, and are willing to diversify internationally. Although these assumptions seem to be narrow, they are adequate to the illustrative nature of this study.

The back-testing framework encompasses the conventional portfolio construction techniques and more sophisticated approaches that employ connectedness-based knowledge. One of the main points of this analysis is to study the Optimal Hedging Strategy in a variety of asset classes including Energy, Gold, Technology, Green Bonds, and APEC Equity Markets. The aim is to reduce systemic risk, increase the effectiveness of hedging, and overall risk-adjusted returns by including dynamic connectedness measures in the portfolio design. Each strategy is only briefly summarized, with the focus on comparative performance and strategic implications.

3.6.2.1 Minimum Variance Portfolio

The Minimum Variance Portfolio (MVP) approach is a popular approach in portfolio construction, which was first proposed by Harry Markowitz (1959) in the Modern Portfolio Theory. The strategy is aimed at reducing the overall volatility of a portfolio by choosing asset weights that minimize total risk, not maximizing returns. The rationale is that by appropriate diversification by mixing assets that are not perfectly correlated- investors can build a portfolio that will have the minimum possible level of variance of a given set of assets. An optimal mathematical modeling technique is used to determine the best weights involved, given the covariance of the returns of the assets such that the overall risk of the portfolio is minimized. We calculate the weights with the following formula and they form the foundation of numerous risk-managed investment strategies that are common in the academic literature and the portfolios of professional asset management.

$$w_{Ht} = \frac{H_t^{-1}I}{IH_t^{-1}I} \quad 12$$

Here, w_{Ht} is an $m \times 1$ vector of portfolio weights at time t with m assets in the portfolio. The vector I is a column vector with elements equals to one and has dimension $m \times 1$; this makes the portfolio completely invested (i.e. the sum of the weights equals one). H_t is the $m \times m$ conditional covariance matrix of asset returns in time t reflecting the seventh component of dynamic connection as well as co-movements of the set of assets. This will be one of the most important matrices that will help the determination of the optimal weights that will reduce portfolio variance when using the Minimum Variance Portfolio(MVP) framework.

3.6.2.2 Minimum Correlation Portfolio

The more recent development on portfolio construction which was proposed by Christoffersen et al. (2014) is that portfolio weights are worked out using the conditional correlation matrix, instead of using the conditional covariance matrix. This approach stresses on the dynamic interconnectedness among asset returns as the aspect that puts into consideration the aspect of the time-varying correlations. Before proceeding to build up such a multivariate portfolio, it is important to define and describe the formation of these conditional correlations where they could be explained as follows.

$$R_t = \text{diag}(H_t)^{-0.5} H_t \text{diag}(H_t)^{-0.5} \quad 13$$

Where R_t is an $m \times m$ dimensional matrix with this the minimum correlation portfolio (MCP) weights are given by:

$$w_{Rt} = \frac{R_t^{-1}I}{I R_t^{-1}I} \quad 14$$

3.6.2.3 Minimum Connectedness Portfolio

Continuing the ideas about the strategies of the portfolios discussed above we create a Minimum Connectedness Portfolio (MCoP) where we use pairwise measure of connectedness, rather than variance or correlation matrices. This approach aims to reduce the overall interconnectedness among assets, thereby limiting spillover effects and enhancing the portfolio's resilience to systemic or network-related shocks. Within this context, the less an asset can impact others and vice versa; it will be given high portfolio weights. Development of this strategy can be described in the following way:

$$w_{Rt} = \frac{PCI_t^{-1}I}{I PCI_t^{-1}I} \quad 15$$

Where PCI_t is the pairwise connectedness index matrix and I is the identity matrix.

3.6.3 Hedging Effectiveness

We use two important performance metrics, i.e., the Sharpe Ratio and the Hedge Effectiveness Score, to measure how well the created portfolios are performing. The latter metrics give significant information regarding the risk mitigation and the prospect of returns of the portfolios. The Sharpe Ratio, pioneered by Sharpe (1966), is commonly known as a risk-adjusted standard measure of return. Also termed reward-to-risk or reward-to-volatility ratio, it measures the number of additional returns that an investor gets on costs of risk. The higher the Sharpe Ratio, the more favourable the balance of the ratio between the return and

the volatility translated to the statements that the portfolio would perform better. It is calculated by dividing the difference between the portfolio Return and the risk-free rate with the standard deviation of the portfolio:

$$SR = \frac{\bar{r}_p}{\sqrt{Var(r_p)}} \quad 16$$

Here, $\bar{r}_p$ represents the returns generated by the portfolio. A higher Sharpe Ratio signifies that the portfolio yields greater returns relative to the amount of risk undertaken.

$$HE = 1 - \frac{Var(y_p)}{Var\sqrt{yunhedge}} \quad 17$$

$Var(y_p)$ Denotes the variance of the portfolio returns, while $Var\sqrt{yunhedge}$ refers to the variance of the returns from the unhedged asset. The **Hedge Effectiveness (HE)** metric indicates the percentage reduction in risk achieved through hedging. A higher HE value reflects a greater reduction in portfolio risk, whereas a lower HE suggests limited risk mitigation.

3.6.4 Wavelet Theory

Although significant progress in wavelet theory was made in the early 1980s, the foundational ideas were already planted in the early 20th century by Alfred Haar. In 1909, Haar introduced an orthogonal function system defined on the interval $[0, 1]$ that forms a series converging uniformly to a continuous function. This system is considered the simplest form of a wavelet basis. The Haar basis starts with the function h such that:

$$h(x) = \begin{cases} 1 & \text{for } x \in [0, 1/2) \\ -1 & \text{for } x \in [1/2, 1) \\ 0 & \text{for otherwise} \end{cases}$$

The basic functions are then defined as:

$$h(x) = 2^{n/2} h(2^n x - k)$$

where $n = 2^j + k, j \geq 0, \text{ and } 0 \leq k < 2^j$. Including the function $h_0(x) = 1$ on the interval $[0,1]$, the sequence $h_0, h_1, h_3 \dots$ forms an orthonormal basis for $L^2[0,1]$. The wavelet transform is expressed as:

$$S_n(f)(x) = \langle f, h_n \rangle h_n(x) + \dots$$

where $\langle \cdot, \cdot \rangle$ is the ordinary inner product, and the series is an approximation of the continuous function $f(x)$ using step functions whose values represent the mean of $f(x)$ over specific intervals.

However, the Haar wavelet basis has some limitations. Its primary issue is a lack of coherence, as it attempts to approximate a continuous function using discontinuous functions. For example, it does not work well for estimating functions that are continuously differentiable. Faber and Schauder (1914) therefore indicated a better system with unbroken polygonal lines or triangles as they are referred to. They defined their basis functions $A_n(x)$ as:

$$A_n(x) = A(2^n x - k), n = 2^j + k, 0 \leq k < 2^j$$

$$(x) = \begin{cases} 2x & \text{for } 0 \leq x \leq 1/2 \\ 2(1-x) & \text{for } 1/2 \leq x \leq 1 \\ 0 & \text{otherwise} \end{cases}$$

This new approach was much more effective, allowing for a consistent approximation of continuous functions. The resulting sequence forms a Schauder basis for continuous functions on $[0,1]$, ensuring that functions can be expressed using these basis functions.

3.6.4.1 Wavelets in Finance

Applications in finance Wavelet methods have been widely employed in finance and especially in time series analysis. The subsection examines the usage of the wavelet theory in the field especially when it comes to the study of decomposition and interdependence of financial data.

3.6.4.2 Wavelet as a Decomposition Tool

The key advantage of the wavelet analysis is the fact that it breaks down time series into different components and therefore has an added advantage when applying it in financial research. Stock market indices and multiresolution analysis of financial time series were also studies recently using wavelets (Capobianchi 2004). These studies have brought out the efficacy of wavelets in demystifying hidden periodic aspects of economic data. Equally, Crowley and Lee (2005) employed wavelets into the frequency of European business cycles. Decomposing economic data into wavelet transforms, they discovered that there is a significant difference between European countries in the aspects of their growth cycles and

economic stability. Wavelets were also used by Gencay et al. (2003) to investigate the volatility of the foreign exchange market and showed how various scaling horizons result in volatility changes at the various time scales.

3.6.4.3 Wavelets in Interdependence Studies

Wavelets have been used in the analysis of interdependencies between economic and financial time series as well. The following is the updated overview of the studies that investigate the co-movements and dynamic interconnections between different markets through wavelet techniques. The works include the study of stock markets, cryptocurrencies, commodities, and economic indicators, examining various time-frequency ranges to determine the existing relationships, particularly in the crisis states, such as the COVID-19 pandemic or geopolitical tensions.

Chen and Jiang (2023) employed the wavelet analysis to examine the co-movement of the green energy stock markets and fossil energy markets in the US, Europe, and China. They detected strong lead-lag effects and two-way spillovers, with the US green stocks leading particularly in the short and long run. This paper highlights the susceptibility of green markets to extreme events in the world. Ahmed et al. (2022) investigated the co-movements of global equity, gold, and oil markets during the pandemic through the wavelet analysis. They found negative co-movements between stock and gold returns, and certain changes in risk in the initial months of the pandemic, which implies various dynamics of risk over time scales. ToguC et al. (2023) investigated the co-movement between earthquakes and financial markets in Turkey and revealed that the effects of the earthquakes on stock markets were time-varying, and the longer-term relationships were stronger during financial crisis periods such as the 2008 financial crisis. This paper assists investors to know the time aspects of such shocks.

Nepal et al. (2024) examined the co-movement of frequency between carbon emissions and currency exchange rates in the COVID-19 period. They had greater positive co-movements with CAD, AUD and GBP and JPY had an anti-phase relation. This observation is important in comprehending the role of environmental events in the currency markets. In Manzoor et al. (2025), wavelet coherence was applied to examine the co-movements between ESG-based equity indices in the US and India and global uncertainty indices. They discovered that ESG markets are more correlated with geopolitical and economic uncertainty during the times of crises, including the COVID-19 pandemic. Lohan and Katoch (2025) used wavelet analysis

to examine the connection between investor attention and stock market performance across 26 emerging economies. They identified large co-movements mainly on the medium to long-term basis, and the investor attention is an important factor in the long-term trends of stocks. Phiri et al. (2023) applied wavelet coherence to analyze the dynamic co-movement between the COVID-19 indicators (cases, deaths, recoveries) and stock returns in G20 countries. Their results indicated that there were mixed correlations that varied with the stage of the pandemic.

The wavelet analysis conducted by Abdullah et al. (2023) revealed that there were significant co-movements between commodity markets (Bitcoin, crude oil) and stock indices. Their study emphasizes the use of Bitcoin and crude oil as the lead indicators in the US and Chinese stock markets. Rafiuddin et al. (2023) employed wavelet coherence to examine the relationship between global equity indices and fintech markets. They found that there was a strong correlation between these markets, which indicates the increasing involvement of fintech in the wider financial system. Karamti and Belhassine (2022) investigated the interdependence between the COVID-19 pandemic and the main financial markets with the help of wavelet coherency. They discovered that markets were highly interconnected in the short run in the first and the second wave of the pandemic. Specifically, the fear in the US markets spread to the foreign markets, and thus gold, SSE, and cryptocurrencies became safer investments. Ali et al. (2022) studied the multiscale spillovers between the crude oil futures market and stock markets in the US, Canada, China, Russia and Venezuela. Their wavelet-based analysis revealed that in the initial stage of COVID-19 (March-May 2020), there were intense co-movements, particularly at high frequencies, and oil marketplaces were safe-haven assets during the crisis period. Urom et al. (2022) investigated the lead-lag connections between real economic activity and financial markets by means of wavelet analysis. Their analysis showed that there was co-movement between economic activity and the selected markets during normal periods but markets dominated economic activity during crises, like during the COVID-19 pandemic.

Jana et al. (2024) examined the co-movement of cryptocurrencies (Bitcoin, Ethereum, Binance Coin, and Ripple) and Nifty 50 index through wavelet analysis. They discovered that cryptocurrencies had hedging advantages to the Indian stock market in normal conditions but they failed to serve as safe havens during economic crises such as the COVID-19 pandemic. Yousfi and Bouzgarrou (2023) studied wavelet analysis of co-movements and contagion risk

among five developed stock markets. They noted that the co-movement risk and contagion risk were higher in the COVID-19 pandemic, especially in the short-term horizon, which implies that diversification and hedging strategies play a vital role during the crisis. Dash and Maitra (2022) examined how pandemic uncertainty influenced stock market volatility and illiquidity in G7 countries. Their wavelet analysis revealed that there was a high co-movement between pandemic uncertainty and market activities, and there was high volatility at the initial phases of the COVID-19 outbreak.

Maghyereh and Abdoh (2022) applied wavelet coherence to study the co-movement between oil price shocks and stock returns in GCC countries. The analysis revealed that extreme oil price shocks had important effects on the returns of the stock market, with different associations at different time horizons, which can be used in risk management practices in oil-based economies. Hung (2022) used wavelet analysis to investigate the dynamic connection between the Chinese stock market and macroeconomic fundamentals. This paper demonstrated that the stock returns have a positive impact on the macroeconomic variables in the long run, but macroeconomic variables affect the stock market returns in the short run. Agyei (2022) used wavelet analysis to examine co-movement between the stock markets of Ghana and Jamaica. The paper has identified low co-movement, particularly at levels beyond the annual level implying that there is little diversification advantage of portfolio management across these markets. Rijanto (2023) analyzed the co-movement between the tech stock index of Asia (China XA90, India NSEIT) and cryptocurrencies (Bitcoin and Ethereum). The analysis indicated that there were major shifts in co-movement patterns during the pandemic, where cryptocurrency markets recovered quicker than tech stocks.

Ramzan et al. (2024) applied wavelet-based approaches to investigate the co-movements between crude oil prices, political risk indices, and the Shanghai Stock Exchange. Their results indicate that political and economic influences are important drivers of Chinese stock market dynamics and can be used by international investors and policymakers. He et al. (2023) examined the causal connection between the returns of Turkish stock market (XU100) and foreign exchange rates (USD/TRY, EUR/TRY) through wavelet coherence. They found that there was a high volatility in critical economic crises (2000, 2001 and 2018) and that there were negative associations and one-way causality between stock market returns and exchange rates in some periods. Sayed and Charteris (2024) examined the wavelet coherence of BRICS stock markets co-movement and integration. They discovered that India and Russia markets were the most integrated whilst China and Brazil markets were more segmented.

Systemic co-movements were observed during crisis periods, which implies that the global factors are behind market integration.

Choi et al. (2024) discussed the short-term and long-term dependence between the natural gas, crude oil, and stock markets in energy producer and consumer nations applying the wavelet coherence. Their results pointed out the nonhomogeneous interdependence of these markets where oil is a long-term diversifier and natural gas is a hedge asset. Athari and Kirikkaleli (2025) examined the co-movement between the Climate Policy Uncertainty Index (CPU) and the Renewable Energy and Clean Technology Index (RECT) through the wavelet approach. They discovered that RECT led CPU in the period 2014-2018, but the causality relationship was reversed after 2019. Çıkıryel et al. (2022) examined the effects of Brexit on the Islamic stock market returns and co-movements through the wavelet analysis. It was discovered that post Brexit, the UK Islamic stock market correlations with other international markets were reduced, with Turkey recording the greatest volatility.

Maneejuk et al. (2022) applied wavelet coherence to examine the co-movement between different financial markets (stocks, commodities, gold, oil, cryptocurrency) pre and during COVID-19. They discovered that the oil-commodity pair exhibited the highest co-movement in all frequencies in both periods. Panazan and Gheorghe (2024) investigated the co-movements between the GPR indices concerning the Crimea annexation and the Russia-Ukraine war and G7 stock market volatility. Their wavelet analysis showed that there was a strong market reaction to both geopolitical crisis, but the financial market response was stronger in 2022. Zorgati et al. (2024) analyzed co-movements in the market during the subprime crisis with the help of wavelet methods. The analysis revealed pure contagion and financial interconnection whereby there were high short-term co-movements and low long-term co-movements in some markets.

Bossman et al. (2022) examined the co-movement of stock and government bond yields in the sub-Saharan African region through the wavelet analysis during the COVID-19 pandemic. They discovered that the stock-bond dynamics in the SSA markets were not homogenous and exhibited safe-haven advantages to short-term and medium-term investors. Radulescu et al. (2024) applied wavelet coherence to investigate the connection between COVID-19 cases, oil prices, and S&P 500 stock returns in the first months of the pandemic. Their results indicated a positive co-movement between the oil prices and stock market returns in the crisis period.

Wavelet analysis remains a powerful tool in the analysis of dynamic co-movements in the financial markets, providing more insights on how stock markets, commodities, cryptocurrencies, and economic indicators behave at various time frequencies. Such studies shed light on the dynamic nature of market interdependencies, particularly in times of crisis, such as the COVID-19 pandemic and geopolitical tensions, which can be helpful in portfolio management, diversification strategies, and policymaking.

3.6.4.4 Wavelet Coherence

Wavelet Coherence (WTC) does not use traditional linear regression-type econometric equations but relies on localized time-frequency correlation measures between two time series. However, for the purposes of clarity and academic presentation, we can denote the pairwise relationships in the following quasi-econometric representation used in wavelet analysis.

To analyze the co-movement between pairs of financial assets and equity indices, we employ the Continuous Wavelet Transform (CWT) followed by Wavelet Coherence (WTC). Wavelet Coherence quantifies the local correlation between two time series in the time-frequency domain.

$$R_{xy}^2(u, s) = \frac{|S(S^{-1}W_{xy(u,s)})|^2}{S(S^{-1}W_{x(u,s)})|^2 \cdot S(S^{-1}W_{y(u,s)})|^2} \quad 18$$

Where:

u is the time position,

s is the scale (related inversely to frequency),

$W_{x(u,s)}$ and $W_{y(u,s)}$ are the continuous wavelet transforms of x and y , respectively,

$W_{xy(u,s)} = W_{x(u,s)}$ is the cross-wavelet transform,

S is a smoothing operator in both time and scale.

This measure takes values in $[0,1]$, where 0 implies no correlation and 1 indicates perfect local correlation at a given time and frequency.

3.6.4.5 Partial Wavelet Coherence

While WTC captures the raw co-movement between two series, it may be confounded by the effect of a third common factor. To account for this, we employ Partial Wavelet Coherence

(PWC), which removes the influence of a third variable in this case, the S&P 500 index, representing global market trends.

The Partial Wavelet Coherence between two series $x(t)$ and $y(t)$, controlling for $z(t)$ is given by:

$$R_{xy|z}^2(u, s) = \frac{|R_{xy}(u, s) - R_{xz}(u, s) \cdot R_{yz}(u, s)|^2}{(1 - |R_{xz}(u, s)|^2)(1 - |R_{yz}(u, s)|^2)} \quad 19$$

Where

$R_{xy}(u, s)$, $R_{xz}(u, s)$ and $R_{yz}(u, s)$ are the wavelet coherence value of each pair.

$Z(t) = \text{S\&P 500}$

This analysis helps determine the true bilateral influence between assets, net of common market trends.

High Coherence (R^2 close to 1): Strong localized co-movement.

Low Coherence (R^2 close to 0): Independence or weak correlation.

Phase Arrows: Determine the direction of influence and lead-lag relationships.

PWC vs WTC: Helps isolate the net relationship between financial instruments by controlling for macro factors.

3.6.4.6 Wavelet Correlation

In this section, we examine a time series of returns, which are derived from the differences in the logarithmic values of a price series. This study employs the generalized autoregressive conditional heteroscedasticity (GARCH) model to compute the time-varying volatility series. Volatility in a time series refers to its conditional variance, which relies on past observations. The GARCH model is an effective tool to model this serial dependence of volatility over time. The model used in this study is represented as follows:

$$y_t = C + \epsilon_t \quad 1$$

$$\sigma_t^2 = A_1 + A_2 \sigma_t^2 + A_3 \epsilon_{t-1}^2 \quad 2$$

In the above equation, y_t represents the time series, and ϵ_t stands for the innovations or errors in the series.

σ_t^2 denotes the conditional variance of the innovations ϵ_t . The model implies that the volatility at any point in time is conditional upon the previous values of both the volatility

itself and the squared error term from the previous time period. This formulation is referred to as the GARCH (1,1) model, where the parameters A_1 , A_2 and A_3 are estimated using the available data.

3.6.4.7 Maximal Overlap Discrete Wavelet Transform (MODWT)

The Maximal Overlap Discrete Wavelet Transform (MODWT) is an advanced method for transforming time series data, proposed by Percival and Walden in 2000. The MODWT is similar to the Discrete Wavelet Transform (DWT) in that both utilize a combination of high-pass and low-pass filters to process the input signal at each level of transformation. However, the key difference between the two techniques lies in the treatment of the output signal: unlike the DWT, which subsamples (decimates) the data at each level, the MODWT avoids subsampling. Instead, the filters are up sampled at each level, which means that the signal retains its full length at every stage of transformation.

Consider a time series $s[n]$ of length N , where $N = 2^J$, with J being an integer. The first step in the MODWT is to apply two filters: a low-pass filter $h_1[n]$, and a high-pass filter $g_1[n]$, both of which are defined by an orthogonal wavelet. These filters are used to decompose the input signal $s[n]$ into two sets of coefficients: approximation coefficients $a_1[n]$ and detail coefficients $d_1[n]$.

$$a_1[n] = \sum_{m=0}^{N-1} h_1[m] \cdot s[n - m]$$

$$d_1[n] = \sum_{m=0}^{N-1} g_1[m] \cdot s[n - m]$$

Unlike the DWT, where the signal is reduced by half at each level, the MODWT produces outputs of the same length as the input series. Once these initial coefficients are obtained, the process continues at higher levels by filtering the approximation coefficients $a_1[n]$ with the same scheme, but using new filters $h_2[n]$ and $g_2[n]$, which are derived from the previous filters through a process called dyadic up sampling.

This procedure is repeated recursively across multiple levels. At each subsequent level j , the approximation coefficients $a_j[n]$ are convolved with a new set of low-pass and high-pass filters $h_{j+1}[n]$ and $g_{j+1}[n]$, resulting in new sets of coefficients $a_{j+1}[n]$ and $d_{j+1}[n]$.

$$a_{j+1}[n] = h_{j+1}[n] * a_j[n] = \sum_{\kappa} h_{j+1}[n - \kappa] a_j[\kappa]$$

$$d_{j+1}[n] = g_{j+1}[n] * a_j[n] = \sum_{\kappa} g_{j+1}[n - \kappa] a_j[\kappa]$$

The process continues recursively, with the filters being up sampled at each stage. These computations produce both the approximation and detail coefficients for each level, with the output consisting of a set of detail coefficients $d_1[n], d_2[n], \dots, d_j[n]$, and the final approximation coefficients $a_0[n]$ Wavelet Correlation Estimator

In this section, we introduce an estimator for wavelet correlation, which is constructed using the MODWT. This method, proposed by Percival (1995), Whitcher (1998), and Whitcher et al. (2000), is a natural extension of the wavelet covariance estimator. It involves a scale-by-scale decomposition of the signal and uses the coefficients obtained from the MODWT at each level to calculate the wavelet correlation.

The wavelet coefficients $d_j[n]$ indicate the changes in the time series at different scales. By applying the MODWT to a stochastic time series, we obtain a decomposition that captures variations at multiple scales. Wavelet variance is a method that replaces traditional sample variance by focusing on variability across different scales of the data (Percival & Walden, 2000). Similarly, wavelet covariance decomposes the sample covariance into components that are associated with different time scales. This approach allows us to examine the contribution of each scale to the overall covariance between two stochastic variables.

The wavelet covariance between two variables X and Y at scale $\lambda_j = 2^{j-1}$ is expressed as:

$$cov_{XY}(\lambda_j) = \frac{1}{N^{\sim}} \sum_{l=L_j-1}^{N-1} d_{l,j}^X d_{l,j}^Y$$

Where $d_{l,j}^X$ and $d_{l,j}^Y$ represent the MODWT wavelet coefficients for variables X and Y at scale λ_j . $N^{\sim} = N - L_j + 1$ is the number of coefficients unaffected by boundary effects, and L_j is the length of the wavelet filter for scale λ_j .

The wavelet covariance is biased to some extent due to its dependence on the magnitude of the variation within the time series. To address this, we introduce the concept of wavelet correlation.

Wavelet correlation is defined as the ratio of the wavelet covariance to the product of the wavelet variances for each of the variables. The MODWT estimator for wavelet correlation is expressed as:

$$\rho_{XX}(\lambda_j) = \frac{cov_{XY}(\lambda_j)}{\sqrt{V_X(\lambda_j) V_Y(\lambda_j)}}$$

Where $V_l(\lambda_j) = \frac{1}{N} \sum_{i=L_j-1}^{N-1} d_{i,j}^X d_{i,j}^Y$ is the wavelet variance of variable l at scale λ_j , and $l = X, Y$.

3.6.4.8. Confidence Intervals for Wavelet Correlation

To compute the confidence intervals for the wavelet correlation, we follow the methodology outlined by Whitcher et al. (1999, 2000). The random interval is given by:

$$\tanh^{-1}(h[\rho_{XY}(\lambda_j)]) - \frac{\Phi^{-1}(1-p)}{\sqrt{N_j-3}}, \tanh^{-1}(h[\rho_{XY}(\lambda_j)]) + \frac{\Phi^{-1}(1-p)}{\sqrt{N_j-3}}$$

This interval provides an approximate $100(1 - 2p)\%$ confidence level for true wavelet correlation. The function $h(p) = \tanh^{-1}(p)$ defines the Fisher's z-transformation, which is used to normalize the correlation (Van Aert, 2023; Shohoji et al., 1981). N_j is representing the number of wavelet coefficients associated with a particular scale and calculated using the DWT rather than the MODWT, since the DWT is known to effectively decorrelate the data over a wide range of power-law processes.

3.7 Model Assumptions and Limitations

While the empirical framework employed in this study is methodologically rigorous, it is essential to explicitly acknowledge the underlying assumptions and limitations of each model. This transparency is critical for interpreting the findings and situating them appropriately within the broader literature.

3.7.1 TVP-VAR Connectedness Framework

The TVP-VAR model (Antonakakis et al., 2020) assumes conditional linearity in the relationships among variables. While the time-varying coefficient structure relaxes the stationarity requirement of standard VAR models, the framework still assumes that the

underlying data-generating process can be adequately captured through linear autoregressive dynamics. In markets exhibiting extreme non-linearities or regime-switching behavior such as those observed during the 2020 COVID-19 crash this assumption may lead to an underestimation of tail-risk connectedness. The forgetting factor $\lambda = 0.99$ was selected to balance responsiveness to new information against parameter stability; robustness checks using $\lambda = 0.96$ and $\lambda = 0.98$ produced qualitatively consistent results. The choice of lag order ($p = 1$, selected via BIC) was validated against alternative lag specifications, which did not materially alter the connectedness rankings.

3.7.2 Wavelet Coherence Analysis

The Continuous Wavelet Transform (CWT) and Wavelet Coherence (WTC) framework is subject to edge effects, referred to as the cone of influence (COI). Near the beginning and end of the sample period (January 2015 and December 2024), wavelet estimates at longer scales are less reliable due to insufficient data in boundary regions. All interpretations in this study are therefore restricted to the interior of the COI. The Morlet wavelet was used as it provides an appropriate balance between time and frequency resolution for financial time series. The scale range of 2–256 trading days was selected to capture short-term (daily) through long-term (approximately one year) co-movement dynamics.

3.7.3 Portfolio Optimization Models (MVP, MCP, MCoP)

All three portfolio optimization frameworks rely on covariance and connectedness matrices estimated over a rolling 250-trading-day window. This window length was validated against a 500-day rolling window, which produced consistent portfolio weights and Sharpe Ratios. The estimation is inherently backward-looking and may not capture abrupt structural changes at crisis onset. Short-sale constraints are imposed throughout, which may restrict the full diversification potential in certain market regimes.

3.7.4 Data Limitations

Three primary data limitations are acknowledged. First, all APEC market indices are composite broad-market indices, which may mask intra-sector heterogeneity; firm-level data could reveal more granular spillover dynamics. Second, all returns are computed in USD, meaning currency risk is embedded in the returns of non-USD APEC markets such as

Vietnam (VND), Malaysia (MYR), and Peru (PEN); exchange-rate effects are not separately controlled. Third, the Green Bond Index (SPGRBND) and Clean Energy Index (SPGTCUP) have shorter historical back-data relative to traditional commodity indices, which may compress statistical power of pre-2017 estimates for these instruments.

Chapter 4

4 Result Analysis and Interpretation

The previous chapter offered a comprehensive overview of the overall research approach and design adopted for this study, outlining the rationale behind the chosen methodology and highlighting the various time series econometric tools employed to investigate the research objectives. These tools were carefully selected to ensure the robustness and reliability of the analysis, particularly in the context of dynamic financial markets. Building upon that foundation, the current chapter delves into the core of the study data analysis. Here, the findings emerging from the application of the selected econometric techniques are presented and interpreted in detail. This involves analysis of patterns, relationships and important trends that have been found in the data and a discussion on how these findings compare or contrast with the existing literature. The purpose is to give a clear and insightful interpretation of the empirical findings, which will pave the way to making meaningful conclusions in the next chapter.

4.1 Overview of Descriptive statistics

This section shows the descriptive statistics of the return series of the chosen variables, including clean energy, green bonds, technology, different commodities, and equity markets of APEC countries. The statistics are the mean, variance, skewness, kurtosis, the Jarque-Bera (JB) test of normality, the ERS (ADF) unit root test of stationarity, and the $Q^2(5)$ statistic of autocorrelation. The mean returns across most assets and indices are close to zero, indicating minimal average daily return, which is consistent with the characteristics of high-frequency financial data. Notably, the Technology sector and the U.S. market show slightly positive mean returns, while markets like the Philippines, Hong Kong, and Chile exhibit marginally negative means.

The variance, serving as a proxy for volatility, varies significantly across the series. Commodities such as natural gas (0.00117) and crude oil (0.00092) display higher volatility compared to financial instruments like green bonds (0.00001) and gold (0.00009). Among equity markets, Russia (0.00058) and Peru (0.00027) also show relatively higher variance, suggesting greater market instability. In terms of skewness, the majority of the return series are negatively skewed, implying a higher probability of extreme negative returns. For instance, crude oil (-2.75) and several equity markets such as Canada (-1.27) and Thailand (-1.17) exhibit strong negative skewness. However, South Korea is an exception with a slightly positive skewness, indicating occasional extreme positive returns. The kurtosis values for all

series significantly exceed the normal value of 3, highlighting the presence of heavy tails or leptokurtic distributions. Crude oil, with a kurtosis of 65.69, and Russia, with 180.44, show extreme peakiness and fat tails, which are common in markets exposed to geopolitical risks and global shocks.

Table 4.1: Summary Statistics

Variables	Mean	Variance	Skewness	Kurtosis	JB	ERS (ADF)	Q ² (5)
Clean Energy	-0.00007	0.00026	-0.24***	6.66***	4647.88***	-11.96***	48.46***
Green Bond	0.00000	0.00001	-0.11***	4.26***	1892.24***	-44.41***	43.95***
Technology	0.00043	0.00015	-0.58***	9.78***	10115.26***	-10.17***	20.15***
Natural Gas	0.00005	0.00117	-0.17***	2.38***	602.34***	-27.65***	18.53***
Crude Oil	0.00002	0.00092	-2.75***	65.69***	453158.46** *	-8.80***	53.09***
Gold	0.00041	0.00009	-0.14***	3.69***	1424.47***	-50.64***	5.56
Philippines	-0.00017	0.00014	-1.25***	14.80***	23497.07***	-26.63***	17.05***
Canada	0.00014	0.00014	-1.27***	23.51***	58304.61***	-11.49***	11.21**
Australia	0.00007	0.00016	-0.91***	8.49***	7869.67***	-13.97***	12.22**
Chile	-0.00015	0.00026	-0.75***	12.84***	17408.35***	-18.78***	22.84***
Singapore	0.00007	0.00010	-0.22***	6.97***	5081.75***	-13.79***	53.99***
Hong Kong	-0.00018	0.00013	-0.26***	4.39***	2033.74***	-47.91***	8.04
Taiwan	0.00033	0.00013	-0.59***	5.28***	3047.26***	-33.73***	8.66
Indonesia	-0.00006	0.00018	-0.23***	12.86***	17257.50***	-26.87***	26.49***
Thailand	-0.00004	0.00012	-1.17***	17.06***	30927.56***	-19.09***	32.10***
Russia	0.00022	0.00058	-1.17***	180.44***	3395984.25* **	-11.70***	498.19***
US	0.00042	0.00013	-0.81***	15.77***	26195.49***	-15.89***	71.16***
Japan	0.00025	0.00014	-0.63***	11.92***	14971.44***	-30.34***	9.28*
South Korea	0.00009	0.00014	0.08***	7.21***	5424.86***	-21.73***	6.98
Vietnam	0.00012	0.00015	-0.68***	3.90***	1778.35***	-32.81***	16.24***
Malaysia	-0.00011	0.00007	-0.24***	8.78***	8053.06***	-14.62***	46.93***
China	-0.00010	0.00017	-0.30***	4.07***	1768.01***	-10.13***	17.62***
Mexico	0.00001	0.00009	-0.48***	4.72***	2415.98***	-35.81***	7.17
New Zealand	0.00016	0.00013	-0.19***	5.11***	2739.46***	-14.31***	15.45***
Peru	0.00019	0.00027	-0.39***	8.24***	7137.49***	-14.06***	13.78**

Notes: ***, **, * denote significance at 1%, 5% and 10% significance level; Skewness: D'Agostino (1970) test; Kurtosis: Anscombe and Glynn (1983) test; JB: Jarque and Bera (1980) normality test; ERS: Elliott et al. (1996) unit-root test; Q2 (5): Fisher and Gallagher (2012) weighted portmanteau test.

Source: Author's Calculations

The Jarque-Bera (JB) test statistics are statistically significant at the 1% level for all series, confirming the rejection of the null hypothesis of normality. This non-normality justifies the use of advanced econometric models that do not assume normally distributed residuals. The ERS (ADF) test values are significantly negative across all series, indicating that the return series are stationary at level, a necessary precondition for many time series econometric models employed later in the analysis. Finally, the $Q^2(5)$ statistics are significant for most variables, indicating the presence of autocorrelation in the squared residuals. This is suggestive of conditional heteroskedasticity, which further supports the application of GARCH-type models to capture time-varying volatility in financial returns.

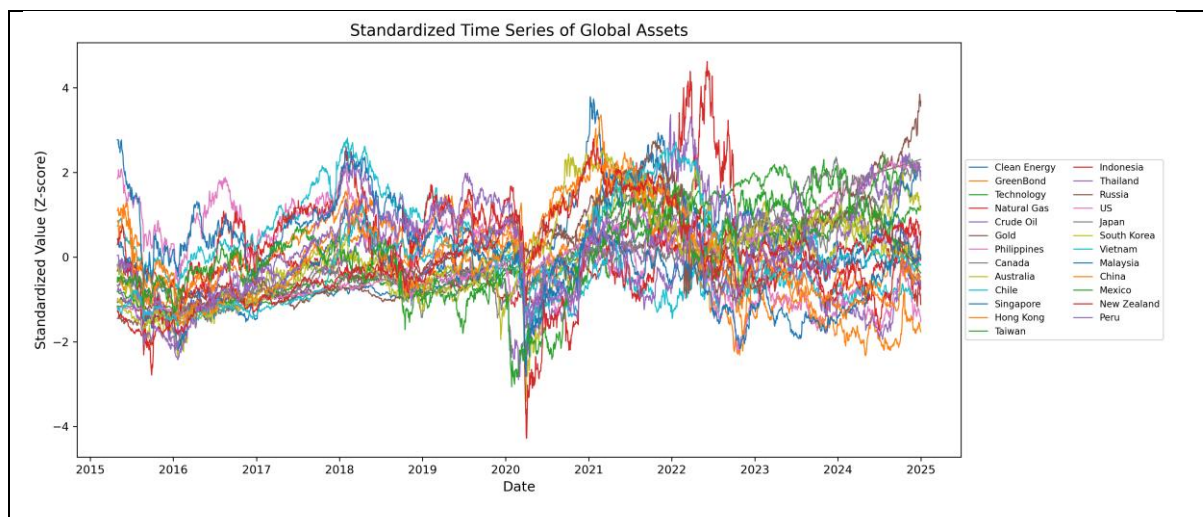


Fig. 4.1 Graphical Presentation of standardized time series data

Fig 4.1 presents the Z-score standardized values of a wide range of global financial assets from 2015 to 2024, including clean energy, green bonds, commodities, and equity indices from various countries. By standardizing each series (transforming them to have a mean of zero and a standard deviation of one), the graph allows for a meaningful comparison of the behavior and volatility of assets that would otherwise operate on different scales. One of the most striking features of the chart is the sharp spike in volatility observed around early 2020, corresponding to the outbreak of the COVID-19 pandemic. During this period, several assets exhibited extreme deviations from their historical average, with Z-scores exceeding ± 4 , indicating the severity of the market shock. Post-2020, the asset paths appear to diverge more noticeably, suggesting differentiated recovery patterns and varying market dynamics across

sectors and countries. While the earlier part of the period shows tighter clustering indicating more stable and correlated movements the post-pandemic era reflects increased dispersion, pointing to structural shifts and decoupling in some markets. Frequent crossovers among the lines also reflect the dynamic interrelationships and cyclical nature of global financial assets. Overall, the graph captures how global asset classes have evolved over the past decade, particularly emphasizing the disruptions caused by global events and the varied paths of stabilization that followed. Fig. 4.2 presents log returns of all the series.

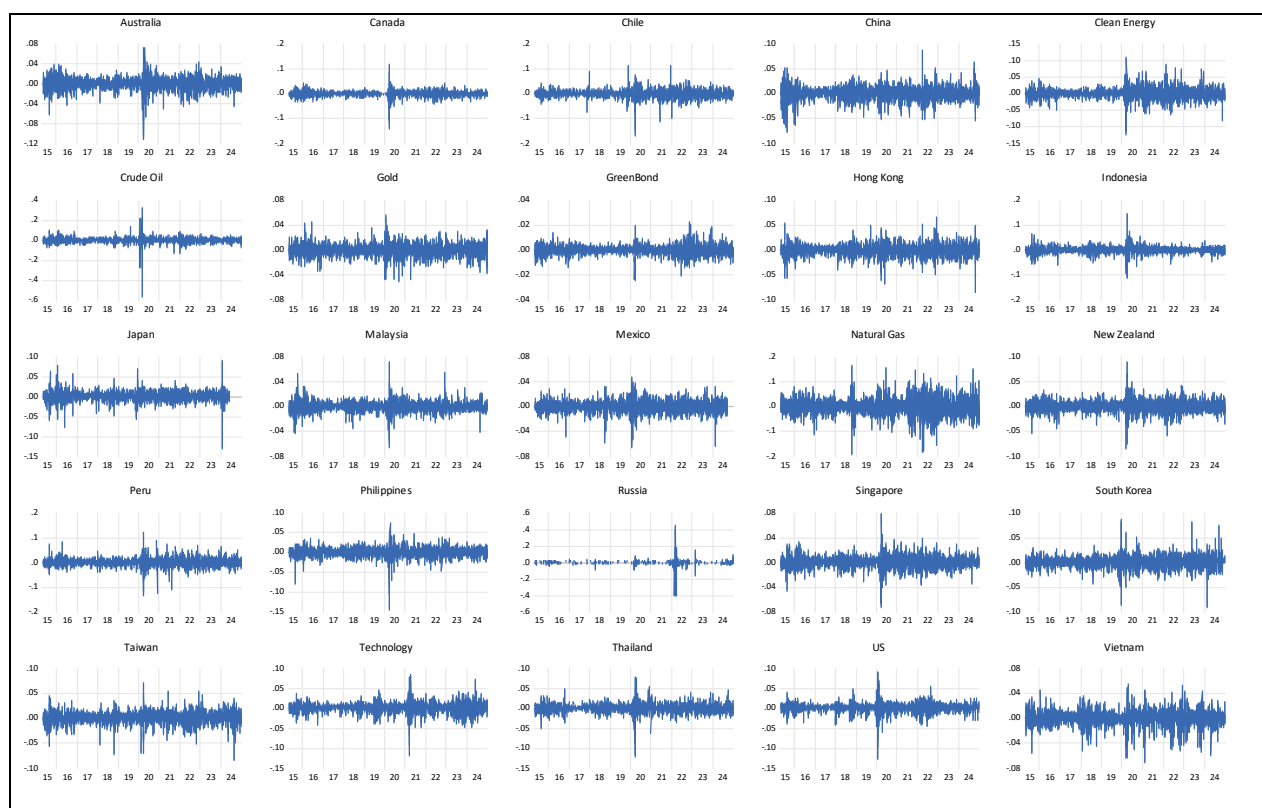


Fig. 4.2 Graphical Presentation of Log returns

The unconditional correlation matrix presented in Fig 4.3 reveals the interrelationships between clean energy, green bonds, traditional commodities (like crude oil and gold), technology, and the equity markets of various countries. Clean energy exhibits moderate positive correlations with Canada (0.132), Australia (0.097), and the Philippines (0.071), suggesting some alignment with these markets. It also has weak positive associations with crude oil (0.030) and gold (0.010), while maintaining nearly zero or slightly negative correlations with natural gas and technology, implying a distinct performance trajectory. Green bonds, however, show negligible or even weak negative correlations with most assets and markets, including technology (-0.031) and Australia (-0.011), reflecting their relatively independent risk-return profile. Technology itself has minimal correlation with most

variables, including a slight negative association with green bonds and crude oil, indicating it operates on different market dynamics. Among commodities, natural gas and crude oil are significantly correlated (0.106), and crude oil also correlates strongly with gold (0.105), affirming the interdependence within energy commodities. Notably, gold maintains weak or negative correlations with most markets, reinforcing its traditional role as a safe-haven asset.

Equity markets of developed economies, particularly Canada (0.587 with Australia), Australia (0.602 with Singapore), and Singapore (0.571 with Hong Kong), exhibit strong inter-correlations, implying regional economic integration or synchronized market behavior. Southeast Asian markets such as the Philippines, Indonesia, Thailand, and Malaysia also exhibit high intra-regional correlations (often above 0.4), highlighting their co-movements and potential spillover effects. Emerging markets like Russia, Vietnam, and Peru show weaker or inconsistent correlations with the broader group, suggesting more localized or idiosyncratic factors driving those markets. Additionally, countries like New Zealand and Peru show a notable connection with Australia and Canada, hinting at potential common exposures or trade relationships. In summary, the correlation matrix highlights that clean energy and green bonds exhibit distinct return characteristics compared to traditional markets, supporting their role in portfolio diversification. Meanwhile, regional equity markets, especially in Asia-Pacific, demonstrate strong interconnectedness, which is vital for assessing systemic risk and portfolio contagion.

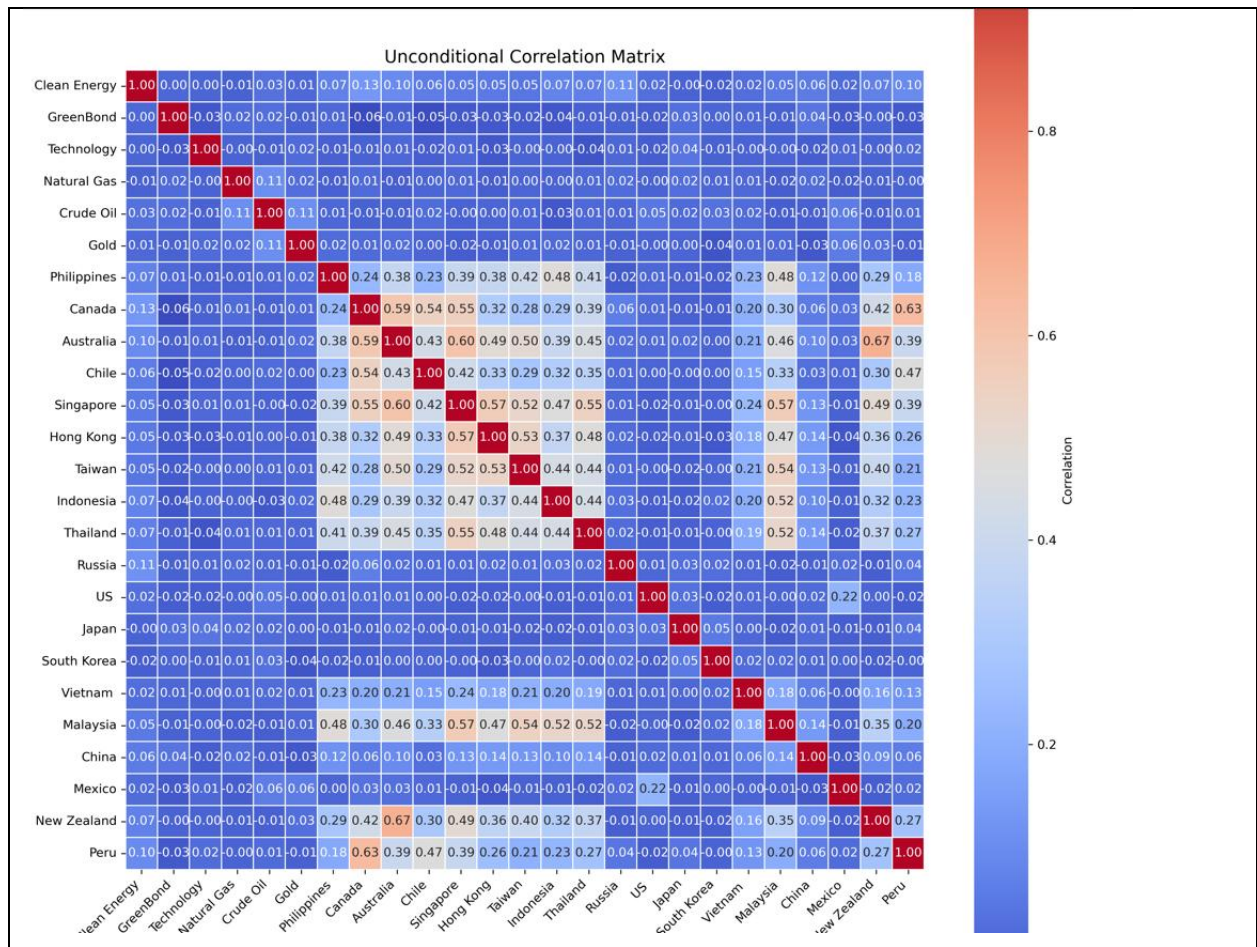


Fig. 4.3. Unconditional Correlations

4.2 Connectedness Analysis

In financial markets, different asset classes like crude oil, natural gas, clean energy stocks, gold, green bonds, and technology stocks don't move independently. Often, a shock in one market (say, a jump in oil prices) affects other markets or countries. The Diebold-Yilmaz connectedness model helps us measure these effects. It tells us who is *sending* volatility to others (called spillover transmitter) and who is *receiving* volatility from others (called spillover receiver). The TO value shows how much a market affects others, and FROM shows how much it is affected. The difference (called NET) tells us the overall impact. A positive NET means the market is spreading volatility (transmitter), and a negative NET means it is mostly receiving volatility (receiver).

4.2.1 Dynamic Connectedness

The Diebold-Yilmaz connectedness matrix paints a vivid, numbers-rich picture of how six global asset classes communicate risk to nineteen APEC equity markets (see Table 4.2., Fig. 4.4.). Overall integration is high: the Total Connectedness Index (TCI) stands at 68.29 %, and when own-series variances are stripped out the cross-market component (TCI) still measures 71.14 %, so more than two-thirds of the forecast-error variance circulating in the system originates outside each individual market.

At the top of the hierarchy sits crude-oil futures. With a TO value of 67.74 % and FROM of 53.82 %, oil posts a strongly positive NET spillover of 13.92 %, confirming it as the single largest transmitter of volatility. One can see the reach of oil shocks in the column figures: they account for 7.26 % of Russia's equity variance, 4.99 % of Vietnam's, and a full 3.30 % each for Malaysia and Mexico. Even net-importing Chile absorbs 3.18 % from oil price swings. Put simply, when Brent or WTI leap or crash, every market in the Pacific basin, producer and consumer alike, feels the tremor.

Natural-gas prices come next. Gas sends nearly as much risk as it takes back: TO 62.62 %, FROM 61.44 %, leaving a small positive NET of 1.18 %. Yet individual countries still register sizable gas footprints: Russia's variance picks up 3.31 % from gas, Vietnam's 2.98 %, China's 2.96 %, and Japan's 2.75 %. The numbers underline a two-way street: exporters transmit, importers absorb, and both sides stay tightly linked to LNG supply disruptions and seasonal demand shocks.

A clear shift is visible in clean-energy equities. Their row sum shows a healthy TO of 60.43 %, but the column total climbs slightly higher to FROM 61.20 %, leaving a marginally negative NET of -0.77 %. In other words, renewables now take in a little more global stress than they propagate. Still, the column reveals pockets of sensitivity: China's stock market variance owes 3.99 % to clean-energy moves, Russia's 3.30 %, and Mexico, Thailand, and Indonesia each register just above the 2.50 % mark. The takeaway is that the renewable-energy supply chain has become large enough to channel volatility but, at this stage of its growth, is no longer an outsized origin of shocks.

Green-bond indices play the opposite role. Their FROM value is a hefty 68.00 % while their TO is only 46.53 %, so the NET figure plunges to -21.47 %, making them the most defensive asset in the panel. Even the countries that feel green-bond reverberations—Russia at 2.59 %, Japan at 2.54 %, Malaysia at 2.19 %, China at 2.32 %, New Zealand at 2.20 %—show

single-digit impacts. Green bonds effectively absorb risk waves, cushioning portfolios when other markets gyrate.

Gold continues to function as a classic haven. Its NET position is -19.38% (TO 45.94, FROM 65.32), confirming that most turbulence flows into gold rather than out of it. Notable exposures appear in China (2.69%), Australia (2.37%), South Korea (2.21%), Vietnam (2.15%), and Thailand (2.09%), reflecting local jeweler demand, mining activity, or central-bank holdings. Yet no equity market's variance is driven by gold beyond three percent, reinforcing its role as a passive absorber rather than a shock engine.

By contrast, technology stocks are highly sensitive receivers. Their FROM score reaches 53.75%, comfortably topping their TO of 34.61%, so their NET reading is -19.14% . Country impacts line up with Asia's electronics corridor: China draws 2.23% of its variance from global tech moves, Australia 2.09%, South Korea 1.92%, Vietnam 1.63%, and Thailand 1.59%. These numbers warn investors that although tech adds growth potential, it also acts as a conduit for macro-financial stress triggered elsewhere, especially from the United States.

Turning from asset classes to equity markets, the FROM column identifies the most externally driven exchanges. Canada tops the list at 75.87%, followed closely by New Zealand (79.75%), Australia (82.67%), and Singapore (81.48%). These markets absorb four-fifths of their risk from outside factors, implying high vulnerability to global swings even if domestic fundamentals look sound. At the other end, South Korea's stock index shows the lowest FROM value (48.91%), suggesting a greater share of country-specific forces and, therefore, better insulation—though not immunity—against foreign shocks.

Pulling the strands together, the matrix reveals a clear pyramid of contagion. Commodity markets—oil first, gas a strong second—sit at the apex, radiating disturbances through energy-intensive supply chains. Equity sectors such as technology and clean energy mostly receive these disturbances, while gold and green bonds quietly dampen them. Russia, China, and Vietnam emerge as the largest country-level transmitters, each sending out more than 66% of the shocks they handle, whereas Japan, Thailand, and New Zealand work as net absorbers importing volatility from the global system without amplifying it.

The connectedness findings of the present study are broadly consistent with, yet extend, the existing empirical literature. The identification of crude oil as the dominant net transmitter (NET = +13.92%) corroborates Yousaf et al. (2024), who reported crude oil as the primary

volatility propagator across energy and equity markets during the 2022 Russia-Ukraine conflict, and Bouri et al. (2023), who found oil to be a systemic risk driver in GCC equity markets during geopolitical shocks. The TCI peak exceeding 80% during the 2024 Iran-Israel War is consistent with findings by Antonakakis et al. (2020), who documented similar extreme TCI levels during the COVID-19 crash in European markets. The near-neutral net spillover position of Clean Energy (NET = -0.77%) and Natural Gas (NET = $+1.18\%$) corroborates Attarzadeh and Balcilar (2022), who found that clean energy markets serve as stabilizers rather than transmitters of systemic risk in mixed energy-equity portfolios. The persistently negative net spillovers of Green Bonds (NET = -21.47%) and Gold (NET = -19.38%) extend the findings of Ren et al. (2023) and Seth and Singh (2025), who reported these assets as shock absorbers in ESG-oriented portfolios, confirming their defensive character in the APEC multi-crisis context examined here.

Table 4.2 Dynamic Connectedness

	Clean Energy	Green Bond	Technology	Natural Gas	Crude Oil	Gold	Philippines	Canada	Australia	Chile	Singapore	Hong Kong	Taiwan	Indonesia	Thailand	Russia	US	Japan	South Korea	Vietnam	Malaysia	China	Mexico	New Zealand	Peru	FROM
Clean Energy	38.8	1.96	1.33	2.92	2.25	2.18	1.88	2.48	3.16	2.5	4.25	2.67	3.19	4.14	3.53	3.08	1.34	1.11	0.69	2	3.89	4.09	1.09	3.02	2.45	61.2
Green Bond	2.85	32	1.79	3.31	3.35	2.45	2.14	1.85	3.16	2.24	4.8	3.39	3.61	4.59	3.58	2.77	1.5	1.52	0.92	2.76	5.24	3.57	1.04	3.43	2.13	68
Technology	2.92	1.86	46.25	3.1	2.32	1.78	2.51	2.18	3.09	1.45	2.23	1.82	2.21	2.69	2.25	1.99	1.37	0.89	1.35	2.08	2.22	4.81	1.04	2.44	3.13	53.75
Natural Gas	2.64	2.45	1.29	38.56	2.9	1.85	2.17	1.96	2.96	2.57	4.17	2.93	3.5	4.65	3.41	2.4	1.59	1.39	0.62	2.33	4.43	2.75	1.19	3.23	2.08	61.44
Crude Oil	2.1	2.86	1.54	3.85	46.18	2.03	1.68	1.46	2.45	1.78	3.1	2.15	2.9	3.41	2.21	2.69	1.97	1.26	1.17	2.02	3.62	2.01	1.28	2.43	1.88	53.82
Gold	3.04	2.61	1.43	3.01	3.3	34.7	2.27	2	3.98	2.88	3.78	2.45	2.85	3.8	4.1	2.49	0.9	1.27	1.37	3.8	3.47	3.44	1.1	3.65	2.33	65.32
Philippines	1.87	1.57	1.35	1.99	3.17	1.92	29.53	2.59	4.65	3.31	2.73	4.13	4.54	6.58	5.25	2.78	0.95	0.89	1.14	4.41	3.69	1.95	1.04	3.81	4.16	70.47
Canada	2.25	1.32	1.24	1.73	2.04	1.33	1.87	24.13	7.03	6.3	7.12	3.72	3.97	3.9	4.91	1.66	1.34	0.8	0.69	2.03	3.98	1.96	1.17	5.17	8.34	75.87
Australia	2.32	2.02	2.09	2.65	2.05	2.37	3.65	5.18	17.33	3.24	6.14	3.91	5.52	5.15	5.04	1.66	1.03	1.17	0.9	3.26	4.42	4.52	1.05	9.12	4.23	82.67
Chile	2.37	1.4	1.08	2.14	3.18	1.9	2.82	6.77	4.69	26.8	5.34	3.64	3.7	4.93	4.55	2.83	1.15	0.87	1.02	2.79	3.78	1.82	0.97	3.78	5.72	73.25
Singapore	2.38	1.96	1.18	2.38	2.4	1.64	1.97	5.4	6.41	3.6	18.52	6.27	6.67	5.68	5.9	1.6	1.25	0.95	0.69	2.13	8.11	3.01	1.04	5.56	3.29	81.48
Hong Kong	2.09	1.64	1.23	2.23	2.18	1.26	3.35	3.56	5.33	3.16	8.3	21.94	7.69	5.36	6.09	1.96	1.38	0.88	0.67	2.73	6.46	2.65	0.98	4.19	2.71	78.06
Taiwan	2.24	1.6	1.32	1.95	1.71	1.23	3.3	3.17	6.5	2.63	7.79	7.07	22.11	6.26	5.53	1.46	1.26	0.9	0.64	2.06	7.93	2.57	1.08	5.17	2.52	77.89
Indonesia	2.55	1.87	1.05	2.65	2.13	1.94	4.43	2.87	5.65	3.94	6.71	4.72	6.22	22.32	5.63	1.72	1.38	1.07	0.6	2.46	7.25	2.46	1.09	4.7	2.6	77.68

Thailand	2.57	1.69	1.59	2.37	2.4	2.09	3.68	4.07	5.55	3.96	6.63	5.48	5.39	5.48	19.18	2.22	1.41	0.97	0.84	3.17	5.97	2.29	1.35	5.91	3.75	80.82
Russia	3.3	2.59	1.34	3.31	7.26	1.88	2.9	2.33	2.54	2.36	2.87	1.91	2.37	3.45	2.83	33.87	1.7	1.35	1.23	3.18	3.82	3.56	1.91	2.46	3.68	66.13
US	2.47	1.47	1.25	2.51	2.29	1.93	2.11	2.15	2.71	2.09	2.92	2.37	2.59	3.81	3.06	2.12	41.9	0.93	1.16	2.11	3.23	3.01	4.13	2.92	2.78	58.12
Japan	2.27	2.54	1.43	2.75	2.33	1.89	1.52	1.72	2.78	2.04	3.09	2.18	2.72	3.07	2.98	2	1.55	47.38	0.76	2.14	2.85	2.38	1.18	2.62	1.83	52.62
South Korea	2.44	1.61	1.92	2.07	2.31	2.21	1.6	1.63	2.43	1.59	2.58	1.97	2.18	2.25	2.23	1.76	1.4	0.94	51.09	2.65	2.51	3.39	1.05	2.45	1.72	48.91
Vietnam	2.3	1.97	1.63	2.98	4.99	2.15	4.1	2.29	3.14	2.51	3.44	3.02	3.41	4.22	3.81	3.39	1.32	0.87	1.29	33.65	3.38	3.2	1.23	3.12	2.58	66.35
Malaysia	2.49	2.19	1.35	2.54	3.3	1.61	2.53	2.87	4.57	2.56	8.62	5.37	7	6.56	5.79	2.42	1.69	1.02	1.03	2.6	21.01	3.28	1.34	3.95	2.32	78.99
China	3.99	2.32	2.23	2.96	2.75	2.69	2.81	2.04	3.86	1.95	4.8	2.85	3.34	4.18	3.04	3.2	2.11	1.04	1.98	4.98	4.86	28.65	1.81	3.06	2.51	71.35
Mexico	2.77	1.42	0.95	2.3	3.3	2.06	1.97	2.48	2.1	2	1.87	1.56	1.88	2.75	2.88	3.29	4.5	0.96	0.98	2.05	1.84	1.91	46.86	2.44	2.88	53.14
New Zealand	2.24	2.2	1.53	2.48	2.08	2.02	2.77	4.31	10.8	3.19	6.53	3.71	5.37	4.99	6.15	1.86	1.33	1	0.77	2.78	4.63	2.58	1.06	20.25	3.37	79.75
Peru	1.97	1.43	1.46	2.44	1.75	1.53	2.51	9.89	5.41	6.06	4.82	2.98	3.11	3.71	4.76	1.73	1.39	0.88	0.71	1.77	3.05	1.64	1.07	4.21	29.7	70.29
TO	60.43	46.53	34.61	62.62	67.74	45.9	62.55	77.27	104.94	69.9	114.64	82.26	95.92	105.61	99.5	55.08	36.8	24.92	23.24	64.28	104.63	68.86	31.28	92.85	75	1707.36
Inc.Own	99.23	78.53	80.86	101.18	113.92	80.6	92.09	101.4	122.27	96.7	133.16	104.21	118.03	127.94	118.68	88.94	78.7	72.3	74.33	97.93	125.63	97.52	78.14	113.11	105	cTCI/TCI
NET	-0.77	-21.47	-19.14	1.18	13.92	-19.4	-7.91	1.4	22.27	-3.35	33.16	4.21	18.03	27.94	18.68	-11.06	-21.3	-27.7	-25.67	-2.07	25.63	-2.48	-21.86	13.11	4.67	71.14/68.29

Table 4.3 Investor Takeaways from Connectedness:

Asset Role /	TO %	FROM %	NET %	Strongest country (variance share %)	impacts	Investor takeaway
Crude Oil	67.74	53.82	+13.92	Russia 7.26, Vietnam 4.99, Malaysia 3.30		Track oil futures; hedge in energy-heavy portfolios
Natural Gas	62.62	61.44	+1.18	Russia 3.31, China 2.96, Japan 2.75		Watch LNG supply gaps; balance exporter/importer exposure
Clean Energy	60.43	61.20	−0.77	China 3.99, Russia 3.30, Mexico 2.77		Sector is stabilizing; still responds to policy shifts
Green Bonds	46.53	68.00	−21.47	Russia 2.59, Japan 2.54, Malaysia 2.19		Low-risk diversifier; anchor long-term ESG allocations
Gold	45.94	65.32	−19.38	China 2.69, Australia 2.37, Korea 2.21		Maintains safe-haven status; moderates tail risk
Technology	34.61	53.75	−19.14	China 2.23, Australia 2.09, Korea 1.92		High beta to global cycles; monitor during rate hikes

For investors, three practical messages follow (see Table 4.3.). First, oil retains unrivalled power over APEC equities; energy derivatives or producer-importer pair trades remain vital risk-management tools. Second, combining gold and green bonds can materially dampen portfolio volatility because both assets exhibit large negative NET spillovers. Third, country selection is as crucial as asset selection: markets such as Hong Kong, Peru, and Singapore—with FROM scores below the high-70s—offer useful refuges when commodity or technology turbulence erupts elsewhere.

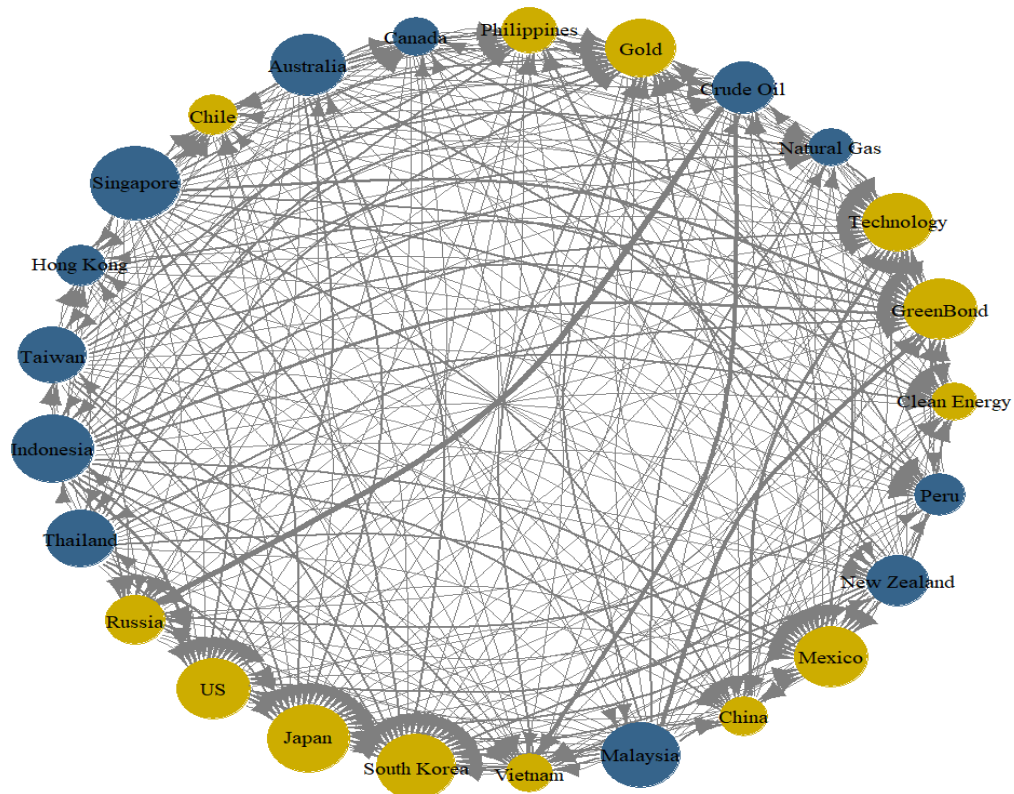


Fig. 4.4 Network of Connectedness

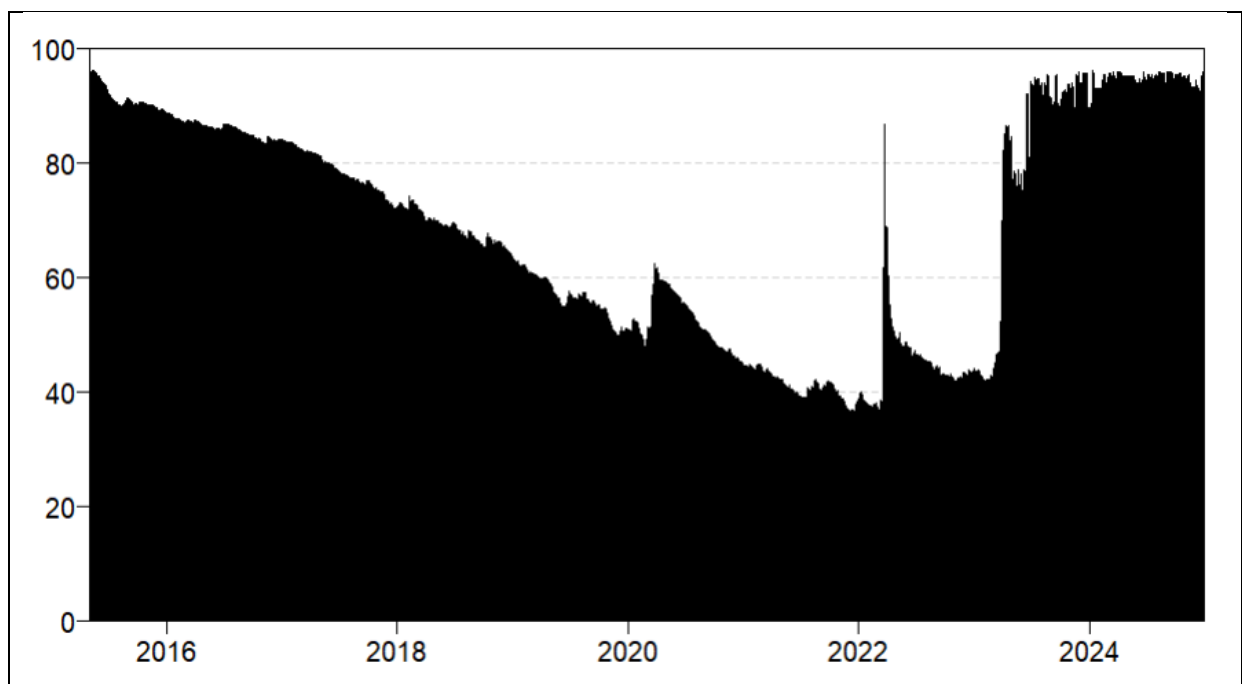


Fig. 4.5: Dynamic Total Connectedness: Results are based on a TVP-VAR (0.99,0.99) model with lag length of order 1 (BIC) and a 20-step-ahead forecast.

4.2.2 Dynamic Total Connectedness

Within the framework of our analysis, large values of the Total Connectedness Index (TCI) signal strong co-movements across the network. These co-movements often reflect increased similarity in perceived risk across asset classes and heightened market synchronization. As depicted in Figure 4.5, that illustrates the Total Connectedness Index (TCI) from 2016 to 2024, reflecting the level of risk spillover across financial markets, likely tied to the Diebold-Yilmaz connectedness matrix you referenced. The TCI begins near 100% in 2016, gradually declines with fluctuations through 2022, and then surges sharply from 2023 to 2024, exceeding 80%. This trend can be analyzed in the context of major events you listed—Oil Crisis(2015-16), Climate Crisis, COVID-19, Russia-Ukraine War, and Iran-Israel War—and their implications for a diversified APEC portfolio including clean energy, green bonds, technology, natural gas, crude oil, gold, and equity markets such as Philippines, Canada, Australia, and others.

From 2016 to 2017, following the (2015-16) Oil Crisis and the onset of climate crisis awareness, the TCI starts high and begins to decline. The stabilization of oil prices post-crisis reduced volatility, lowering interconnectedness, while early shifts toward renewables may have diminished traditional energy dominance. This period's high initial TCI highlights crude oil's strong risk transmission (NET +13.92%), suggesting the need to diversify away from oil-dependent markets like Russia and Malaysia. As the climate crisis intensified from 2018 to 2019, the TCI continued its downward trend to 60-40%, reflecting the stabilizing influence of clean energy (NET -0.77%) and green bonds (NET -21.47%), which absorb rather than transmit shocks, favouring allocations in markets like China and Japan.

The COVID-19 pandemic in 2020-2021 saw the TCI dip to a low of 40%, as global lockdowns disrupted supply chains, but monetary stimulus and safe-haven demand for gold (NET -19.38%) helped dampen volatility spillovers. This period underscored the importance of gold and green bonds as stabilizers, while technology (NET -19.14%) faced increased risk, warranting caution in tech-heavy markets like South Korea and China. The Russia-Ukraine War in 2022-2023 kept the TCI low with a slight uptick, as energy price spikes (crude oil NET +13.92%, natural gas NET +1.18%) boosted connectedness, particularly for exporters like Russia and Vietnam. Diversification into gold and green bonds mitigated risks, while reducing exposure to volatile commodities was advisable.

The sharp TCI rise in 2024, linked to the Iran-Israel War, pushed the index above 80%, indicating heightened systemic risk as geopolitical tensions amplified spillovers from crude

oil and natural gas. This affected high-FROM markets like Australia (82.67%) and Singapore (81.48%), necessitating stronger hedges with gold and green bonds, and a focus on resilient markets like South Korea (FROM 48.91%). For portfolio diversification, allocate 40-50% to defensive assets—25-30% to green bonds for stability in Japan and Russia, and 15-20% to gold for hedging in China and Australia. Growth assets (30-40%) should include 15-20% in clean energy (China, Mexico) and 10-15% in technology (South Korea, Taiwan), with caution during high-TCI phases. Limit commodity exposure (10-15%) to 5-7% in natural gas (Russia, China) and 3-5% in crude oil (Russia, Vietnam), and select low-FROM equity markets (10-20%) like South Korea and Peru to enhance resilience, adjusting dynamically with TCI fluctuations.

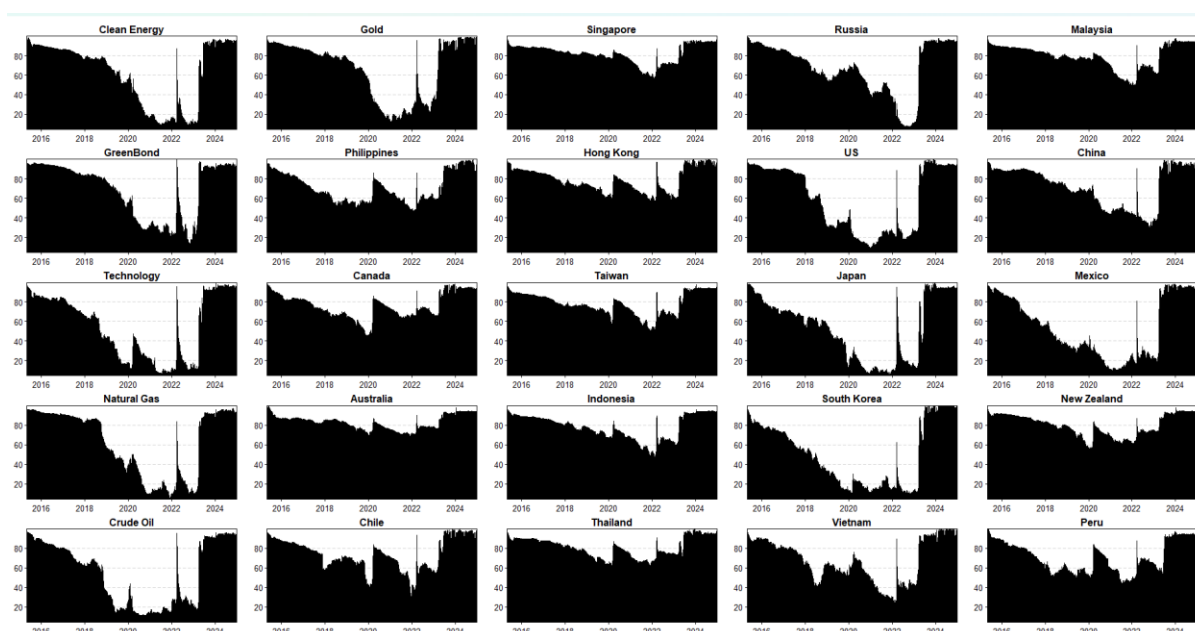


Fig. 4.6 FROM Spillover, (2016-2024)

Fig. 4.6 displays the FROM spillover plots for various asset classes (Clean Energy, Gold, Green Bond, Technology, Natural Gas, Crude Oil) and equity markets (Singapore, Russia, Malaysia, Philippines, Hong Kong, US, China, Canada, Taiwan, Japan, Mexico, Australia, Indonesia, South Korea, New Zealand, Chile, Thailand, Vietnam, Peru) from 2016 to 2024. These plots indicate the proportion of variance in each asset or market that originates from external sources, reflecting their sensitivity to global risk spillovers. Across the board, the FROM values show a general decline from 2016, with notable spikes around 2020 (COVID-19) and 2024 (Iran-Israel War), aligning with the TCI trend. For instance, Crude Oil and Natural Gas exhibit significant spikes, reflecting their role as risk receivers during energy

price shocks, particularly impacting Russia (7.26% from oil) and Vietnam (4.99%). Defensive assets like Green Bond and Gold show lower and more stable FROM values, consistent with their NET -21.47% and -19.38% spillovers, indicating resilience. Equity markets like Australia (82.67%) and Singapore (81.48%) display high and volatile FROM spillovers, underscoring their vulnerability to external shocks, while South Korea (48.91%) remains relatively insulated. This suggests that during high-TCI periods (e.g., 2024), portfolios should reduce exposure to high-FROM markets and emphasize defensive assets.

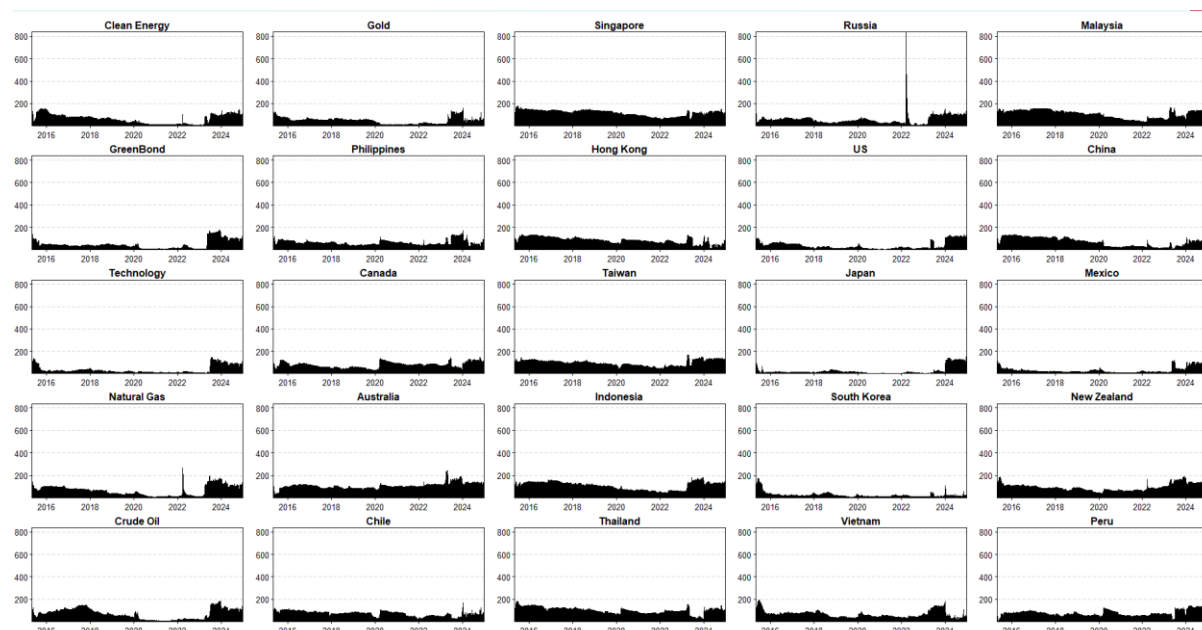


Fig. 4.7 TO Spillover, (2016-2024)

The fig.4.7 shows the TO spillover plots, representing the extent to which each asset class and equity market transmits risk to others over the same period. Unlike the FROM plots, the y-axis here likely indicates the magnitude of outgoing spillovers (e.g., in percentage terms), though the scale appears inconsistent with the first Fig, possibly due to a different unit or normalization. Crude Oil stands out with significant TO spikes, reflecting its NET +13.92% transmission (e.g., 7.26% to Russia), peaking during the 2022 Russia-Ukraine War and 2024 Iran-Israel War. Natural Gas also shows notable TO activity (NET +1.18%), affecting China (2.96%) and Japan (2.75%). Clean Energy (NET -0.77%) and Technology (NET -19.14%) have lower TO values, indicating they transmit less risk, with peaks tied to policy shifts or tech cycles. Among equity markets, Russia and China emerge as key transmitters, consistent with their high TO percentages (>66%), while Japan and Thailand act as net absorbers. The 2024 surge suggests increasing risk transmission, implying that investors should monitor oil and gas exposures and favor markets with lower TO spillovers, such as Japan, during volatile periods.

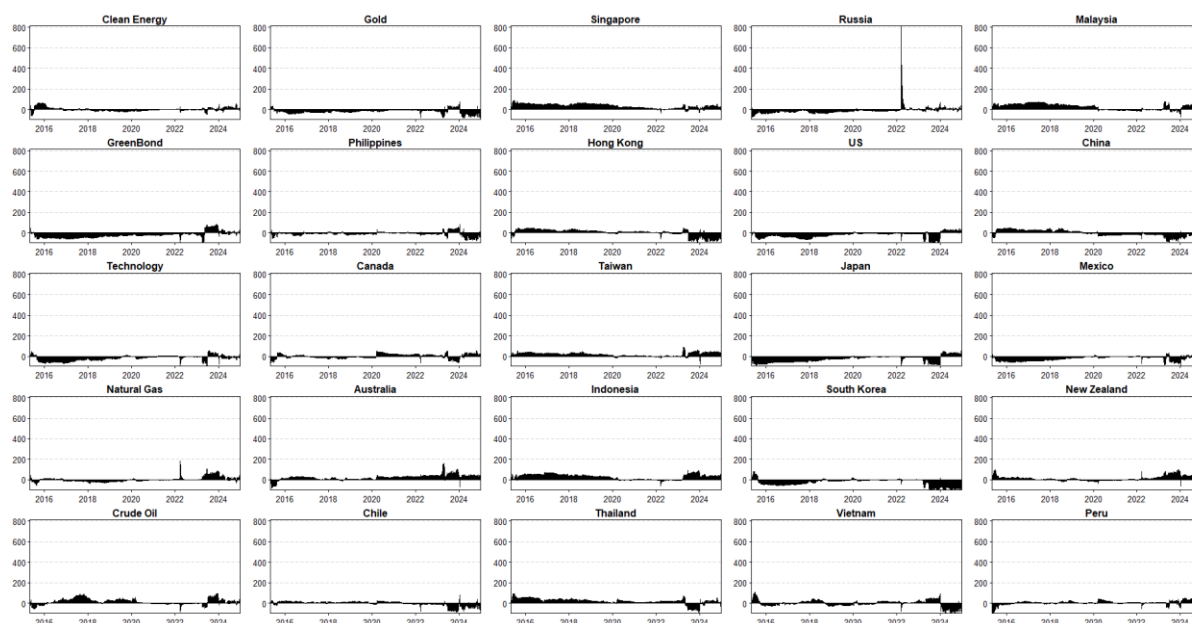


Fig. 4.8 NET Spillover, (2016-2024)

Fig.4.8. presents the NET spillover plots, calculated as TO minus FROM, highlighting each asset or market's net contribution to or absorption of risk. Positive NET values indicate net transmitters (e.g., Crude Oil at +13.92%, Natural Gas at +1.18%), with prominent spikes in 2022 and 2024, aligning with energy crises and geopolitical tensions. Crude Oil's dominance is evident, transmitting risk to markets like Russia and Vietnam, while Natural Gas shows a balanced role with minor net transmission. Negative NET values reflect net absorbers, with Green Bond (-21.47%) and Gold (-19.38%) showing consistent stability, reinforcing their role as portfolio stabilizers during high-TCI phases (e.g., 2024). Technology (-19.14%) and Clean Energy (-0.77%) also absorb risk, with Technology's vulnerability peaking in 2020 due to global tech disruptions. Among equities, Russia and China are net transmitters, while Japan and New Zealand absorb risk, consistent with them FROM and TO dynamics. This underscores a diversification strategy favoring Green Bond and Gold, limiting exposure to Crude Oil and Natural Gas, and balancing growth assets like Clean Energy and Technology with resilient markets like South Korea, especially as NET spillovers fluctuate with global events.

Table 4.3.1: Consolidated Summary of Key Empirical Findings

Objective	Key Finding	Supporting Statistic	Implication
Objective 1:	Crude oil is dominant net	NET = +13.92%; TCI peak	Strengthen

Connectedness	transmitter across all 19 APEC markets	>80% during Iran-Israel War 2024	petroleum reserve buffers; monitor oil prices as crisis early-warning
Objective 1: Connectedness	Green bonds and gold are persistent net receivers of shocks	Green Bonds NET = -21.47%; Gold NET = -19.38%	Core holdings in defensive portfolios; expand sovereign green bond issuance
Objective 1: Connectedness	Clean Energy and Natural Gas are near-neutral transmitters	Clean Energy NET = -0.77%; Natural Gas NET = +1.18%	Stable diversifiers; suitable for ESG-aligned APEC portfolios
Objective 2: Hedging	MVP with 42% Green Bond allocation achieves highest risk-adjusted return	Sharpe = 0.0306; HE (Green Bond) = 0.59	Allocate 30–42% to green bonds in variance-minimizing portfolios
Objective 2: Hedging	Clean Energy has very low weight but highest hedge effectiveness	Weight = 0.02%; HE = 0.98	Even small clean energy allocations significantly

			reduce portfolio risk
Objective 3: Wavelet	Clean Energy leads 14 of 19 APEC equity markets at medium-long horizons	Coherence scales 32–256 (approx. 1.5–12 months)	Use clean energy ETFs as portfolio rotation signals esp. Australia, China, Vietnam
Objective 3: Wavelet	Gold acts as leading indicator during COVID-19 and war periods	Short-medium term leadership in 17/19 APEC markets	Increase gold allocation dynamically during geopolitical crises

Source: Author's calculations

4.3 Portfolios

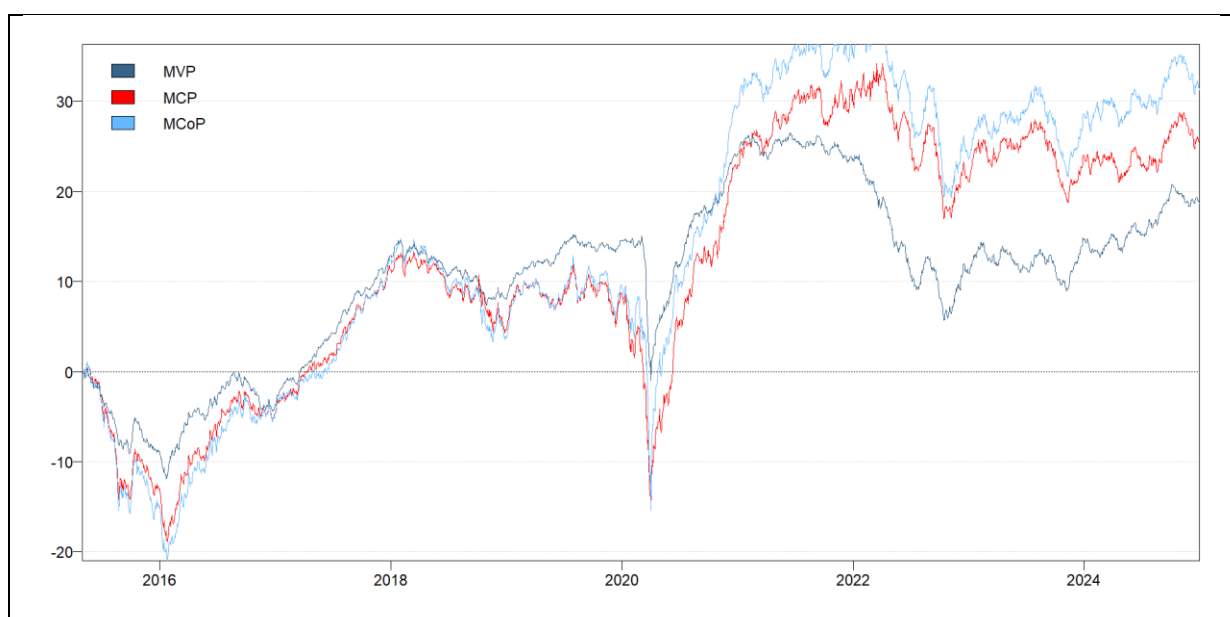
In this section, we present the investment portfolios developed using three distinct optimization approaches as detailed in Methodology Chapter 4. These are: (i) the Minimum Variance Portfolio (MVP), which aims to minimize the total risk of a portfolio by computing the asset weights that result in the lowest possible variance; (ii) the Minimum Correlation Portfolio (MCP), which focuses on minimizing the average correlation between portfolio elements to maximize the diversification effect; and (iii) the Minimum Connectedness Portfolio (MCoP), a more recent strategy that aims to minimize the interconnectedness of assets to reduce the risk of contagion during market stress. To compare and assess the performance of each portfolio strategy, we use two main performance measures. The first is the Sharpe Ratio, which measures risk-adjusted returns by dividing excess returns by portfolio volatility, with a higher ratio indicating a more efficient portfolio with better returns

at a given level of risk. The second measure is Hedge Effectiveness (HE) that quantifies the reduction in variance of the hedged portfolio relative to the un-hedged portfolio, which is a measure of the potential to reduce downside risk, particularly in times of high market volatility. Looking at the Sharpe Ratios and the HE scores, we can conclude which of the three portfolio construction techniques provides the best performance and stability under different market conditions.

Dynamic variance-covariance matrices based on a one-lag TVP-VAR model are used to compute portfolio weights. The figure contrasts the three optimization methods Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP) and shows their flexibility to changing market conditions.

Dynamic variance-covariance matrices are estimated using a TVP-VAR model with one lag to obtain weights. The figure contrasts three portfolio optimization strategies: Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP), which are sensitive to the changing market conditions.

The good performance of the MCoP highlights the strategic advantage of considering interconnectedness, as captured by systemic spillovers, overusing only variance or correlation measures. MCoP is more prepared to deal with the increased volatility and structural market changes by lessening the effects of systemic connections between assets. This is especially true in its strong recovery after 2020 and continued positive trend, which implies that exposure to network-based contagion effects can be reduced to achieve better risk-adjusted returns.



Dynamic variance-covariance matrices are estimated using a TVP-VAR model with one lag to obtain weights. The figure contrasts three portfolio optimization strategies: Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP) in terms of their sensitivity to changing market conditions.

Figure 4.8: Time-Varying Portfolio Weights of TVP-VAR (0.99, 0.99) with MVP, MCP, and MCoP Strategies

The performance of the three portfolios is illustrated in figure 4.9, which shows that the overall trend of the three portfolios is quite similar. All portfolios show a minor decrease in the period around 2016 and then a stable increase until the middle of 2020. Following a short pause, growth continues until the middle of 2023, and then declines again. This coordinated action implies that, regardless of the various construction approaches, all portfolios react in a similar way to the existing market conditions. Of the three, the MCoP is always better than MVP and MCP, particularly after the COVID-19 market crash in early 2020. It shows a rapid recovery and maintains an upward trend during the next market stress and recovery periods. On the other hand, the MVP shows the worst performance over the period, which means that the sole focus on reducing variance is not sufficient in highly dynamic and interconnected markets. The MCP offers moderate performance, which is better than MVP because it considers pairwise correlation structures, but it is not as good as MCoP.

The good performance of the MCoP highlights the strategic advantage of focusing on interconnectedness, as captured by systemic spillovers, instead of focusing on variance or correlation measures. MCoP is also more prepared to deal with the increased volatility and structural market shifts by minimizing the effects of systemic connections between assets. This is especially true in its strong recovery after 2020 and continued positive trend, which indicates that exposure to network-based contagion effects can be reduced to achieve better risk-adjusted returns.

Table 4.4 Dynamic Multivariate Portfolio Weights: Results are based on the time-varying variance-covariance retrieved from the TVP-VAR (0.99,0.99) with one lag.

Minimum Variance Portfolio						
	Mean	Std.Dev.	5%	95%	HE	p-value
Clean Energy	0.02	0.01	0.00	0.04	0.98	0.00
Green Bond	0.42	0.12	0.22	0.59	0.59	0.00
Technology	0.05	0.02	0.01	0.08	0.96	0.00
Natural Gas	0.00	0.00	0.00	0.01	1.00	0.00
Crude Oil	0.00	0.00	0.00	0.01	0.99	0.00

Gold	0.05	0.02	0.01	0.08	0.93	0.00
Philippines	0.01	0.01	0.00	0.04	0.96	0.00
Canada	0.04	0.02	0.00	0.08	0.96	0.00
Australia	0.00	0.00	0.00	0.01	0.96	0.00
Chile	0.01	0.01	0.00	0.02	0.98	0.00
Singapore	0.01	0.02	0.00	0.05	0.94	0.00
Hong Kong	0.02	0.02	0.00	0.05	0.96	0.00
Taiwan	0.01	0.02	0.00	0.05	0.96	0.00
Indonesia	0.02	0.03	0.00	0.08	0.97	0.00
Thailand	0.02	0.02	0.00	0.05	0.95	0.00
Russia	0.03	0.02	0.00	0.05	0.99	0.00
US	0.04	0.03	0.00	0.10	0.95	0.00
Japan	0.03	0.02	0.01	0.06	0.96	0.00
South Korea	0.04	0.02	0.01	0.07	0.96	0.00
Vietnam	0.02	0.01	0.00	0.05	0.96	0.00
Malaysia	0.06	0.03	0.00	0.11	0.92	0.00
China	0.02	0.02	0.00	0.05	0.97	0.00
Mexico	0.06	0.03	0.02	0.10	0.93	0.00
New Zealand	0.02	0.02	0.00	0.05	0.95	0.00
Peru	0.00	0.01	0.00	0.02	0.98	0.00

4.3.1 Minimum Variance Portfolio

Table 4.4 presents the time-varying portfolio weights of the Minimum Variance Portfolio (MVP) built based on the TVP-VAR (0.99, 0.99) model with one lag. The information shows the role of asset classes and country-specific equity indices in reducing the total portfolio risk. Green Bonds are allocated the largest average (mean weight = 0.42), which highlights their importance in stabilizing the portfolio. This allocation fluctuates moderately, ranging from 0.22 to 0.59, with a Hedge Effectiveness (HE) of 0.59 indicating a moderate reduction in variance compared to an un-hedged portfolio. Technology (0.05) and Clean Energy (0.02) also maintain consistent, though smaller, allocations, reflecting their perceived stability and diversification benefits. Commodities such as Natural Gas and Crude Oil are assigned near-zero average weights due to their high volatility and limited risk-reduction potential; however, their HE values (1.00) suggest a high degree of variance reduction when included. Gold, a traditional safe-haven asset, carries a mean weight of 0.05 with a high HE of 0.93, emphasizing its stable and dependable role in reducing portfolio variance. Geographically, higher weights are allocated to Malaysia (0.06), Mexico (0.06), the US (0.04), Canada (0.04), and South Korea (0.04), likely due to their stable market structures and diversification benefits. Moderate allocations are given to Japan, Russia, Vietnam, Thailand, and Indonesia, while countries like Australia, Peru, Chile, and the Philippines receive minimal allocations.

Most assets and indices display high HE values (above 0.90), indicating strong variance reduction consistency over time. Additionally, all variables are statistically significant, with p-values of 0.00, confirming that the observed weight patterns are not random.

The analysis of the Minimum Correlation Portfolio (MCP), based on the time-varying variance-covariance matrix in Table 4.4, presents a diversified structure aimed at reducing systemic risk by selecting assets and equity indices with the lowest mutual correlations. This approach shifts the focus from pure volatility reduction to identifying uncorrelated or negatively correlated assets to enhance portfolio diversification. Clean Energy, Technology, and Green Bonds receive moderate average weights (0.05 to 0.07), indicating their positive contribution to diversification. Notably, Green Bonds exhibit a negative Hedge Effectiveness (HE) of -0.23, suggesting a limited reduction in variance compared to an un-hedged portfolio, which contrasts with the performance of most other assets and calls for caution regarding their long-term role in the MCP.

Natural Gas (0.06) and Crude Oil (0.04) are assigned relatively higher weights compared to the MVP, reflecting their low correlation with equity markets despite their volatility, with high HE values (0.98) indicating significant variance reduction when included. Gold maintains a significant allocation (0.06 mean weight, HE = 0.80), reinforcing its utility as a hedge and diversifier by effectively reducing portfolio variance. Geographically, the portfolio features a broad distribution with notable allocations to South Korea (0.07), Japan (0.06), Mexico (0.06), Vietnam (0.05), Russia (0.05), and the US (0.05), likely chosen for their lower correlations with other markets to support diversification goals. Smaller yet pertinent allocations are made to Philippines, Chile, Hong Kong, Taiwan, Thailand, and China, which can provide distinctive patterns of returns with less global connections.

Other countries such as Australia and Singapore are allocated very little (mean 0.00), perhaps because they are more highly correlated with the large markets or because they do not offer much diversification advantage. HE values across assets are typically between 0.80 and 0.94, which means that the variance is reduced significantly, and the portfolio is stable in the long run. Exceptions, including Malaysia (HE = 0.75) and Green Bonds (negative HE), indicate more dynamic or volatile weight changes. All the allocations are statistically significant (p-values = 0.00), which confirms the validity of these findings. Overall, the MCP allocates weights strategically among asset classes and geographies that are lowly correlated, and the focus is on broad diversification, but the low variance reduction of assets such as Green Bonds necessitates flexible management approaches.

Table 4.5 Minimum Correlation Portfolio

Minimum Correlation Portfolio						
	Mean	Std.Dev.	5%	95%	HE	p-value
Clean Energy	0.05	0.02	0.02	0.08	0.93	0.00
Green Bond	0.07	0.02	0.05	0.11	-0.23	0.00
Technology	0.07	0.02	0.04	0.11	0.88	0.00
Natural Gas	0.06	0.02	0.03	0.10	0.98	0.00
Crude Oil	0.04	0.02	0.00	0.07	0.98	0.00
Gold	0.06	0.02	0.03	0.10	0.80	0.00
Philippines	0.03	0.02	0.00	0.05	0.88	0.00
Canada	0.02	0.02	0.00	0.05	0.87	0.00
Australia	0.00	0.01	0.00	0.01	0.89	0.00
Chile	0.03	0.02	0.00	0.07	0.93	0.00
Singapore	0.00	0.01	0.00	0.02	0.82	0.00
Hong Kong	0.03	0.02	0.00	0.07	0.87	0.00
Taiwan	0.02	0.02	0.00	0.05	0.87	0.00
Indonesia	0.02	0.02	0.00	0.06	0.90	0.00
Thailand	0.02	0.02	0.00	0.05	0.86	0.00
Russia	0.05	0.01	0.03	0.09	0.97	0.00
US	0.05	0.02	0.02	0.08	0.86	0.00
Japan	0.06	0.02	0.04	0.09	0.87	0.00
South Korea	0.07	0.01	0.04	0.09	0.87	0.00
Vietnam	0.05	0.02	0.01	0.07	0.88	0.00
Malaysia	0.02	0.02	0.00	0.06	0.75	0.00
China	0.05	0.02	0.01	0.09	0.90	0.00
Mexico	0.06	0.02	0.03	0.09	0.80	0.00
New Zealand	0.04	0.02	0.00	0.08	0.86	0.00
Peru	0.03	0.02	0.00	0.07	0.94	0.00

4.3.2 Minimum Correlation Portfolio

Table 4.5 shows the Minimum Correlation Portfolio (MCP) that is built on a time-varying parameter model to minimize the systemic risk by minimizing the interconnectedness of assets. The table shows a balanced and diversified allocation strategy, with a preference to assets and markets with low dynamic connectedness to hedge against contagion and co-movement shocks. Clean Energy, Green Bonds, Technology, Natural Gas, Crude Oil, and Gold each receive average weights of 0.05 to 0.06, highlighting their strategic importance. Natural Gas and Crude Oil maintain persistent roles (Hedge Effectiveness = 0.98) despite volatility, likely due to low systemic linkages with equity indices, indicating a high level of variance reduction. Green Bonds, with a steady mean weight of 0.06, show a negative HE of -0.52, suggesting limited variance reduction and unstable weight dynamics, necessitating active management.

Gold remains a stable presence (mean = 0.06, HE = 0.75), effectively mitigating portfolio variance and systemic influence. Among country indices, Russia, Japan, South Korea, Vietnam, China, Mexico, New Zealand, and the US receive mean allocations of 0.05 to 0.06, suggesting their value in reducing network connectedness and variance. Markets like Philippines, Peru, Chile, Indonesia, and Australia have smaller but notable allocations. Countries with minimal allocations (e.g., Singapore, Canada, Malaysia) likely have higher systemic ties or lower efficiency, though their HE values (e.g., Canada = 0.84, Singapore = 0.78) indicate stable marginal contributions to variance reduction. Most HE values exceed 0.80, demonstrating high consistency in variance reduction and enhancing reliability over time. All p-values of 0.00 confirm statistical significance. The MCP effectively balances asset classes and geographic exposures, making it ideal for investors seeking resilience against financial contagion and spillover risks.

Table 4.6 Minimum Connectedness Portfolio

Minimum Connectedness Portfolio						
	Mean	Std.Dev.	5%	95%	HE	p-value
Clean Energy	0.05	0.01	0.03	0.06	0.92	0.00
Green Bond	0.06	0.01	0.05	0.07	-0.52	0.00
Technology	0.06	0.01	0.05	0.08	0.85	0.00
Natural Gas	0.06	0.01	0.05	0.07	0.98	0.00
Crude Oil	0.05	0.01	0.04	0.06	0.98	0.00
Gold	0.06	0.01	0.05	0.07	0.75	0.00
Philippines	0.04	0.01	0.01	0.05	0.85	0.00
Canada	0.00	0.01	0.00	0.04	0.84	0.00
Australia	0.01	0.01	0.00	0.04	0.86	0.00
Chile	0.03	0.02	0.00	0.05	0.92	0.00
Singapore	0.00	0.01	0.00	0.02	0.78	0.00
Hong Kong	0.02	0.01	0.00	0.04	0.84	0.00
Taiwan	0.02	0.01	0.00	0.04	0.84	0.00
Indonesia	0.03	0.01	0.00	0.05	0.88	0.00
Thailand	0.02	0.01	0.00	0.04	0.82	0.00
Russia	0.06	0.01	0.04	0.07	0.96	0.00
US	0.05	0.01	0.04	0.06	0.83	0.00
Japan	0.06	0.01	0.05	0.07	0.84	0.00
South Korea	0.06	0.01	0.05	0.07	0.85	0.00
Vietnam	0.05	0.01	0.04	0.06	0.86	0.00
Malaysia	0.02	0.01	0.01	0.04	0.69	0.00
China	0.05	0.01	0.03	0.06	0.87	0.00
Mexico	0.05	0.01	0.04	0.06	0.76	0.00
New Zealand	0.05	0.02	0.02	0.06	0.83	0.00
Peru	0.04	0.01	0.02	0.05	0.92	0.00

4.3.3 Minimum Connectedness Portfolio

The Minimum Connectedness Portfolio (MCoP) in Table 4.6, constructed using a time-varying parameter model, aims to reduce systemic risk by minimizing asset interconnectedness. The table reveals a balanced and diversified allocation strategy, favoring assets and markets with low dynamic connectedness to hedge against contagion and co-movement shocks. Clean Energy, Green Bonds, Technology, Natural Gas, Crude Oil, and Gold each receive average weights of 0.05 to 0.06, highlighting their strategic importance. Natural Gas and Crude Oil maintain persistent roles (Hedge Effectiveness = 0.98) despite volatility, likely due to low systemic linkages with equity indices, indicating a high level of variance reduction. Green Bonds, with a steady mean weight of 0.06, show a negative HE of -0.52, suggesting limited variance reduction and unstable weight dynamics, necessitating active management.

Gold remains a stable presence (mean = 0.06, HE = 0.75), effectively mitigating portfolio variance and systemic influence. Among country indices, Russia, Japan, South Korea, Vietnam, China, Mexico, New Zealand, and the US receive mean allocations of 0.05 to 0.06, suggesting their value in reducing network connectedness and variance. Markets like Philippines, Peru, Chile, Indonesia, and Australia have smaller but notable allocations. Countries with minimal allocations (e.g., Singapore, Canada, Malaysia) likely have higher systemic ties or lower efficiency, though their HE values (e.g., Canada = 0.84, Singapore = 0.78) indicate stable marginal contributions to variance reduction. Most HE values exceed 0.80, demonstrating high consistency in variance reduction and enhancing reliability over time. All p-values of 0.00 confirm statistical significance. The MCoP effectively balances asset classes and geographic exposures, making it ideal for investors seeking resilience against financial contagion and spillover risks.

The comparative study of the Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP) built on the TVP-VAR (0.99, 0.99) model shows different strategic priorities and risk mitigation profiles. The MVP is aimed at minimizing the volatility of the whole portfolio, which leads to a concentrated allocation, especially in Green Bonds (mean weight = 0.42), which is a stabilizing asset with a moderate HE of 0.59. Nevertheless, its omission of volatile commodities such as Natural Gas and Crude Oil does not take into consideration their diversification potential. The MCP seeks to reduce pairwise correlations, resulting in a more balanced distribution across asset classes and countries, with significant weights of Natural Gas (0.06), Crude Oil (0.04), and

Gold (0.06), and HE values (0.98 of commodities, 0.80 of Gold) showing significant variance reduction. The MCoP, which aims at reducing systemic connectedness, provides an even more balanced structure, with lower contagion risks, stable weights of Crude Oil, Natural Gas, and Gold (0.05-0.06) and high HE values (0.98), indicating high variance reduction. Green Bonds, which are included in every portfolio, have negative or low HE values in MCP (-0.23) and MCoP (-0.52), indicating low variance reduction and unstable dynamics that need active rebalancing. Geographically, the MVP favors stable, developed markets like the US, Canada, and South Korea, while the MCP and MCoP incorporate a broader mix of emerging markets, including Vietnam, Russia, Mexico, and Chile, reflecting their utility in reducing correlation and connectedness. Across all portfolios, most assets display high HE values (>0.80), underscoring consistent variance reduction over time. The results are robust as all variables are statistically significant ($p\text{-value} = 0.00$). In general, MVP is appropriate in conservative risk-averse strategies, whereas MCP and MCoP offer dynamic and diversified strategies that respond to co-movement or systemic risks, which can be used to develop a resilient and adaptive investment strategy.

4.4 Portfolio analysis

This part is devoted to the assessment of various portfolio strategies, the necessity of flexibility to the market changes and the role of portfolio restructuring. It discusses bivariate and multivariate portfolio strategies, the benefits of diversification and proper asset allocation in a dynamic financial environment. The discussion starts by giving an overview of bivariate and multivariate hedging portfolios and then proceeds to examine the strategies that are used to minimize the risk of investment. The performance of these strategies is assessed using key financial metrics, including the Sharpe Ratio, which measures risk-adjusted returns by comparing excess returns to portfolio volatility, and Hedge Effectiveness (HE), calculated as the variance reduction in the hedged portfolio compared to the un-hedged portfolio, indicating the ability to mitigate downside risk. The analysis of hedge ratios and HE for bivariate portfolios combining national equity indices with Clean Energy, Green Bonds, Technology, Natural Gas, Crude Oil, and Gold reveals significant cross-country and cross-asset heterogeneity in risk mitigation performance. Although all HE values are statistically significant at the 1% level ($p \leq 0.01$), the magnitude of variance reduction and the efficiency of each hedge vary considerably.

4.4.1 Optimal bivariate portfolio weights of clean energy with APEC

This section delves into bivariate portfolio techniques designed to minimize portfolio risk while indirectly enhancing risk-adjusted returns, typically measured via the Sharpe Ratio. Tables 4.7-4.12 show empirical results using the methodology of Kroner and Ng (1998) that estimates optimal hedge ratios of bivariate portfolios of Clean Energy and other national equity indices in the APEC region. These estimates are justified by the Hedge Effectiveness (HE) measure proposed by Ederington (1979) and its statistical significance as described by Antonakakis et al. (2020). The findings show that there is a varied performance of risk mitigation among countries. It is interesting to note that bivariate portfolios like Clean Energy-Peru and Clean Energy-Chile have relatively high average hedge ratios of 0.54 and 0.51 respectively. Their respective HE values of 0.46 and 0.51 however indicate that although large amounts are allocated to Clean Energy, the variance reduction is not very high, perhaps because of low correlations or high volatility in these new markets. Conversely, other portfolios such as Clean Energy-Malaysia and Clean Energy-Mexico provide better results. These portfolios have higher HE values of 0.79 and 0.76, respectively, with lower mean hedge ratios of 0.22 and 0.30, respectively, which implies better variance reduction, probably due to high inverse correlations or low covariance.

Other portfolios like Clean Energy-Singapore, Clean Energy-US and Clean Energy-Japan also exhibit high risk mitigation ($HE > 0.70$) with moderate Clean Energy allocations (mean weights of about 0.28-0.41) indicating that market structure and correlation dynamics are important factors in hedging efficiency and not necessarily the size of allocation. The Clean Energy-Russia portfolio, however, is quite variable, with a mean weight of 0.48, a broad 90 percent confidence interval (0.09 to 0.86), and a lower HE of 0.48. The high standard deviation (0.22) suggests time-varying and uncertain hedging performance, which may limit its reliability in real-time strategies. All estimated HE values are statistically significant at the 1% level ($p = 0.00$), confirming that including Clean Energy assets significantly reduces risk across all portfolios. While some pairs, like Clean Energy–Peru, require high allocations for marginal variance reduction, others, such as Clean Energy–Malaysia and Clean Energy–Mexico, achieve substantial effectiveness with lower weights.

Table 4.7 Optimal bivariate portfolio weights of Clean Energy/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Clean Energy/Philippines	0.37	0.13	0.21	0.56	0.64	0.00
Clean Energy/Canada	0.34	0.10	0.20	0.50	0.64	0.00

Clean Energy/Australia	0.37	0.13	0.19	0.54	0.61	0.00
Clean Energy/Chile	0.51	0.10	0.37	0.69	0.51	0.00
Clean Energy/Singapore	0.28	0.09	0.15	0.45	0.72	0.00
Clean Energy/Hong Kong	0.34	0.12	0.18	0.56	0.66	0.00
Clean Energy/Taiwan	0.35	0.12	0.19	0.55	0.66	0.00
Clean Energy/Indonesia	0.42	0.18	0.18	0.71	0.60	0.00
Clean Energy/Thailand	0.32	0.10	0.17	0.49	0.68	0.00
Clean Energy/Russia	0.48	0.22	0.09	0.86	0.48	0.00
Clean Energy/US	0.34	0.14	0.15	0.58	0.71	0.00
Clean Energy/Japan	0.41	0.18	0.17	0.65	0.71	0.00
Clean Energy/South Korea	0.39	0.13	0.23	0.60	0.69	0.00
Clean Energy/Vietnam	0.41	0.14	0.22	0.70	0.65	0.00
Clean Energy/Malaysia	0.22	0.10	0.09	0.38	0.79	0.00
Clean Energy/China	0.45	0.17	0.23	0.76	0.63	0.00
Clean Energy/Mexico	0.30	0.14	0.14	0.54	0.76	0.00
Clean Energy/New Zealand	0.35	0.11	0.21	0.51	0.65	0.00
Clean Energy/Peru	0.54	0.07	0.43	0.64	0.46	0.00

Table 4.8 Optimal bivariate portfolio weights of Green Bond/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Green Bond/Philippines	0.90	0.05	0.81	0.96	0.12	0.00
Green Bond/Canada	0.87	0.06	0.77	0.96	0.20	0.00
Green Bond/Australia	0.89	0.06	0.78	0.96	0.13	0.00
Green Bond/Chile	0.92	0.04	0.86	0.97	0.11	0.00
Green Bond/Singapore	0.84	0.08	0.71	0.94	0.21	0.00
Green Bond/Hong Kong	0.88	0.06	0.77	0.97	0.14	0.00
Green Bond/Taiwan	0.88	0.06	0.78	0.96	0.14	0.00
Green Bond/Indonesia	0.89	0.10	0.67	0.97	0.19	0.00
Green Bond/Thailand	0.86	0.07	0.71	0.95	0.17	0.00
Green Bond/Russia	0.92	0.04	0.86	0.99	0.10	0.01
Green Bond/US	0.87	0.08	0.73	0.97	0.18	0.00
Green Bond/Japan	0.90	0.07	0.72	0.98	0.14	0.00
Green Bond/South Korea	0.90	0.06	0.78	0.98	0.14	0.00
Green Bond/Vietnam	0.91	0.05	0.84	0.98	0.11	0.00
Green Bond/Malaysia	0.79	0.11	0.60	0.91	0.24	0.00
Green Bond/China	0.92	0.05	0.81	0.98	0.09	0.02
Green Bond/Mexico	0.85	0.08	0.68	0.95	0.22	0.00
Green Bond/New Zealand	0.89	0.05	0.80	0.96	0.13	0.00
Green Bond/Peru	0.94	0.03	0.89	1.00	0.10	0.01

4.4.2 Optimal bivariate portfolio weights of Green Bond/APEC

Green Bonds display varied performance across countries. Portfolios such as Green Bond–Malaysia and Green Bond–Mexico, with modest average hedge ratios of 0.79 and 0.85, respectively, achieve the highest HE values of 0.24 and 0.22, indicating significant variance reduction with minimal allocation, likely due to favorable correlation dynamics or low covariance. Conversely, portfolios like Green Bond–Peru and Green Bond–Chile, with high mean hedge ratios of 0.94 and 0.92, show lower HE values of 0.10 and 0.11, suggesting that heavy reliance on Green Bonds yields limited variance reduction, possibly due to market inefficiencies or volatility clustering. Portfolios such as Green Bond–Singapore (mean ratio 0.84, HE 0.21), Green Bond–Indonesia (0.86, HE 0.19), and Green Bond–US (0.87, HE 0.18) offer balanced outcomes with consistent variance reduction. In markets like China and Russia, high hedge ratios (0.92) correspond to low HE values (0.09 and 0.10), indicating limited benefits, potentially due to synchronized market movements. Intermediate performers like Thailand (0.86, HE 0.17), Japan (0.90, HE 0.14), and South Korea (0.90, HE 0.14) show stable but moderate hedging capacity.

Table 4.9 Optimal bivariate portfolio weights of Technology/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Technology/Philippines	0.50	0.17	0.22	0.78	0.60	0.00
Technology/Canada	0.48	0.19	0.21	0.88	0.64	0.00
Technology/Australia	0.50	0.20	0.22	0.86	0.58	0.00
Technology/Chile	0.63	0.15	0.40	0.88	0.47	0.00
Technology/Singapore	0.42	0.17	0.17	0.75	0.66	0.00
Technology/Hong Kong	0.48	0.13	0.27	0.69	0.59	0.00
Technology/Taiwan	0.49	0.15	0.23	0.69	0.58	0.00
Technology/Indonesia	0.54	0.21	0.19	0.87	0.58	0.00
Technology/Thailand	0.46	0.16	0.26	0.79	0.64	0.00
Technology/Russia	0.60	0.22	0.23	0.95	0.53	0.00
Technology/US	0.47	0.19	0.17	0.75	0.66	0.00
Technology/Japan	0.53	0.17	0.22	0.76	0.58	0.00
Technology/South Korea	0.52	0.13	0.29	0.76	0.57	0.00
Technology/Vietnam	0.54	0.15	0.30	0.80	0.56	0.00
Technology/Malaysia	0.34	0.17	0.10	0.65	0.74	0.00
Technology/China	0.56	0.15	0.27	0.77	0.55	0.00
Technology/Mexico	0.43	0.16	0.20	0.70	0.68	0.00
Technology/New Zealand	0.49	0.16	0.24	0.77	0.60	0.00
Technology/Peru	0.66	0.13	0.45	0.92	0.42	0.00

4.4.3 Optimal bivariate portfolio weights of Technology/APEC

Technology assets demonstrate high hedging effectiveness across all portfolios, despite generally low hedge ratios. For instance, Technology–Mexico (ratio 0.43, HE 0.68), Technology–Malaysia (0.34, HE 0.74), and Technology–Singapore (0.42, HE 0.66) achieves significant variance reduction with modest allocations. Even in Peru and Chile, where hedging performance is typically weaker, Technology portfolios maintain moderate ratios (0.66 and 0.63) and strong HE values (0.42 and 0.47), indicating efficient risk reduction without excessive exposure.

Table 4.10 Optimal bivariate portfolio weights of Natural Gas/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Natural Gas/Philippines	0.11	0.06	0.04	0.26	0.90	0.00
Natural Gas/Canada	0.10	0.09	0.03	0.29	0.91	0.00
Natural Gas/Australia	0.12	0.08	0.04	0.28	0.89	0.00
Natural Gas/Chile	0.18	0.09	0.09	0.38	0.84	0.00
Natural Gas/Singapore	0.08	0.06	0.02	0.20	0.93	0.00
Natural Gas/Hong Kong	0.10	0.04	0.05	0.19	0.90	0.00
Natural Gas/Taiwan	0.10	0.05	0.04	0.21	0.90	0.00
Natural Gas/Indonesia	0.14	0.10	0.02	0.34	0.88	0.00
Natural Gas/Thailand	0.09	0.07	0.02	0.22	0.91	0.00
Natural Gas/Russia	0.19	0.14	0.06	0.52	0.78	0.00
Natural Gas/US	0.10	0.07	0.04	0.20	0.91	0.00
Natural Gas/Japan	0.13	0.08	0.02	0.27	0.90	0.00
Natural Gas/South Korea	0.12	0.06	0.05	0.25	0.90	0.00
Natural Gas/Vietnam	0.13	0.07	0.07	0.24	0.89	0.00
Natural Gas/Malaysia	0.07	0.05	0.02	0.16	0.95	0.00
Natural Gas/China	0.14	0.08	0.06	0.31	0.88	0.00
Natural Gas/Mexico	0.09	0.04	0.04	0.18	0.93	0.00
Natural Gas/New Zealand	0.11	0.05	0.05	0.21	0.90	0.00
Natural Gas/Peru	0.19	0.08	0.11	0.38	0.83	0.00

4.4.4 Optimal bivariate portfolio weights of Natural Gas/APEC

Natural Gas stands out as the most effective hedging asset, achieving the highest HE values with the lowest hedge ratios. For example, Natural Gas–Malaysia (ratio 0.07, HE 0.95), Natural Gas–Mexico (0.09, HE 0.93), and Natural Gas–Singapore (0.08, HE 0.93) delivers substantial variance reduction with minimal exposure. Even in Russia and China, where commodity market linkages might limit diversification, the portfolios maintain strong HE values (0.78 and 0.88), confirming Natural Gas’s efficiency as a low-exposure, high-impact hedge.

Table 4.11 Optimal bivariate portfolio weights of Crude Oil/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Crude Oil/Philippines	0.15	0.05	0.07	0.22	0.87	0.00
Crude Oil/Canada	0.14	0.04	0.07	0.21	0.88	0.00
Crude Oil/Australia	0.15	0.04	0.08	0.20	0.86	0.00
Crude Oil/Chile	0.26	0.10	0.12	0.42	0.80	0.00
Crude Oil/Singapore	0.11	0.03	0.07	0.16	0.91	0.00
Crude Oil/Hong Kong	0.15	0.07	0.06	0.28	0.88	0.00
Crude Oil/Taiwan	0.15	0.06	0.06	0.22	0.88	0.00
Crude Oil/Indonesia	0.19	0.07	0.08	0.30	0.85	0.00
Crude Oil/Thailand	0.13	0.05	0.07	0.21	0.89	0.00
Crude Oil/Russia	0.27	0.21	0.08	0.78	0.82	0.00
Crude Oil/US	0.11	0.07	0.00	0.23	0.89	0.00
Crude Oil/Japan	0.18	0.10	0.04	0.39	0.88	0.00
Crude Oil/South Korea	0.18	0.10	0.05	0.40	0.88	0.00
Crude Oil/Vietnam	0.19	0.11	0.03	0.38	0.88	0.00
Crude Oil/Malaysia	0.08	0.03	0.04	0.13	0.93	0.00
Crude Oil/China	0.21	0.09	0.05	0.34	0.86	0.00
Crude Oil/Mexico	0.11	0.06	0.03	0.21	0.91	0.00
Crude Oil/New Zealand	0.15	0.04	0.08	0.22	0.88	0.00
Crude Oil/Peru	0.28	0.09	0.16	0.44	0.79	0.00

4.4.5 Optimal bivariate portfolio weights of Crude Oil/APEC

Crude Oil provides consistent hedging performance, though slightly less effective than Natural Gas. Portfolios like Crude Oil–Mexico (ratio 0.11, HE 0.91), Crude Oil–Malaysia (0.08, HE 0.93), and Crude Oil–Singapore (0.11, HE 0.91) achieve efficient variance reduction. In oil-dependent markets like Russia (ratio 0.27, HE 0.82), higher allocations suggest reduced marginal benefits due to existing exposure, while Crude Oil–US (0.11, HE 0.89) maintains strong performance.

Table 4.12 Optimal bivariate portfolio weights of Gold/APEC

	Mean	Std.Dev.	5%	95%	HE	p-value
Gold/Philippines	0.59	0.08	0.46	0.71	0.40	0.00
Gold/Canada	0.56	0.11	0.42	0.74	0.44	0.00
Gold/Australia	0.58	0.10	0.42	0.74	0.38	0.00
Gold/Chile	0.71	0.11	0.52	0.86	0.31	0.00
Gold/Singapore	0.50	0.10	0.35	0.63	0.51	0.00
Gold/Hong Kong	0.56	0.11	0.34	0.71	0.42	0.00
Gold/Taiwan	0.56	0.08	0.46	0.71	0.41	0.00
Gold/Indonesia	0.62	0.12	0.43	0.83	0.38	0.00

Gold/Thailand	0.54	0.09	0.40	0.68	0.44	0.00
Gold/Russia	0.67	0.15	0.50	0.98	0.37	0.00
Gold/US	0.55	0.12	0.36	0.74	0.47	0.00
Gold/Japan	0.61	0.10	0.45	0.77	0.44	0.00
Gold/South Korea	0.60	0.10	0.41	0.75	0.44	0.00
Gold/Vietnam	0.62	0.12	0.46	0.80	0.40	0.00
Gold/Malaysia	0.40	0.10	0.25	0.57	0.57	0.00
Gold/China	0.64	0.12	0.45	0.81	0.41	0.00
Gold/Mexico	0.51	0.09	0.35	0.71	0.50	0.00
Gold/New Zealand	0.57	0.08	0.46	0.67	0.41	0.00
Gold/Peru	0.74	0.08	0.61	0.84	0.29	0.00

4.4.6 Optimal bivariate portfolio weights of Gold/APEC

Gold, a traditional safe-haven asset, offers stable but modest variance reduction. Portfolios like Gold–Malaysia (ratio 0.40, HE 0.57) and Gold–Mexico (0.51, HE 0.50) provide reliable hedging. In Peru and Chile, high allocations (0.74 and 0.71) yield lower HE values (0.29 and 0.31), suggesting marginal benefits with significant exposure. Portfolios like Gold–US (0.55, HE 0.47), Gold–China (0.64, HE 0.41), and Gold–Russia (0.67, HE 0.37) show consistent but moderate efficiency, requiring higher allocations compared to Natural Gas or Technology.

In summary, all assets contribute significantly to hedging, with performance varying by country and market conditions. Natural Gas leads in HE per unit of exposure, followed by Technology and Crude Oil. Green Bonds and Gold offer diversification benefits in specific contexts but require careful allocation due to correlation and volatility factors, emphasizing the need to consider dynamic co-movement patterns and market structures in portfolio construction.

Table 4.13 Sharpe Ratio

Portfolio	Mean Return	Std. Dev.	Sharpe Ratio
MVP	7.39E-05	0.002465	0.0300
MCP	0.000108	0.004219	0.0256
MCoP	0.000123	0.004737	0.0260

4.4.7 Sharpe Ratio

The Sharpe Ratio is a widely used measure of risk-adjusted return, indicating how much excess return an investor earns per unit of risk undertaken (Grau-Carles, 2025). In this analysis, the Minimum Variance Portfolio (MVP) outperforms the other two strategies—Minimum Correlation Portfolio (MCP) and Minimum Connectedness Portfolio (MCoP)—with a Sharpe ratio of 0.0300. Although MVP has the lowest average return among the three

portfolios, at approximately $7.39\text{E-}05$, it also has the lowest standard deviation (0.002465). This lower volatility results in a superior Sharpe ratio, highlighting MVP's efficiency in producing more return per unit of risk compared to MCP and MCoP, which have slightly higher returns but also higher risk levels, thereby resulting in lower Sharpe ratios of 0.0256 and 0.0260 respectively.

MVP is rooted in Markowitz's Modern Portfolio Theory (1959), which aims to construct a portfolio that minimizes overall risk or variance without necessarily maximizing returns. Instead of focusing on expected return alone, MVP emphasizes reducing exposure to fluctuations by selecting assets whose returns are not highly correlated. This becomes especially relevant in times of crisis or heightened market uncertainty.

The asset composition of the MVP provides deeper insights into its risk-minimization behavior. Despite their low or even zero returns, assets such as crude oil and natural gas appear crucial in the MVP because of their extremely high hedge effectiveness (HE), which is around 0.99. Hedge effectiveness reflects the reduction in portfolio volatility offered by a specific asset, and values closer to 1 indicate strong volatility dampening. These assets are included not for generating returns but for stabilizing the overall portfolio.

Other assets like green bonds, technology stocks, gold, and clean energy play a dual role in the MVP. Green bonds, with a mean return of 0.40 and a standard deviation of 0.13, are likely a core return generator in the MVP, even though their hedge effectiveness (0.58) is moderate. On the other hand, gold, technology, and clean energy contribute not only modest returns but also demonstrate high hedge effectiveness—ranging from 0.93 to 0.98—thereby justifying their inclusion from both a return and risk perspective.

Geographically, the MVP includes exposures to markets like Canada, the U.S., Malaysia, Mexico, and others, many of which have shown positive returns with relatively low standard deviations and high hedge effectiveness. These indices enhance diversification while contributing to the return profile. Even Australia and Peru, despite showing near-zero mean returns, may be included in the MVP for their risk-buffering properties.

In conclusion, the MVP emerges as the most suitable strategy for risk-averse investors, particularly during periods of high volatility or economic uncertainty. While its returns are modest, the portfolio delivers the best risk-adjusted performance due to the strategic inclusion of assets with high hedge effectiveness and low interconnectedness. The analysis validates

the foundational principle of the MVP: minimizing variance leads to more stable returns, which can be more valuable than chasing high but volatile gains.

4.5 Wavelet Analysis

Wavelet analysis is a strong time-frequency analysis that is applied to examine the variation of relationships between variables over time and across investment horizons. Wavelet analysis is suitable in analyzing dynamic market behavior unlike the traditional methods which assume that data is stationary over time. It assists in determining both the short-term shocks and long-term trends by indicating when and how frequently two variables move in the same direction. Wavelet coherence is a common tool in finance, particularly in times of crisis such as the COVID-19 pandemic or geopolitical events, to identify time-varying co-movements between markets or asset classes, which can provide useful information in portfolio diversification, risk management, and policy planning.

4.5.1 Wavelet Coherence

This study employs the bivariate wavelet coherence method to examine the co-movement of financial time series. The approach is unique in its ability to analyze relationships in the joint time frequency domain and is therefore very appropriate when dealing with financial data which tend to have complex dynamics, including non-stationarity and non-normality (Grinsted et al., 2004). Conventional linear econometric models, including vector autoregressions or cointegration methods, are usually based on the assumption that the data generating process is stationary and normally distributed, which restricts their use in practice in financial applications where these assumptions are frequently not met. Conversely, wavelet analysis does not impose these stringent assumptions and is therefore more suited to deal with the irregularities and structural breaks that are often present in high-frequency financial data. Among the most important strengths of the wavelet coherence method is the possibility to detect time-varying lead-lag relationships between variables. The technique also shows not only that two series are moving together over time, but also which variable is affecting the other at any point in time through point-by-point phase difference analysis. This dynamic understanding is essential to policymakers, investors, and researchers who must know the changing market connections and transmission channels across assets or markets.

In addition, wavelet coherence can identify co-movements across time horizons, both short-term and long-term fluctuations in the same analysis. This multi-scale view gives a complete picture of market interdependencies, which is especially useful in times of market turbulence or crisis when asset relationships can shift quickly. Wavelet coherence provides a more detailed and robust picture of inter-market relationships compared to other time series approaches, including simple correlation, partial correlation, conditional correlation, or classical causality models. With these benefits, the wavelet coherence technique has gained popularity in financial studies to analyze asset integration, contagion, and risk transmission. It is particularly well-suited to high-frequency and structurally complex data, and thus it is an effective method of studying the co-movements and interdependencies in global financial markets, as recent studies have shown (Ozkan et al., 2024).

The outcomes of the wavelet coherence analysis are usually displayed in the form of two-dimensional contour plots that are effective in depicting the dynamic comovements pattern between financial markets. The horizontal axis in these plots is the time dimension, which enables the researcher to see the changes in relationships over time. The vertical axis represents the frequency or scale, typically 0 to 1024, which is associated with various investment horizons or periodicities. The lower frequency values (e.g., 0-4) are associated with short-term fluctuations and the higher frequency bands (e.g., 256-1024) are associated with long-term trends. The frequency spectrum is usually divided into ranges like 0-4, 4-16, 16-64, 64-256 and 256-1024 to enable the interpretation of short-, medium-, and long-run comovements. The strength of comovements or correlation between two markets is shown graphically as a color gradient. Red lines show high coherence or correlation, usually between 0.7 and 0.9, which denotes the time when the market pairs are highly interdependent. Blue lines indicate low coherence, which is usually between 0 and 0.3, with little or no market connections. The intermediate values of comovements are represented in yellow and green colors, which reflect moderate values of correlation. This visual structure enables the researcher to quickly determine the strength and the time of inter-market relationships.

The plots also contain solid black contours that delineate regions in which the wavelet coherence is significant at the 5% level to determine the statistical significance of these comovements. These contours are Monte Carlo based and are used to test the null hypothesis of no correlation with the observed data. This makes sure that the relationships that are identified are not because of random noise but are statistically significant. The other important aspect of the wavelet coherence plots is that they contain directional arrows that

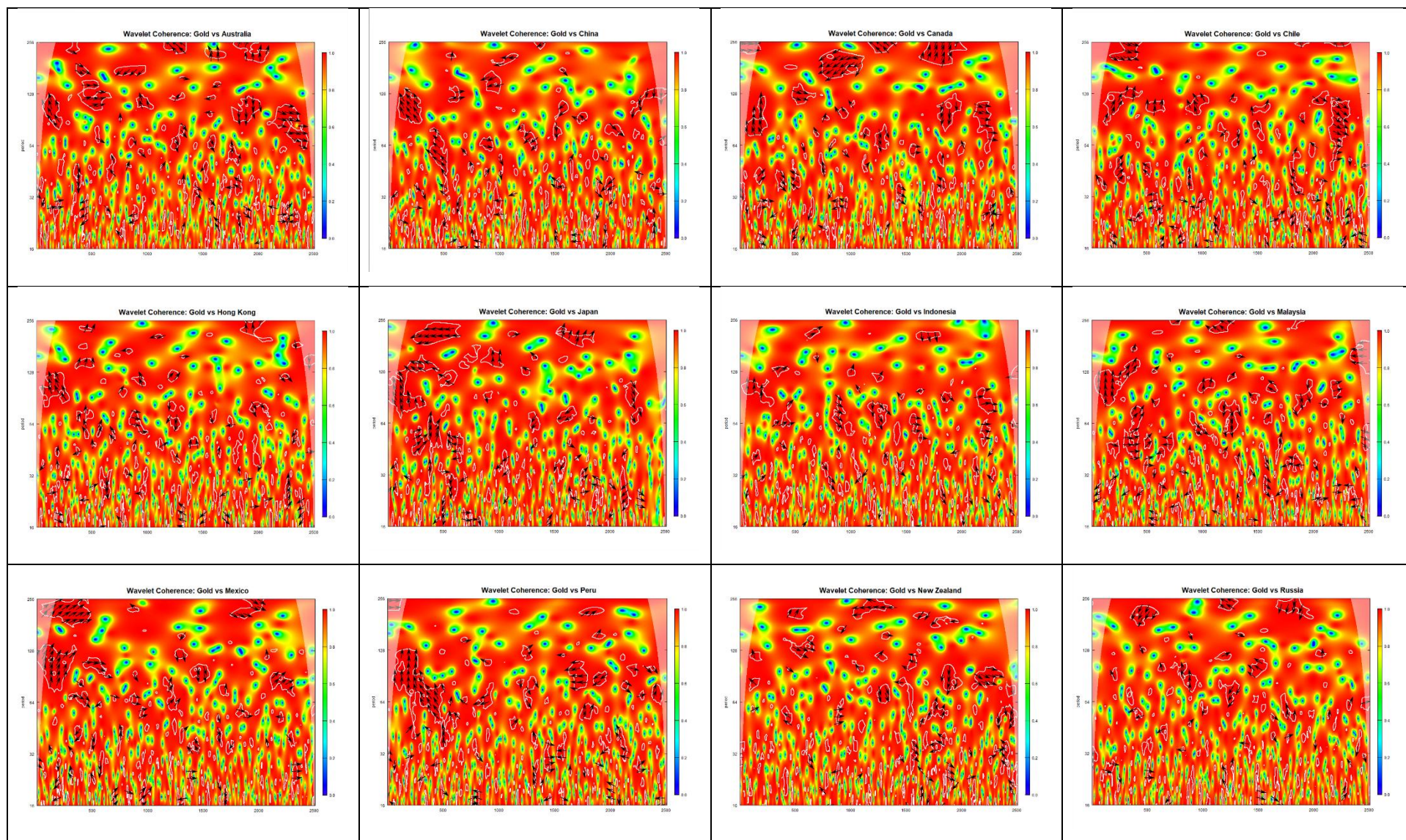
give information about the direction of the correlation (positive or negative) and the lead-lag relationship between the two-time series being analyzed. The positive correlation is represented by arrows pointing to the right, and the negative correlation is represented by arrows pointing to the left, where the markets move in the same direction or opposite directions respectively. In addition, the angle and direction of the arrows assist in determining the lead-lag structure. In particular, the arrows that are directed straight up, right-up, or left-down indicate that the first market is ahead of the second, which means that the changes in the first market are ahead of the changes in the second. On the other hand, downward, left-upward, and right-downward arrows show that the second market is dominating the first.

Figure 4.10 to 4.15 illustrates the co-movement between APEC stock markets and Energy, Technology, Gold and Green Bond markets across various countries. The analysis reveals a significant increase in co-movement during major crises, such as the Russia–Ukraine conflict and the COVID-19 pandemic. This observation aligns with the findings of Creti et al. (2013), who argue that the financialization of energy commodities marked by increased participation of financial investors and the integration of commodities into diversified investment portfolios—has strengthened the linkages between energy and equity markets, particularly following the Global Financial Crisis.

The wavelet coherence analysis also shows that the magnitude and direction of co-movement is not constant across time horizons and frequency bands. Short-term movements can be seen as the short-term response of the market to news and events, whereas long-term trends can be seen as the long-term response of the market to underlying economic connections and structural shifts. This multi-scale approach offers a subtle insight into the changing interdependencies between financial markets and energy commodity markets.

The co-movement between APEC stock markets and Energy, Technology, Green Bonds and Gold market is highly different across countries and across different time-frequency domains in terms of nature and intensity. These variations can be explained by the varying macroeconomic situations, regulatory systems, and policy measures adopted by the respective countries in response to the local and international developments. The strength and direction of these financial linkages are influenced by factors like fiscal and monetary interventions, trade policies, energy dependency, and geopolitical positioning. The next section is a country-specific analysis of these co-movement patterns, which throws light on the role of the unique economic structure and crisis management strategies of each country in the dynamic

interactions between APEC stock markets and Energy, Technology, Green Bonds and Gold markets.



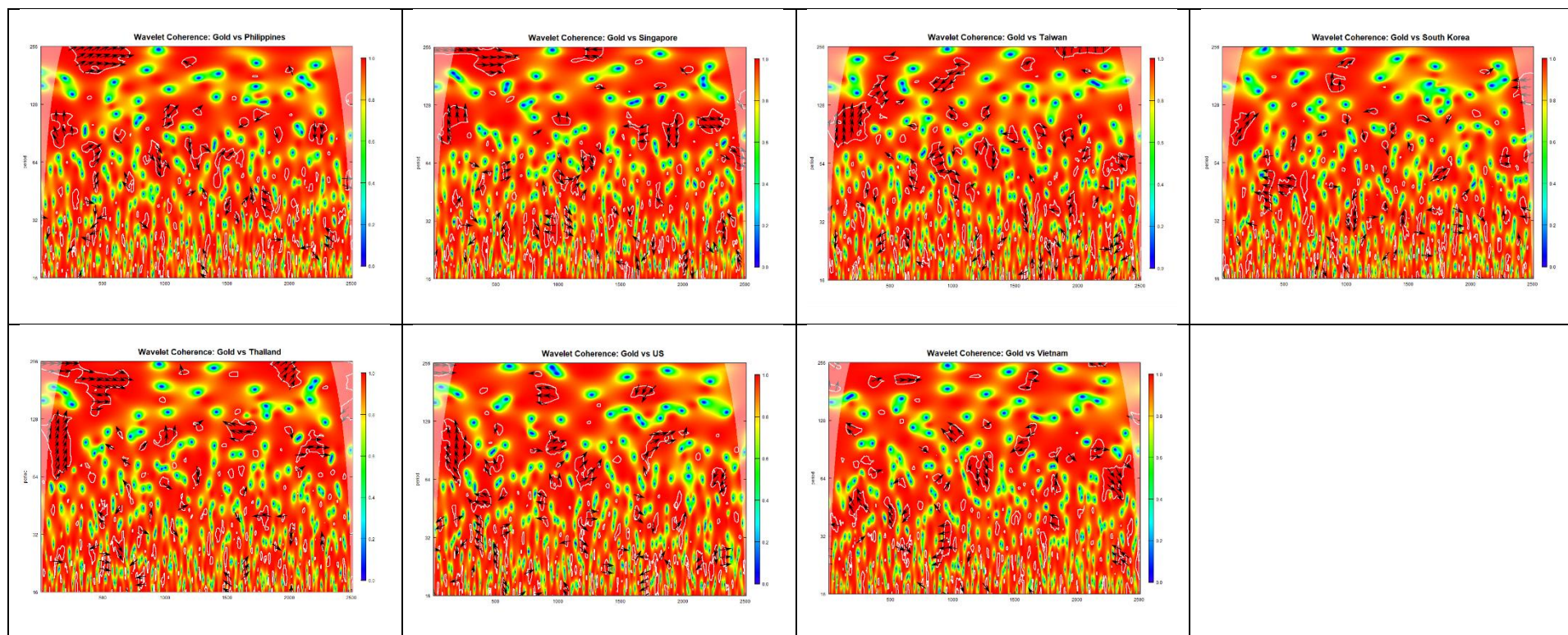


Fig. 4.10 Wavelet Coherence between Gold and APEC

4.5.1.1 Wavelet Coherence between Gold and APEC

The wavelet coherence analysis Fig. 4.10 reveals that gold consistently acted as a leading indicator for equity markets across several APEC countries during different global crises. This leadership is observed across various time horizons—short, medium, and long—and varies depending on the nature and origin of the crisis. The presence of gold as a leading variable implies that movements in gold prices preceded changes in the equity markets of these countries, offering important predictive signals for investors.

During the Oil Crisis (1–195), gold demonstrated widespread medium-term leadership across numerous APEC economies, including Canada, Australia, Chile, Singapore, Hong Kong, Taiwan, Indonesia, Thailand, Japan, South Korea, China, New Zealand, Mexico, Peru, and the Philippines. In the short term, countries like Chile, Japan, Vietnam, New Zealand, Peru, and the Philippines also experienced gold’s leading behavior. This indicates that during commodity-driven shocks, such as those arising from disruptions in oil supply, gold served as a key asset reflecting early market sentiment. Investors in these countries could have utilized gold price movements to anticipate equity downturns or volatility, positioning themselves defensively ahead of stock market reactions.

The Climate Crisis period (436–695) showed more selective leadership, with gold leading mainly in China in both short and medium terms, in Australia in the long term, and in Mexico and Peru during the medium term. This implies a more localized effect of gold, which is probably related to the exposure of each country to climate policy shifts and environmental susceptibility. As an example, in resource-rich nations like Australia and Peru, the price of gold could have reacted more quickly to environmental uncertainty or investor sentiment related to green transition risks, providing clues that equity markets subsequently internalized.

The most significant role of gold as a haven was observed during the COVID-19 pandemic (1213-1731), when it was the leader of equity markets in all horizons in the USA, Russia, Vietnam, and New Zealand (1213-1731). It also exhibited leadership in Taiwan, Japan and Philippines in two horizons. This robust leadership in the face of a global systemic crisis underscores the role of gold as a crisis hedge. The dynamics of gold prices may have been of interest to investors in these markets, as they gave early indicators of market stress, allowing them to better time exits of equity markets or defensive reallocations.

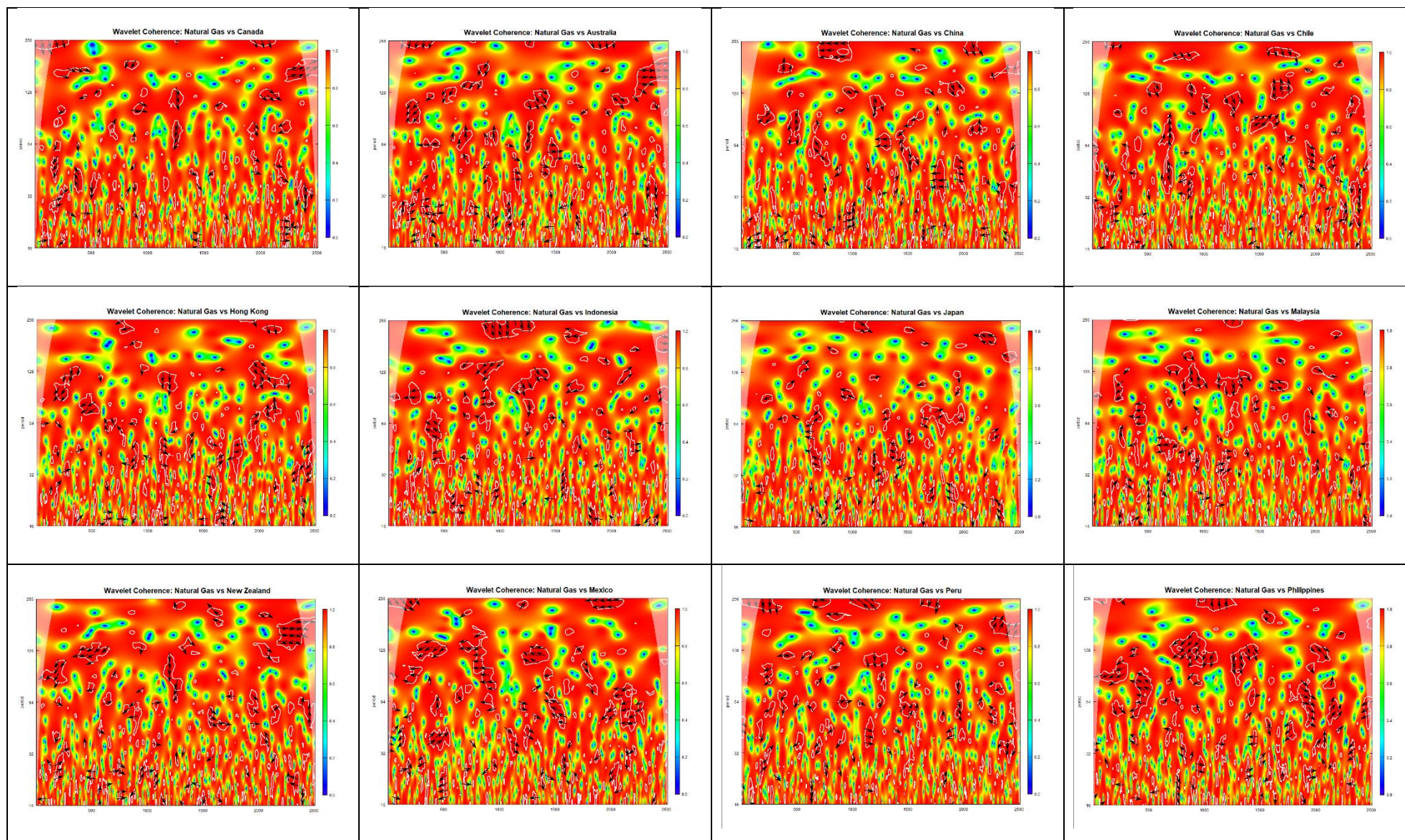
During the Russia -Ukraine War (1770-2230), the medium and long-term gold leadership was focused on Russia, the USA, Chile, Canada, and Japan. Short-term leadership was lacking,

which means that the equity market responses to this long-lasting geopolitical shock occurred on a longer time scale. To investors, particularly in such countries as Canada and Japan, this implies that gold can be used as a stable medium-term indicator of equity corrections in the event of global conflicts and help in more prudent and prospective portfolio rebalancing.

Lastly, gold showed medium-term leadership in Canada, Australia, Malaysia, and Mexico, and long-term leadership in Malaysia during the Iran-Israel War (2317-2513). This modest yet significant impact demonstrates that even geographically localized conflicts may have indirect impacts on investor behavior, and gold may capture these sentiments before equity markets adjust in certain APEC countries. To investors in these areas, this implies that they should monitor the gold prices even in conflicts that appear far away since they can indirectly affect the situation in the domestic markets.

To conclude, gold proves to be an effective leading indicator of APEC equity markets in times of global crisis. It is particularly powerful in the medium term, and its impact is increased in the case of major systemic events like the COVID-19 pandemic or energy and geopolitical crises. Investors who want to have exposure to APEC equities must pay close attention to the movements in the price of gold because it can give early indicators of equity market stress, which can be used to make better investment decisions. The results indicate that gold is not only a safe-haven asset but also a prospective measure of market sentiment, especially in crisis-prone markets, which can be used in risk management and strategic asset allocation.

Table 4.14: Summary Table Wavelet coherence between Gold and APEC															
Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada		✓										✓			
Australia		✓				✓			✓			✓		✓	
Chile	✓	✓													
Singapore		✓													
Hong Kong		✓													
Taiwan		✓				✓		✓							
Indonesia		✓													
Thailand		✓						✓				✓			
Russia								✓	✓						
USA		✓		✓				✓	✓		✓				
Japan	✓	✓		✓		✓			✓						
South Korea		✓		✓											
Vietnam	✓						✓	✓					✓		
Malaysia		✓													
China		✓		✓								✓			✓
New Zealand	✓			✓			✓	✓							
Mexico		✓	✓											✓	
Peru		✓			✓										
Philippines		✓		✓		✓									



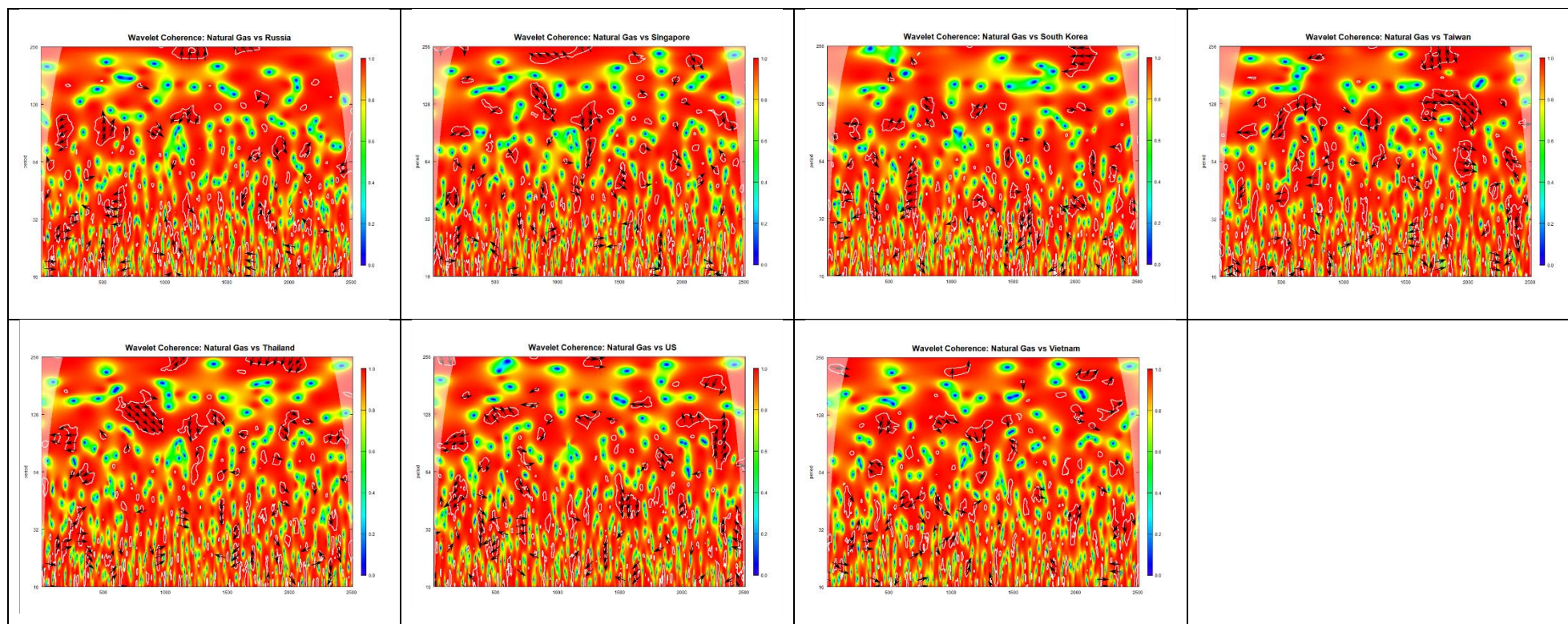


Fig. 4.11: Wavelet Coherence between Natural Gas and APEC

4.5.1.2 Wavelet Coherence between Natural Gas and APEC

The wavelet coherence analysis Fig. 4.11 for Natural Gas as a leading indicator reveals selective but significant leadership effects across APEC equity markets during major global crises. The presence of a check mark (✓) in the table indicates that natural gas prices lead the respective country's equity market at short, medium, or long-term frequencies. Such leadership suggests that fluctuations in natural gas prices precede equity market reactions, offering predictive signals to investors, especially during periods of heightened energy or geopolitical risk.

During the Oil Crisis (1–195), natural gas exhibited limited but targeted short-term leadership in Australia and Indonesia, and medium-term leadership in Malaysia. This suggests that in energy-sensitive economies—especially those involved in production or reliant on energy imports—natural gas price shocks during the oil crisis served as early indicators of equity market shifts. Investors in these countries could have interpreted rising or volatile natural gas prices as precursors to broader equity adjustments driven by energy inflation or supply concerns.

In the Climate Crisis period (436–695), natural gas again played a selective leading role, with medium-term leadership seen in Australia, USA, and Japan, and short-term leadership in China. These findings suggest that countries actively engaged in energy transition policies or facing decarbonization pressures were more sensitive to natural gas price dynamics during this period. For investors, this implies that monitoring natural gas prices during environmental or policy-driven transitions may offer foresight into equity market behavior, particularly in countries balancing between fossil fuels and renewables.

During the COVID-19 pandemic (1213–1731), the leadership of natural gas was limited to a few countries, with short-term leadership in Australia and Indonesia, and medium-term leadership in Indonesia and Mexico. The influence of natural gas here appears to have been more regional and tied to local market structures or energy dependency. Investors in these countries may have used movements in natural gas as leading signals to adjust positions in industrial or energy-intensive sectors that were more exposed to pandemic-induced disruptions.

In the Russia–Ukraine War period (1770–2230), natural gas led only in the short term for Chile, and in the medium term for Vietnam. This is noteworthy because the war had substantial implications for global gas markets, particularly in Europe. The limited leadership in APEC countries may reflect regional differences in exposure, although in cases like

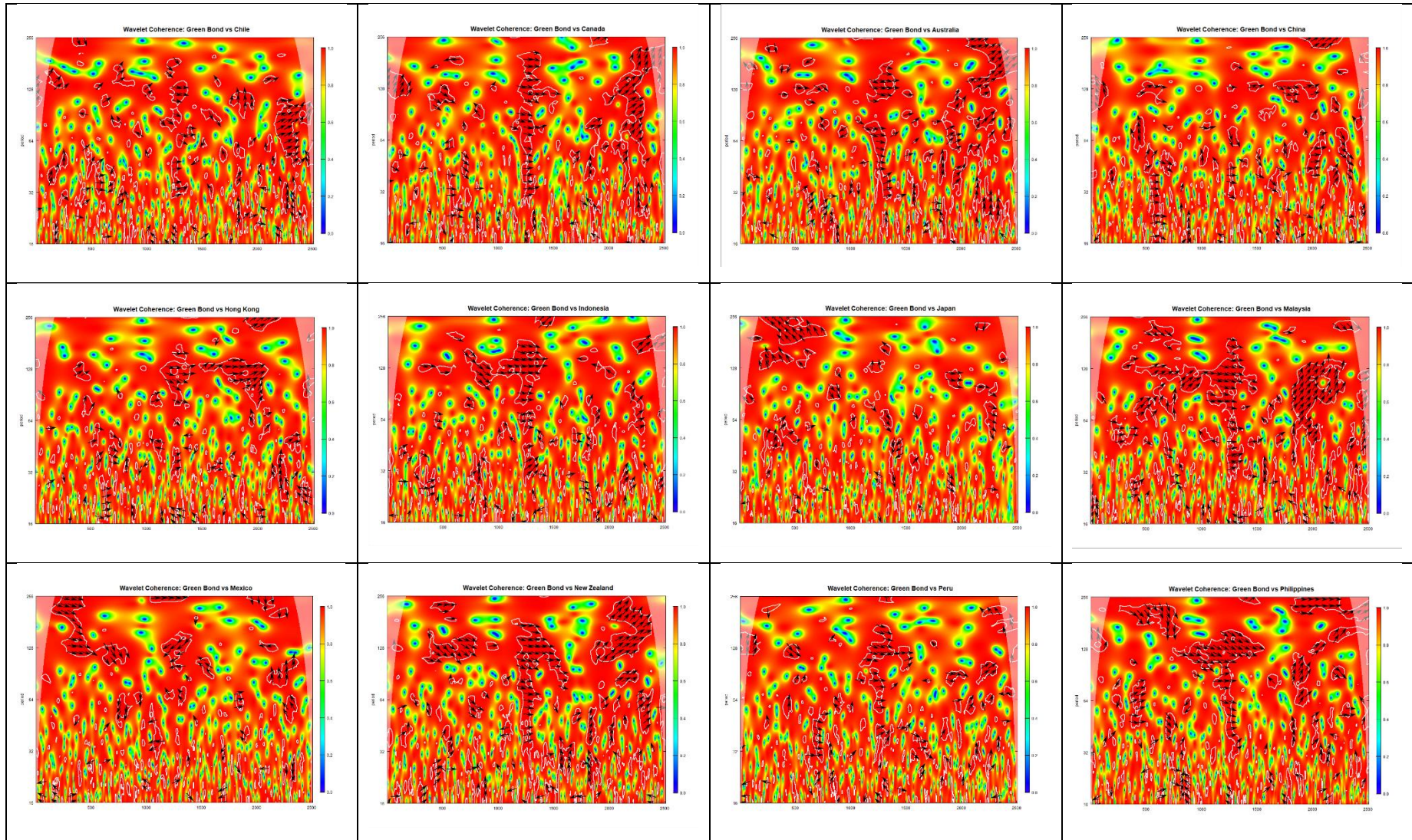
Vietnam, the medium-term leadership indicates natural gas price volatility had some spillover effect on equity performance. Investors in countries like Vietnam and Chile could have tracked natural gas movements as indicators of potential downstream equity impacts, especially in energy, transport, or manufacturing sectors.

Finally, during the Iran–Israel War (2317–2513), natural gas displayed long-term leadership in Canada and Australia, and medium-term leadership in the USA. This could be an indication of the overall financial market mood in the face of extended geopolitical tensions, with natural gas still being used in investor hedging activity or economic anticipation. To the investors in North American and Pacific nations, the results indicate that natural gas may affect equity expectations in the event of a long-term regional conflict, especially when energy routes or supply chains are involved.

In conclusion, natural gas shows a more selective but meaningful leadership role compared to gold. Its influence is strongest during periods with direct energy market implications, such as oil and climate crises. Unlike gold, which acts as a universal hedge, natural gas leadership is more region- and event-specific, with time-frequency dynamics that vary across crises. For investors targeting APEC equity markets, especially in energy-sensitive economies such as Australia, the USA, Indonesia, and Mexico, tracking natural gas price trends can serve as a useful early indicator of equity market stress or adjustment, particularly in the context of energy policy, supply disruption, or geopolitical tension.

4.15: Summary Table Wavelet coherence between Natural Gas and APEC

Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada															✓
Australia	✓			✓				✓							✓
Chile											✓				
Singapore									✓						
Hong Kong															
Taiwan															
Indonesia				✓					✓						
Thailand															
Russia															
USA					✓								✓	✓	
Japan				✓			✓								
South Korea															
Vietnam															
Malaysia				✓											
China										✓					
Mexico				✓				✓							
New Zealand										✓					
Peru									✓						✓
Philippines				✓	✓										



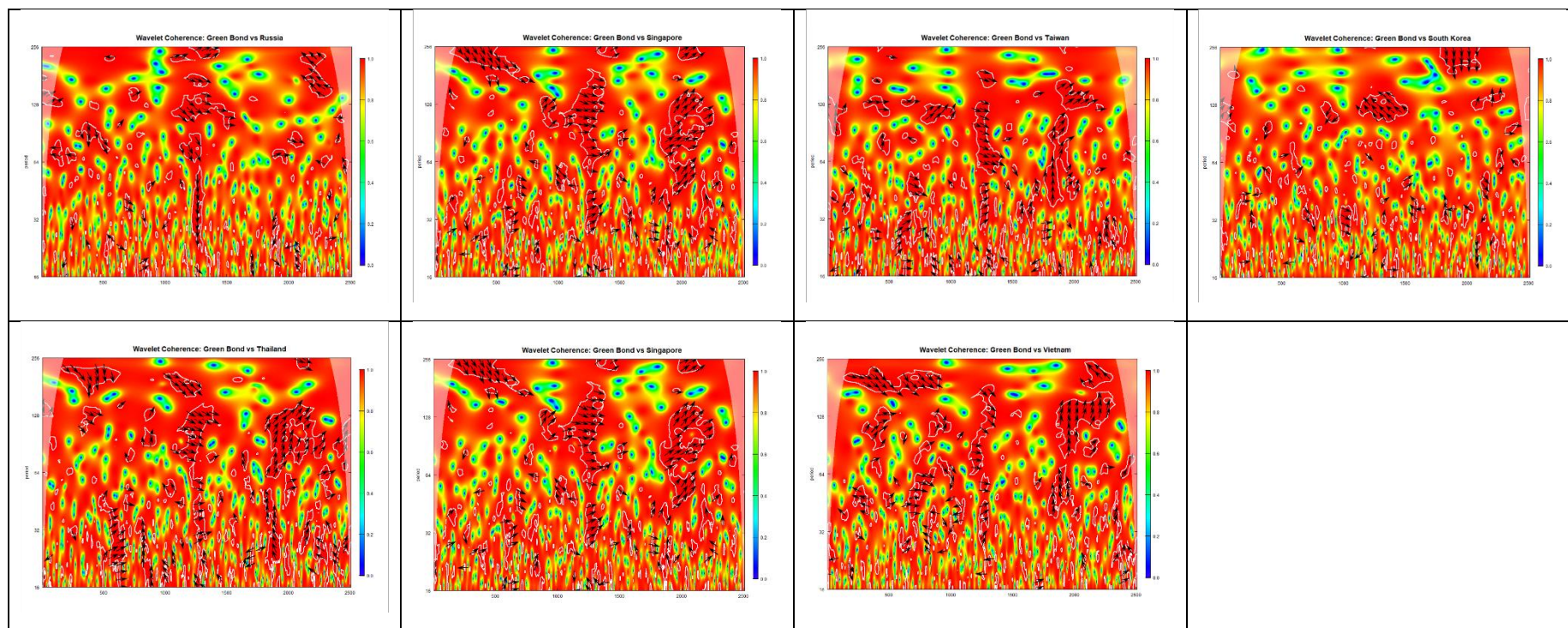


Fig. 4.12: Wavelet Coherence between Green Bonds and APEC

4.5.1.3 Wavelet Coherence between Green Bonds and APEC

The wavelet coherence analysis Fig. 4.12 for green bonds as a leading indicator presents a distinct pattern of influence across APEC countries, highlighting the evolving role of sustainable finance in shaping equity market movements. A check mark (✓) indicates periods and time horizons—short, medium, or long—during which green bonds led the respective country's stock market during major global crises. This leadership implies that changes in green bond prices or yields preceded equity market responses, providing potential early signals for investors attuned to sustainability trends, regulatory shifts, and climate-related financial risks.

During the Oil Crisis (1–195), green bonds had limited leadership. Short-term leadership was visible only in Chile, Japan, and Philippines, while medium-term leadership occurred in Canada, Australia, Chile, Hong Kong, Taiwan, Thailand, Vietnam, and Malaysia. Long-term leadership was particularly sparse, with visible impact only in Taiwan. The moderate level of green bond leadership during this period suggests that the sustainable finance market had not yet matured as a systemic barometer. However, in countries such as Malaysia and Chile, the early signs of medium-term leadership could indicate that sustainable investment instruments were beginning to influence broader financial sentiment. Investors in these markets could have used green bond price movements as soft signals of policy or regulatory reactions tied to fossil fuel dependencies and decarbonization pressures emerging from oil volatility.

In the Climate Crisis (436–695) period, green bonds demonstrated relatively stronger leadership. Short-term leadership emerged in China, while medium-term leadership was evident in USA, Japan, Malaysia, and China. Long-term leadership was again sparse but included Taiwan and Vietnam. This reinforces the idea that climate-sensitive events amplify the signaling power of green finance instruments. The markets of countries with active climate policies or carbon neutrality commitments were more likely to react to shifts in green bond dynamics. For investors in these regions, particularly in East and Southeast Asia, green bond movements could have served as a forward-looking gauge for equity market sensitivity to environmental transition risks.

During the COVID-19 pandemic (1213–1731), green bond leadership became more visible. Australia, Indonesia, Vietnam, and Malaysia all exhibited medium-term leadership, and countries like Vietnam, Malaysia, and New Zealand showed long-term leadership. This reflects a shift in how investors perceived green bonds—not just as tools for climate mitigation, but also as instruments of resilience during health-induced economic stress.

Investors in these economies may have relied on green bond pricing as an early signal for safe assets or sectors expected to perform under sustainable recovery agendas, particularly where governments promoted green stimulus programs.

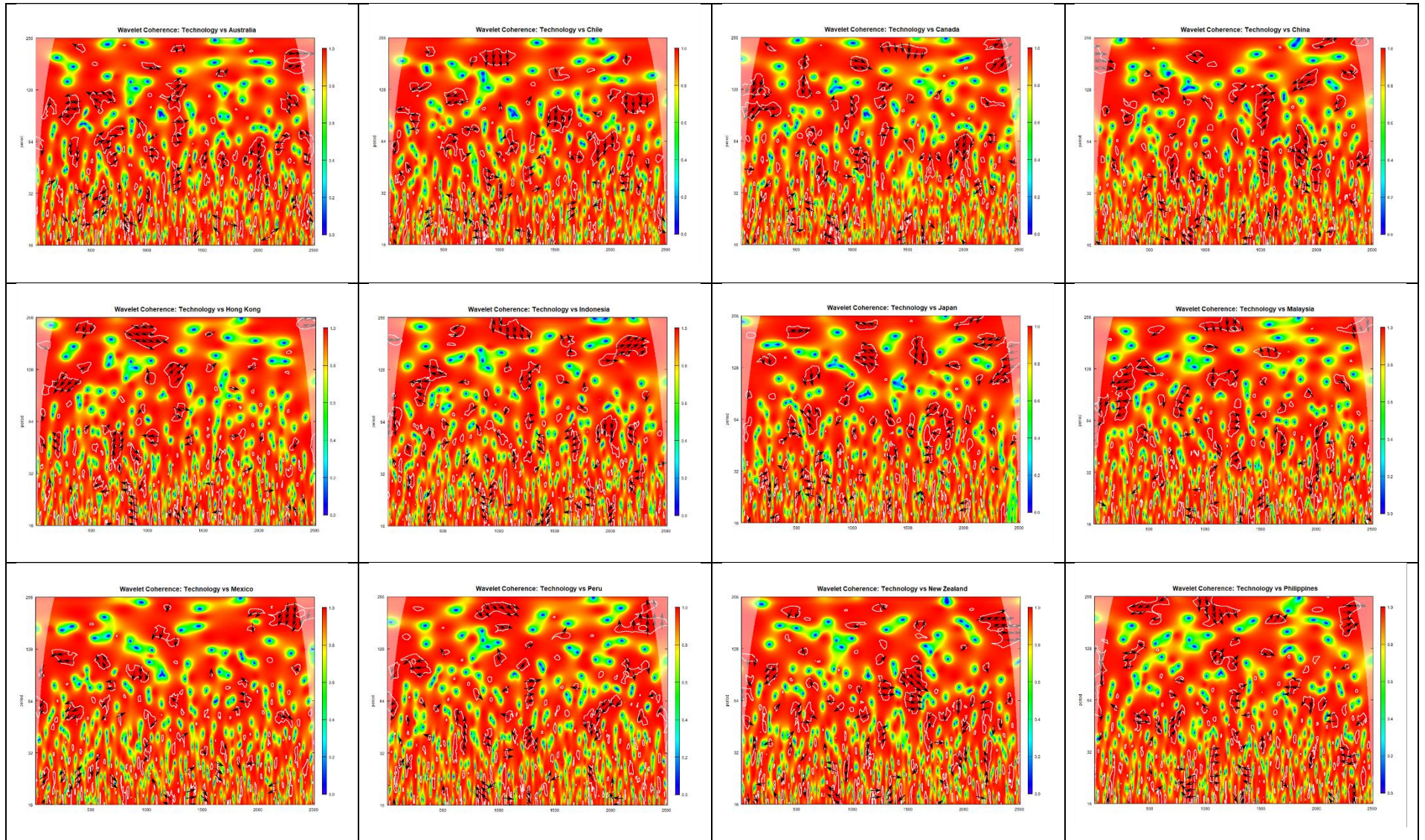
In the Russia–Ukraine War (1770–2230), the leadership of green bonds expanded, with short-term influence seen in Singapore, Hong Kong, and Vietnam, and medium-term leadership in Hong Kong, Taiwan, Thailand, Vietnam, and Malaysia. Long-term leadership was strongest in Vietnam, Malaysia, and New Zealand. The war’s implications for global energy transition and European carbon policies may have increased global sensitivity to green bond markets, especially in Asia-Pacific regions seeking to align with climate goals while navigating energy price volatility. Investors in these markets may have increasingly viewed green bonds as a predictive indicator of sectoral shifts, particularly in renewable energy, infrastructure, and ESG-compliant stocks.

Finally, during the Iran–Israel War (2317–2513), green bonds exhibited widespread leadership in Canada, Australia, Chile, Indonesia, Thailand, Malaysia, Mexico, New Zealand, and Philippines, across all time horizons. This implies an increasing maturity and internationalization of green finance, where green bonds have now started to affect even long-term investor expectations in geopolitical crises. In the case of countries such as Canada and Australia, where the resource and defense industries are predominant, the green bond leadership in equity markets is an indication of greater responsiveness to ESG stories and global sustainability demands. In Southeast Asian economies like the Philippines and Malaysia, green bond leadership is a sign of increased investor interest in sustainable investment structures and the possible inclusion of climate-related risks in equity valuations.

To sum up, green bonds are becoming an important leading indicator of equity markets in the APEC countries, especially in times of crisis related to climate, energy, or geopolitical changes. They have different predictive abilities over time horizons and are particularly high in countries that are actively pursuing sustainability agendas or are integrated into global ESG investment flows. To investors, the results highlight the need to track the dynamics of the green bond market as a component of a larger plan to predict the behavior of the equity market. The findings also support the position of green bonds as not just climate finance tools but also macro-financial instruments that affect risk pricing, investor sentiment, and sustainable capital allocation in the Asia-Pacific region.

4.16 Summary Table Wavelet coherence between Green Bonds and APEC

Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada			✓										✓	✓	✓
Australia				✓			✓						✓	✓	✓
Chile	✓			✓							✓		✓	✓	
Singapore							✓			✓	✓	✓			
Hong Kong				✓							✓	✓	✓		
Taiwan				✓		✓	✓				✓	✓			
Indonesia							✓						✓	✓	✓
Thailand				✓						✓	✓				
Russia															✓
USA					✓								✓	✓	
Japan				✓		✓									
South Korea								✓							
Vietnam				✓			✓	✓		✓	✓	✓			
Malaysia				✓	✓			✓			✓			✓	
China					✓										✓
Mexico														✓	
New Zealand				✓						✓			✓	✓	✓
Peru			✓											✓	✓
Philippines				✓							✓				✓



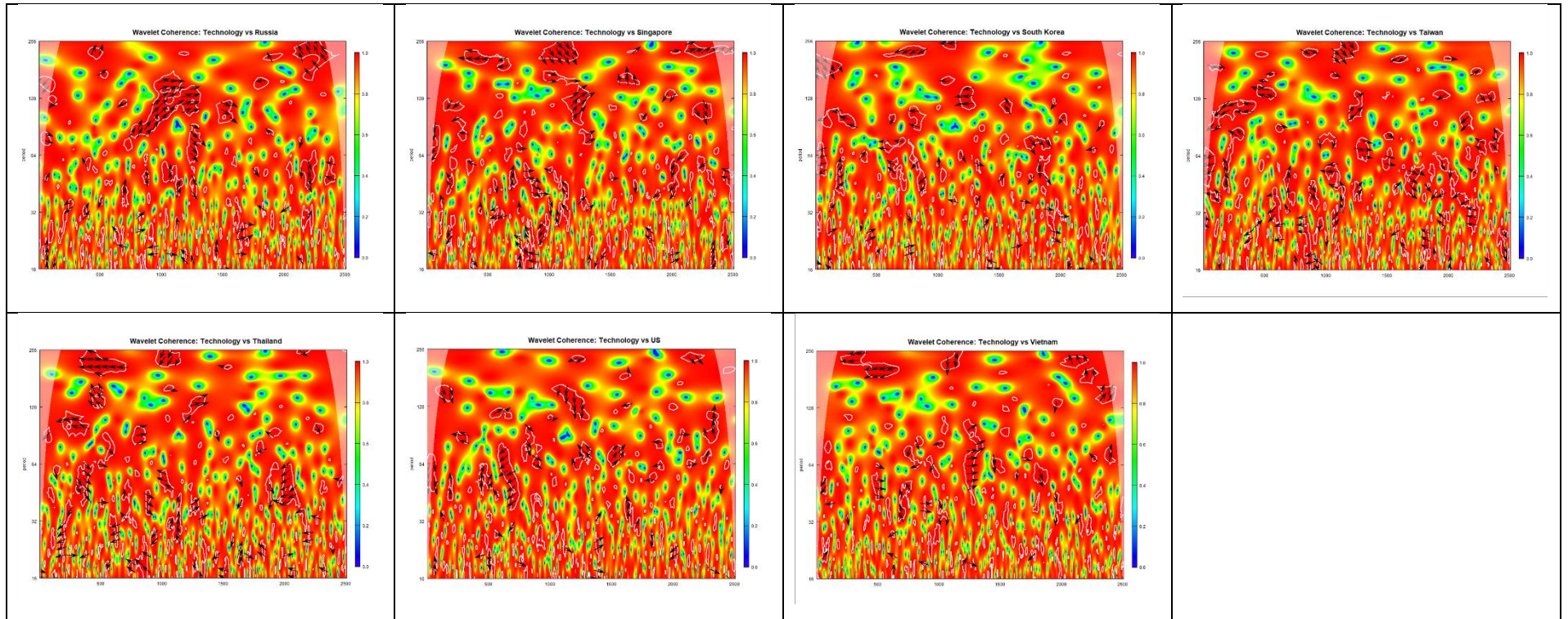


Fig. 4.13: Wavelet Coherence between Technology and APEC

4.5.1.4 Wavelet Coherence between Technology and APEC

The wavelet coherence analysis fig. 4.13 for technology as a leading indicator reveals its evolving and event-sensitive influence on APEC equity markets across five major global crises. A check mark (✓) in the table denotes that technology led the respective country's equity market at a given time horizon (short, medium, or long). Such leadership implies that shifts in the technology sector—whether reflected through innovation trends, digital transformation, or tech index movements—preceded equity market responses in these economies. This insight holds value for investors, as technology represents both a sectoral growth engine and a broader market sentiment gauge during periods of systemic disruption or transformation.

During the Oil Crisis (1–195), the role of technology as a leading force was limited, showing only medium-term leadership in Canada and Australia, and short-term leadership in Chile, Japan, and Malaysia. This pattern suggests that even in energy-driven crises, technology exerted early influence in some advanced and emerging markets, likely due to its indirect role in energy efficiency, automation, and digital innovation. For investors, this leadership highlights how even in traditional crises, like oil supply shocks, the performance of tech firms (especially those working on alternative energy solutions or infrastructure optimization) may serve as forward signals for broader market movements.

In the Climate Crisis period (436–695), technology leadership became more visible. It showed short-term leadership in Chile, Singapore, and Hong Kong, and medium-term leadership in Australia, USA, and Vietnam. Notably, Australia and the USA—both active in renewable tech development—exhibited medium-term tech leadership, reflecting investor expectations tied to climate innovation and green technology investments. Investors in these markets may have increasingly tracked the tech sector for cues on how equity markets were likely to respond to emerging climate finance frameworks or regulatory reforms aimed at carbon reduction.

During the COVID-19 pandemic (1213–1731), technology displayed its most robust leadership. It led in medium term for Canada, Indonesia, and Japan, and in the short term for Singapore and Indonesia. The pandemic catalyzed a surge in tech adoption across sectors—from remote work and e-commerce to digital finance and healthcare technology. Equity markets in these countries responded to tech-driven adaptations and disruptions, making the sector an important early indicator of resilience and recovery trends. Investors in Indonesia,

Singapore, and Japan could have used tech movements to position for pandemic winners or sector rotation in equities as the crisis evolved.

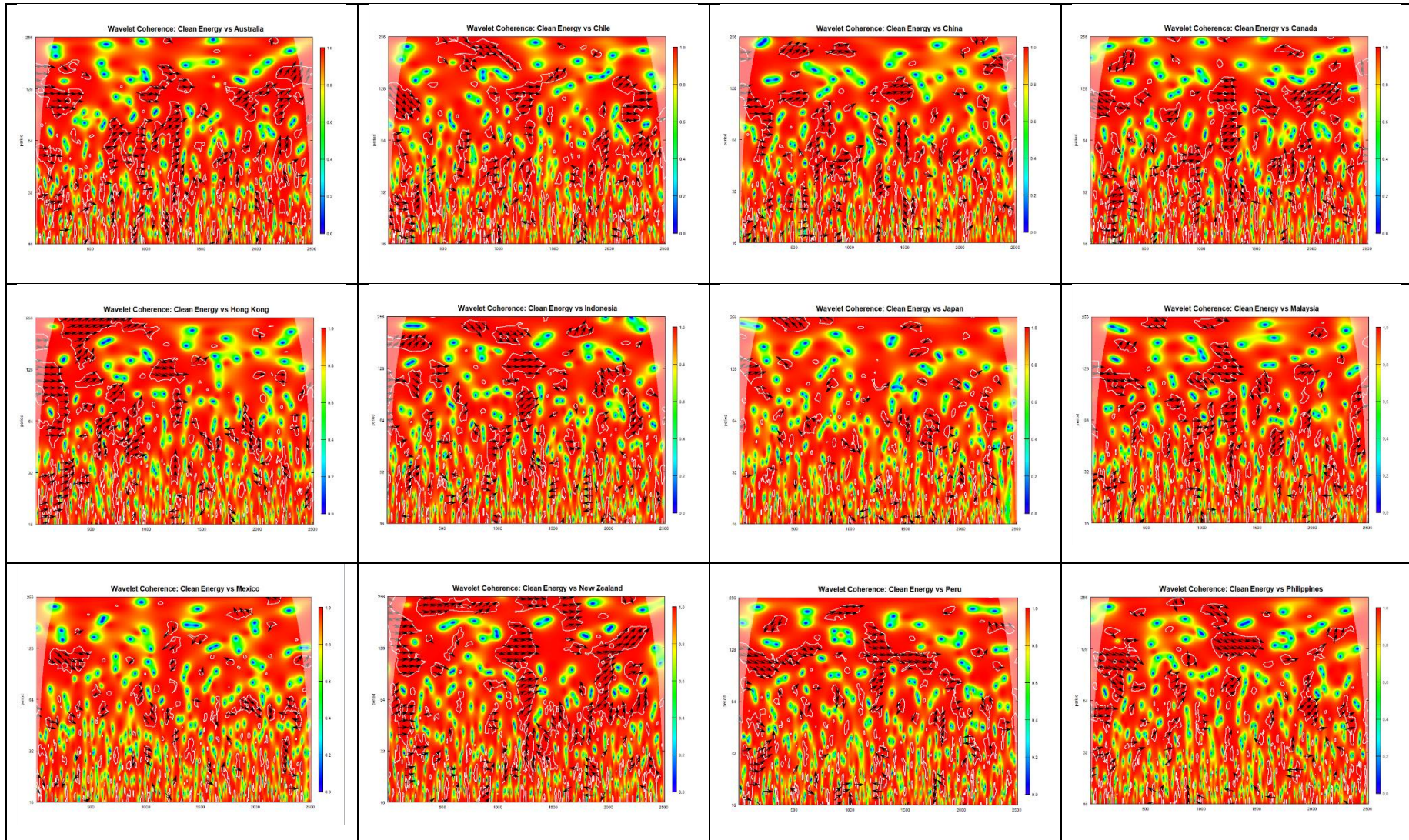
During the Russia Ukraine War (1770-2230), the technological leadership was low but locally important. Tech was the leader in short term in Russia, medium term in the USA, and long term in China and the Philippines. The geopolitical tension also had significant implications on cybersecurity, semiconductors, and digital infrastructure resilience, which could have been the factors that pushed tech performance before equity market changes. In other countries, such as China and the Philippines, the long-term leadership implies that markets were priced on tech-related geopolitical factors, including supply chain disruptions or defense-tech innovation. The behavior of the technology sector in these countries might have been viewed by investors as a long-horizon indicator of changes in equity valuations related to national security and strategic autonomy themes.

Lastly, the leadership of technology in long term was experienced in Canada, Australia, and Indonesia, and in medium term in China and Vietnam during the Iran-Israel War (2317-2513). This shows that there is a continued appreciation of tech as a structural growth theme despite geopolitical uncertainty. Investor sentiment was probably motivated by the role of tech in surveillance, AI, energy-tech applications, and digital resilience. In the case of markets like China and Vietnam, medium-term leadership means that the technology industry was a strategic positioning and policy alignment to the global economic realignments due to conflicts. In Australia and Canada, the long-term tech leadership highlights the way developed markets incorporate the expectations of innovation into equity performance over long periods.

In conclusion, the technology sector has grown into a strategically influential and forward-looking signal for APEC equity markets during global crises. While its leadership is crisis-contingent, the consistent appearance across various events—especially during COVID-19 and climate-related crises—suggests that technology has become a key anticipatory asset class. For investors, tracking the performance and innovation cycles of technology firms offers not only sectoral alpha but also broader market timing advantages. In a world increasingly shaped by digital transformation, geopolitical tech competition, and climate tech adoption, technology's role as a leading indicator will likely intensify across emerging and developed APEC markets alike

4.17: Summary Table Wavelet coherence between Technology and APEC

Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada				✓			✓								✓
Australia				✓	✓		✓	✓							
Chile															
Singapore				✓				✓							✓
Hong Kong				✓											
Taiwan															
Indonesia								✓							✓
Thailand															
Russia								✓							✓
USA						✓								✓	
Japan				✓	✓				✓						
South Korea															
Vietnam						✓									✓
Malaysia				✓											
China										✓					
Mexico															
New Zealand															✓
Peru				✓											✓
Philippines															



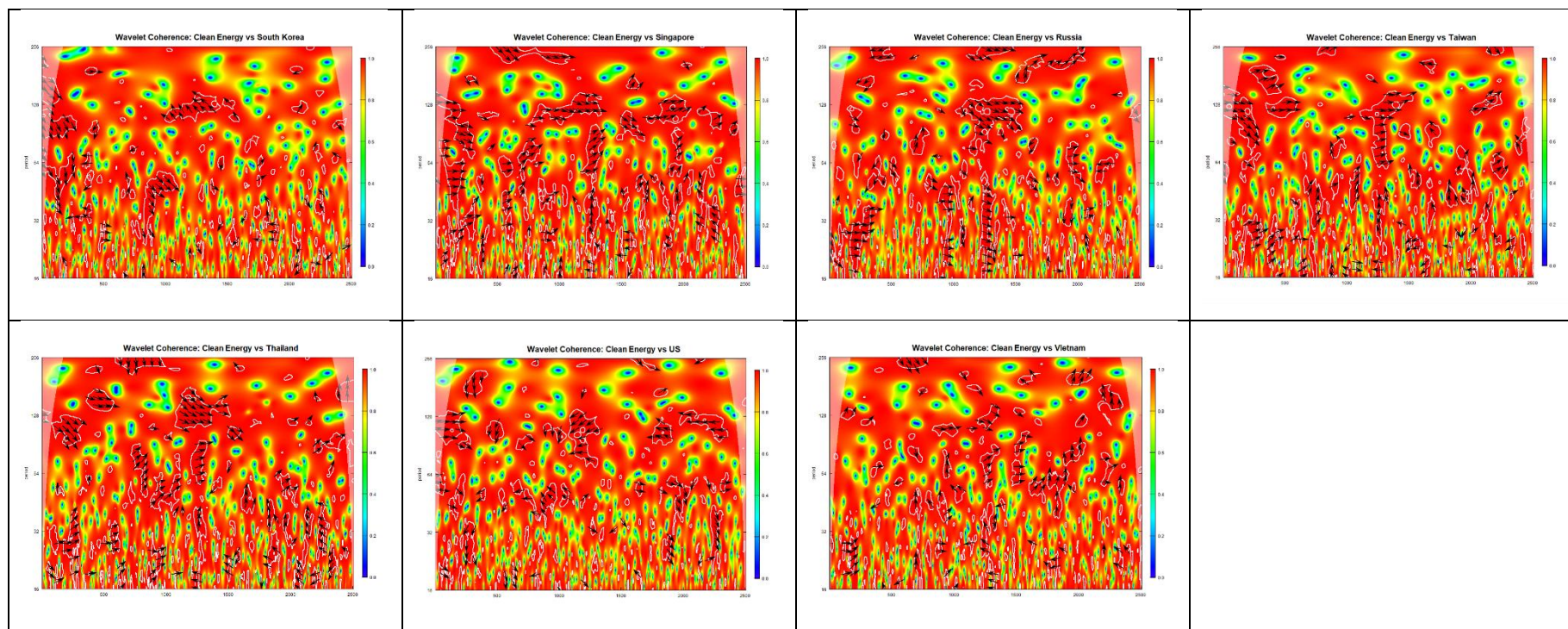


Fig. 4.14 Wavelet Coherence between Clean Energy and APEC

4.5.1.5 Wavelet Coherence between Clean Energy and APEC

The wavelet coherence analysis Fig. 4.14 for clean energy as a leading indicator across APEC equity markets highlights its growing role in forecasting market movements during global crises. A tick (✓) in the table indicates that clean energy led the respective country's equity market at a particular time frequency (short, medium, or long) during major global events. The emergence of clean energy as a market leader reflects its strategic importance not only in addressing climate change but also in driving investor sentiment, energy security strategies, and long-term sustainability transitions.

During the Oil Crisis (1–195), clean energy showed leadership across several economies, including Canada, Australia, Hong Kong, Taiwan, Thailand, Malaysia, China, and Vietnam, primarily in the short and medium terms. Notably, Australia and China exhibited both short- and medium-term leadership, while Malaysia and Taiwan also had medium-term influences. This pattern implies that early signals from clean energy markets—possibly linked to interest in alternatives during fossil fuel shocks—preceded adjustments in equity markets of energy-importing or transitioning economies. For investors, this highlights clean energy's role in reflecting anticipated policy shifts or technological substitution, offering forward-looking cues even during oil-dominated crises.

In the Climate Crisis period (436–695), clean energy exhibited widespread and consistent leadership. Countries like Chile, Singapore, Hong Kong, Taiwan, China, and Vietnam showed either short- or medium-term responsiveness to clean energy signals, with China and Vietnam standing out for exhibiting both short- and medium-term coherence. This strong influence underscores the increased attention to decarbonization, renewable infrastructure, and ESG-aligned investment during climate-driven transitions. Investors in these economies could have benefited from tracking clean energy trends to anticipate how climate legislation or public sustainability discourse might affect equity valuations, particularly in energy, industrials, and transport sectors.

During the COVID-19 pandemic (1213–1731), clean energy leadership continued across a more selective set of markets, notably Australia, China, Indonesia, and Vietnam, particularly in the medium term. Clean energy stocks may have represented both safe-haven and recovery-oriented investments, benefiting from global green stimulus programs and post-COVID sustainability narratives. The presence of medium-term leadership during the pandemic suggests that clean energy sectors were perceived as a structural growth story, even during short-term economic disruptions. Investors could have used this signal to rotate capital

toward sectors expected to benefit from long-term decarbonization and energy transformation.

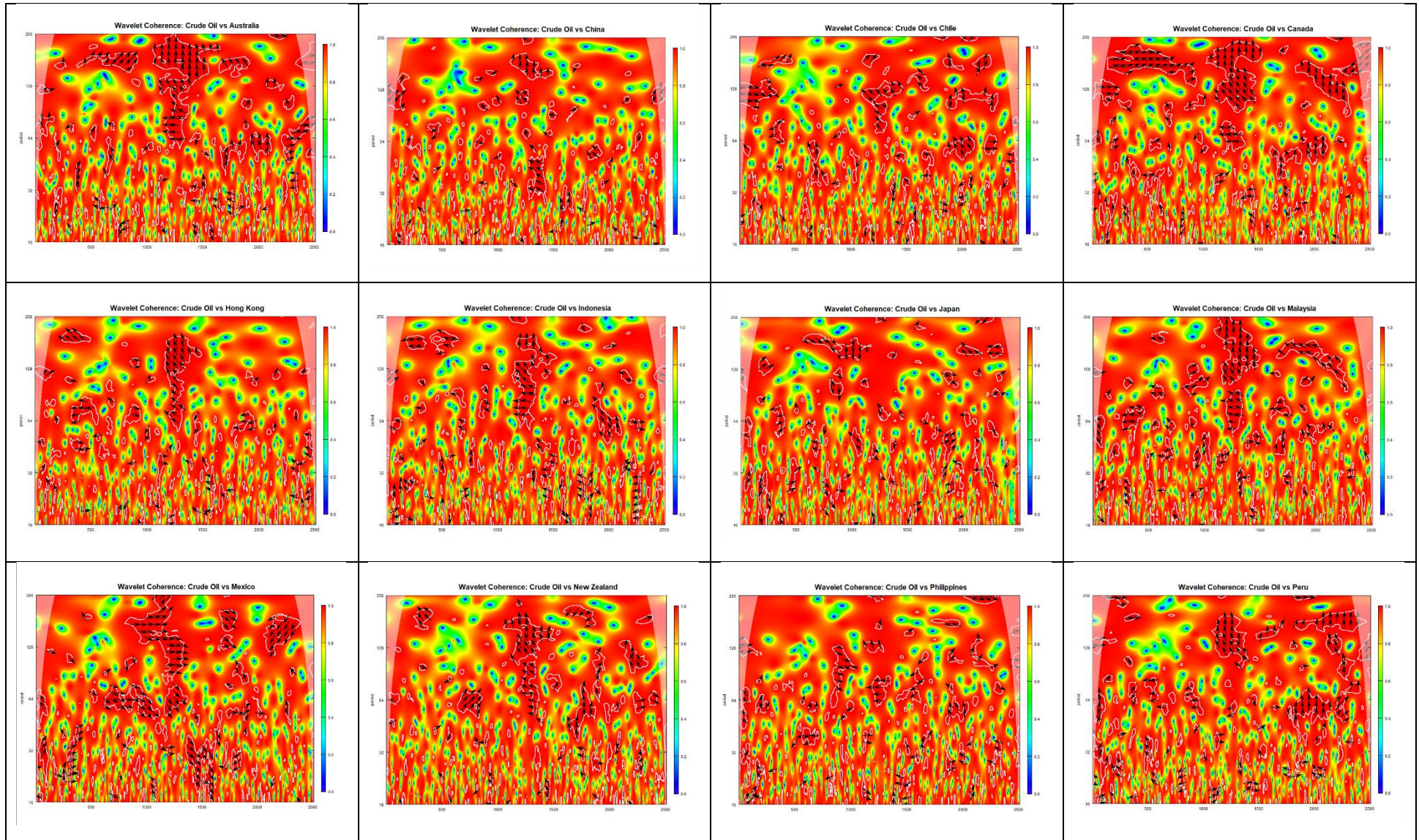
The strategic significance of clean energy was increased during the Russia Ukraine War period (17702230). Australia, Chile, Singapore, Hong Kong, Taiwan, Indonesia, China, and Vietnam were countries that demonstrated leadership in all horizons. This is indicative of the increased importance of clean energy in the context of geopolitical shocks in conventional energy markets. The long-term leadership that has been witnessed in Taiwan and Vietnam is probably the anticipation of the investors in the change of policy to energy independence and sustainable infrastructure development. To investors in these areas, the dynamics of clean energy markets provided important early indicators of changing sectoral dynamics and rebalancing of investments associated with energy diversification and resilience.

Lastly, clean energy remained dominant in Canada, Australia, Chile, Singapore, Hong Kong, Indonesia, China, Mexico, Peru, and the Philippines in the Iran-Israel War (2317-2513). The fact that clean energy leadership is present in developing economies like Mexico, Peru, and the Philippines, particularly at the long horizon, is an indication of the globalization of clean energy finance and its growing incorporation into national growth and risk stories. To investors, this implies a wider applicability of clean energy as a predictive driver, not only in established ESG markets, but also in emerging economies where green financing, infrastructure building, and international climate funds are increasingly influencing equity expectations.

In conclusion, clean energy has evolved into a robust and multi-crisis leading indicator for equity markets in APEC countries. Its leadership is evident across a broad range of geographies and time horizons, with particularly strong signals during climate-related disruptions and geopolitical energy shocks. For investors, this means that clean energy trends—reflected through sectoral ETFs, green utilities, and innovation indexes—should be monitored not only for sustainability exposure but also for broader portfolio positioning. The sector's ability to lead equity markets confirms its strategic function as both a thematic investment and a forward-looking barometer of economic transformation in the Asia-Pacific region.

4.18: Summary Table Wavelet coherence between Clean Energy and APEC

Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada	✓						✓	✓		✓	✓				
Australia	✓			✓	✓		✓	✓	✓		✓		✓	✓	✓
Chile				✓				✓		✓			✓	✓	
Singapore					✓		✓	✓			✓		✓	✓	
Hong Kong	✓			✓	✓	✓	✓			✓					
Taiwan				✓		✓		✓					✓		
Indonesia			✓	✓				✓				✓		✓	
Thailand	✓			✓				✓					✓		
Russia												✓			
USA							✓								
Japan						✓									
South Korea								✓							
Vietnam	✓									✓	✓	✓			✓
Malaysia							✓	✓		✓			✓	✓	
China				✓	✓	✓	✓	✓							✓
Mexico													✓		
New Zealand	✓					✓	✓	✓		✓				✓	
Peru	✓									✓					
Philippines										✓			✓		



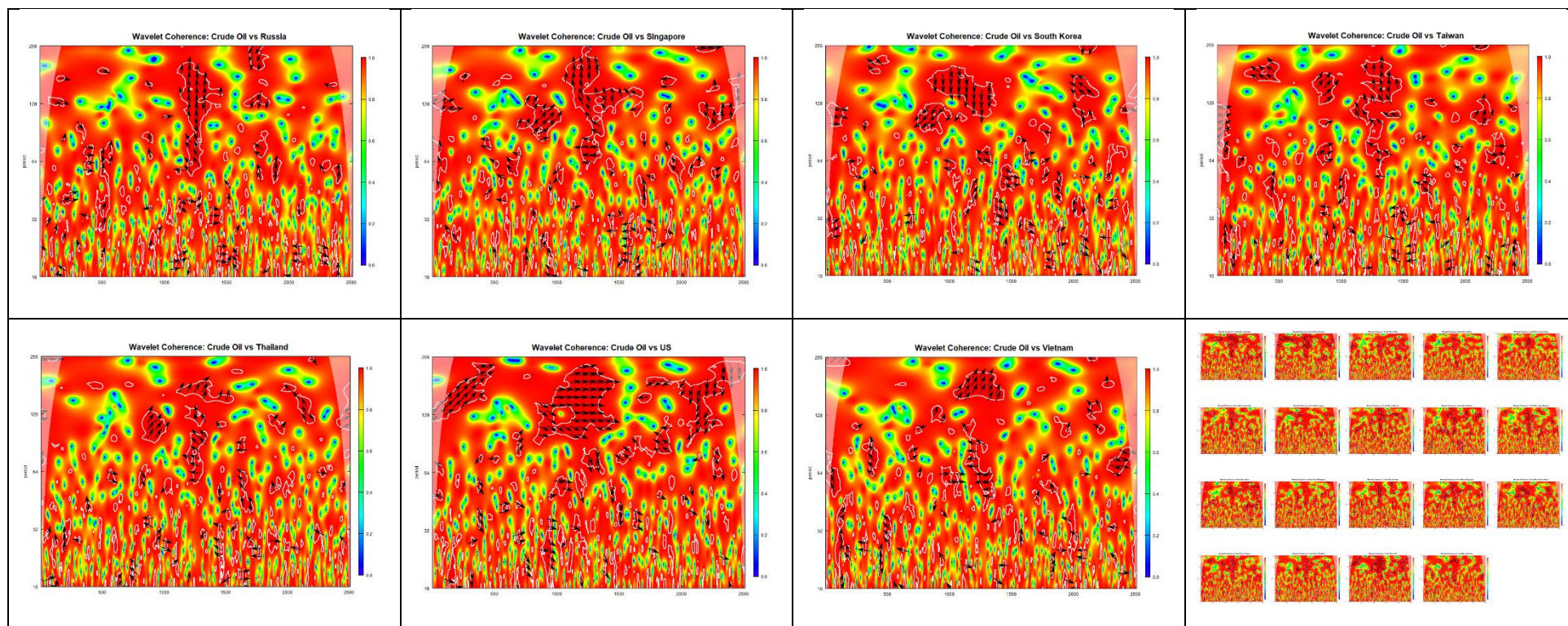


Fig. 4.15 Wavelet Coherence between Crude Oil and APEC

4.5.1.6 Wavelet Coherence between Crude Oil and APEC

The Fig. 4.15 analysis shows us that the prices of crude oil have been able to significantly affect the stock market of different APEC economies in case of major global crises and the magnitude and the length of effect was also not same among countries and also went to the different global crises. The period (1-195) recorded the effect of Oil Crisis that affected countries such as Canada, Australia, Chile, Singapore, and Mexico significantly. As both Canada and Australia are the largest energy exporters, the dominance of the crude oil was observed both in short- and medium-term indicators of the influence of alterations in the global oil prices on the economic base and the listed energy companies. Non-oil producing nations like Singapore and Chile were also influenced in a short term which could be as a result of dependence on oil imports and the exposure to market fluctuations on oil production in the world. Mexico is a major exporter of oil reflected sensitivity on medium as well as long horizons, a fact that shows that oil revenue has a long term effect on the fiscal and equity markets performance of Mexico.

During the era referred to Climate Crisis (436 to 695), the crude oil still played its dominating role over the equities markets of Canada, Australia, Singapore, China, Mexico, New Zealand, and Peru. The long- and medium-period impact of oil on such states as Canada, Australia, and China is rather likely to be caused by the wider consequences of climate policy and energy transition risks. The long-run volatility of the oil-linked stocks could be due to change the expectations of investors regarding carbon taxes, fossil fuel divestment, and regulatory environments. Countries; Singapore, New Zealand, and Mexico were more reactive in the short run, and this may be due to reaction to temporary shocks or market corrections in the form of climate-related news or fluctuations in fossil fuel prices. The medium-term sensitiveness of Peru can be attributed to the fact that it depends on export-oriented economy where the oil contribution in the mining and the infrastructure projects has contributed to make the market sensitive to the dynamics in oil costs.

Another degree of complexity was introduced with the COVID-19 pandemic, period of 1213 to 1731. In this case, there is a broad range of countries, which have once more been affected by crude oil flows, featuring Canada, Australia, Singapore, China, Mexico, New Zealand, and Peru. The most apparent impacts in short- and medium-term were experienced in Canada, Australia, and China, which implies that the energy production has been disrupted, demand has collapsed, and underlying stock prices movements during the global lockdowns. The massive drop and consequent rise of the oil prices brought about in this crisis had

repercussions that were long felt even to the net oil importers, because oil has its effects on transportation, manufacturing and inflation. The systemic characterization of oil as a global financial indicator during times of economic contractions was further confirmed by the spread of dominance of crude oil in this crisis.

The Russia Ukraine war (1770 to 2230) added more weight to the centrality of oil within the stock market history. The oil-related influences were evident in the countries like Canada, Australia, Singapore, China, Indonesia, Mexico, New Zealand, and Peru which, in many cases, were identified within several time perspectives. The geopolitical tension has caused fear of oil supply to the world as Russia is hit by sanctions and oil prices have risen as a result of disruption of supply chains. The countries administering export, such as Canada, Australia, China, and Mexico, were highly volatile since the performance of energy was intertwined with the increase in oil prices. At the same time, New Zealand and Peru had the intermediate results, indicating that the effect appeared after some certain adjustment period as the postwar increase in import prices or inflation penetrated in the stock markets. The factors that contributed to the inflationary pressures caused by the oil probably resulted in monetary policy reactions which also affected the sentiment of investors in these markets.

During the Iran-Israel war in the more recent years (2317 to 2513) the stock market effects of the crude oil and the narrower range of APEC economies, Australia, Chile, China, Mexico, and New Zealand were observed. Australia and China have remained sensitive to multi-period oil, which is an indication of long-term dependence of the two countries to oil in their manufacturing and transport industries. Chile and Mexico responded over the short-run potentially indicating immediate response of investors to unprecedented geopolitical tensions and potential risks in oil supply chain. Vulnerability to energy importations and subsequent macro-economic consequences, like inflation or current accounts adjustments, could also influence New Zealand prices during its medium term reaction.

In general, the statistics indicate that oil-producing APEC economies and particularly Canada, Australia, Mexico, and China have had crude oil prices dominating over their stock markets, especially when they were undergoing a crisis, which explored disruption of oil or geopolitical upheaval. In the meantime, importer countries of oil are equally sensitive, but in the main, the sensitivity is along the short- or medium-term, due in large part to macroeconomic vulnerability to international oil prices, currency exchange rates, and outlook inflation.

Table 4.19. Summary Table Wavelet coherence between Crude Oil and APEC

Variables	Oil Crisis (1-195)			Climate Crisis (436 to 695)			COVID -19 (1213 to 1731)			Russia Ukraine War (1770 to 2230)			Iran-Israel war (2317 to 2513)		
	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long	Short	Medium	Long
Canada						✓		✓	✓	✓					✓
Australia				✓		✓		✓	✓	✓			✓		
Chile			✓	✓				✓		✓	✓	✓			
Singapore		✓			✓										✓
Hong Kong						✓		✓	✓						
Taiwan	✓	✓				✓		✓	✓					✓	
Indonesia							✓	✓	✓	✓	✓				
Thailand					✓			✓	✓						✓
Russia								✓							
USA			✓												
Japan										✓		✓			
South Korea															✓
Vietnam	✓			✓					✓						
Malaysia	✓			✓	✓			✓	✓	✓		✓			
China		✓					✓		✓						
Mexico				✓					✓						
New Zealand			✓	✓			✓	✓	✓	✓	✓			✓	
Peru	✓			✓					✓	✓			✓	✓	✓
Philippines															

Based on the wavelet coherence output in Fig 4.10, 4.11, 4.12, 4.13, and 4.14, 4.15 the dynamic relationship between APEC equity markets and various asset classes including clean energy, green bonds, crude oil, natural gas, technology, and gold reveals several notable and time-varying patterns. These insights are crucial in understanding how different financial instruments interact with regional equity markets under varying macroeconomic and geopolitical conditions. Notably, during periods of global crises such as the oil price crash in 2016, the COVID-19 pandemic in 2020, and the geopolitical turmoil associated with the Russia-Ukraine war in 2022 the APEC equity markets demonstrated a strong co-movement with clean energy assets, especially at a coherence scale above 64. Such coherence in times of crisis is an indication of a behavioural change among investors who are increasingly matching their portfolios with sustainable investments in times of uncertainty. It also indicates an increasing policy interest in green transition policies, renewable energy policies, and low-carbon economic reforms in APEC countries. Clean energy, therefore, has not only become a growth-oriented industry but also a systemic element of the regional financial ecosystem in turbulent periods.

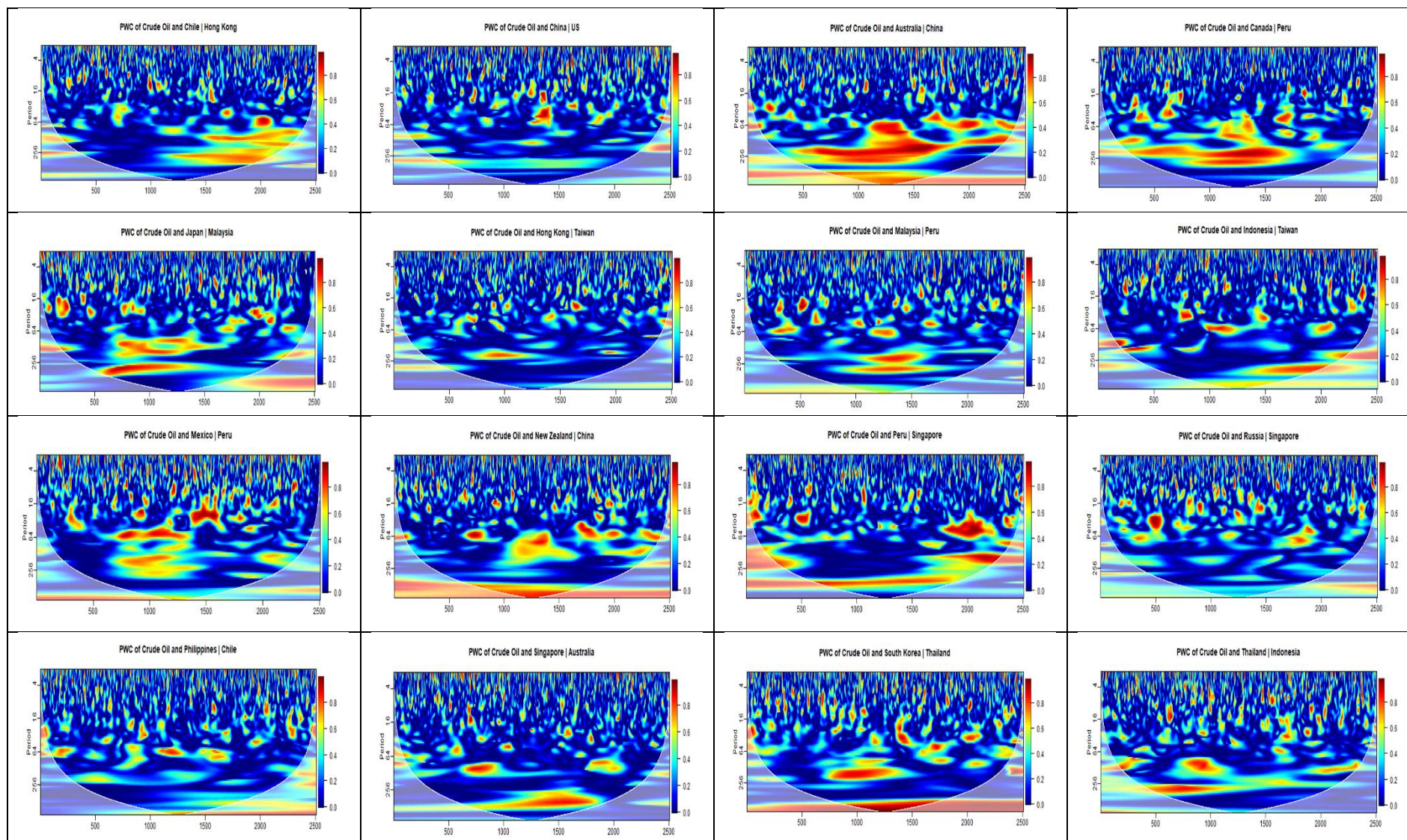
In the same way, the correlation between APEC equities and green bonds has been strengthened in the context of global stress events, which was especially noticeable during the COVID-19 pandemic and the Russia-Ukraine war. The coherence above the scale of 64 is indicative of the strategic position green bonds have started to occupy in financial markets not only as a tool of environmental financing, but also as a stabilizing asset in times of volatility. This increasing co-movement indicates that sustainable finance instruments, including green bonds, are increasingly becoming part of the mainstream equity markets, particularly in APEC economies. It is also an indication of the increased focus of institutional investors and governments on environmental, social, and governance (ESG) principles, which are transforming capital allocation structures and asset pricing dynamics.

Conversely, the correlation between APEC markets and crude oil prices is highly heterogeneous. The high coherence values especially in the case of the United States and Canada in the period 2015,2019 and in 2023 indicate the high sensitivity of these economies to changes in the price of crude oil since they are major producers and exporters of oil. This long-term correlation shows that the performance of the equity markets of these countries is highly dependent on the health of the energy sector and that the volatility of oil prices is directly transferred to the stock market. For other APEC members, particularly those that are net oil importers, the wavelet coherence results show weaker or insignificant relationships

with crude oil prices, possibly due to the diversified nature of their economies or the existence of hedging mechanisms that mitigate oil price risk at the macroeconomic level.

The coherence between APEC equity markets and natural gas is generally low, with minimal influence observed across most economies. However, long-term coherence was identified in a select group of countries Russia, Mexico, Taiwan, and New Zealand during the 2020 to 2024 period, with coherence appearing at a larger scale (above 256). This suggests that in these cases, the relationship is more structural and policy-driven rather than cyclical or speculative. These countries may have undergone energy transitions, changes in trade dynamics, or faced geopolitical pressures that affected natural gas markets and, in turn, their stock market behavior. The high scale of coherence implies deep-rooted linkages, perhaps related to infrastructure investments, energy security concerns, or long-term contracts affecting pricing and investment decisions.

4.5.2 Partial Wavelet Coherence



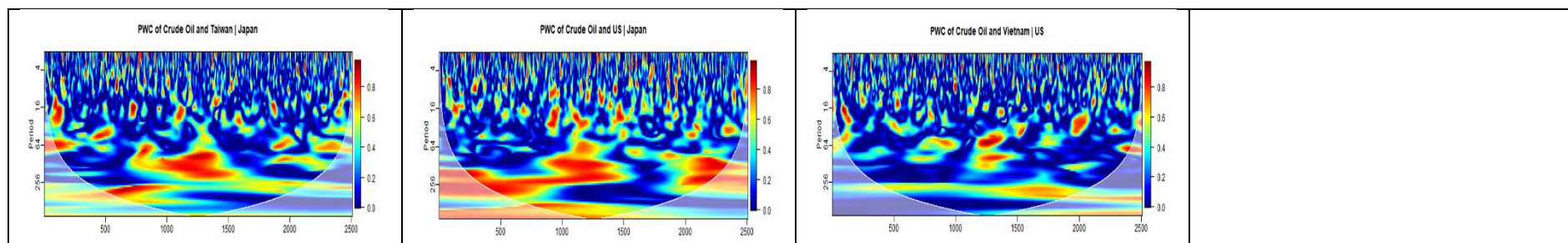


Fig. 4.16: PWC between Crude Oil and APEC

4.5.2.1 Partial Wavelet Coherence Crude Oil and APEC

The Partial Wavelet Coherence (PWC) plots in the Fig. 4.16 attached are used to robustly confirm and validate the wavelet coherence results by controlling the effect of a third variable in each of the bilateral relationships between crude oil and APEC equity markets. These PWC plots are useful in isolating the direct co-movement and lead-lag relationship between crude oil prices and country-specific stock markets, and this makes the conclusions made based on the previous full wavelet coherence results more reliable.

In all the crises examined, the PWC analysis has clearly supported the existence of statistically significant co-movements between crude oil and various APEC stock markets, even when the possible confounding effects are removed. During the Oil Crisis era (1- 195), the temporary dominance of crude oil over Vietnam, Malaysia, Taiwan, and Peru is clearly confirmed by the continuous and large coherence (red to orange areas in the (0- 64) period band) in the corresponding PWC plots. This affirms that oil shocks directly passed to these emerging economies without involving other asset dynamics, probably as a result of energy import exposure or dependence on oil-export-based income. China and Malaysia remain strongly coherent in the medium-term band (64-128), which further argues the case of structural sensitivity in these manufacturing-intensive economies. The long-term band (128- 256) of Chile and China once more shows strong coherence, which proves that oil had an effect on the long-run investor expectations and macroeconomic trends.

The Climate Crisis (436-695) PWC plots support the previous results of the wider oil dominance. The short-term results show definite high-coherence areas in Australia, Singapore, Hong Kong, Taiwan, Malaysia, and China, confirming that the uncertainty in oil prices spread to the developed and emerging equity markets in this time of global climate pressure. Thailand and the USA exhibit mid-term (64-128) coherence, which is probably caused by the increasing salience of green energy regulations and fossil fuel policies. It is worth noting that long-term coherence in Australia, Chile, Malaysia, and Taiwan in the (128- 256) band proves that the impact of crude oil was deeply rooted in the market structure and investor expectations on energy policy transition and climate risk exposure.

The PWC plots indicate a high degree of coherence with various APEC economies during the COVID-19 crisis (1213-1731), which is a strong confirmation of the previous argument of the systemic significance of oil. The short-term relationships (0-64) with Indonesia, Malaysia, New Zealand, and China are especially strong, as can be seen by the large contiguous red and orange areas. These are short-term effects that are indicative of instantaneous supply-chain

shocks and demand breakdowns. The medium-term coherence (64-128) can be observed in the plots of Canada, Australia, Chile, Hong Kong, Taiwan, Indonesia, Russia, Malaysia, Mexico, New Zealand, China, and Peru, which confirms the importance of oil as a macroeconomic indicator in the global recovery period. The consistency in the long-term frequencies also adds more weight to the fact that these equity markets were structurally in line with the oil prices during the recovery and economic recalibration phases.

During the Russia Ukraine war era (1770-2230), the PWC plots of Canada, Australia, Chile, Taiwan, Indonesia, Japan, Malaysia, Mexico, New Zealand, China, and Peru once more show strong coherence in short and medium bands. This confirms the hypothesis that investors responded to geopolitical tensions in energy markets, which had both short-run and lasting impacts on stock prices. The fact that high coherence was repeated even after the third-variable influence was controlled shows that oil was a direct transmission channel of geopolitical risk. Coherence is maintained in the long run with Chile, Indonesia, Malaysia, Mexico, New Zealand, China, and Peru, and it is clear that crude oil prices remained the key to long-term investment stories and valuation expectations in commodity-sensitive or energy-dependent markets.

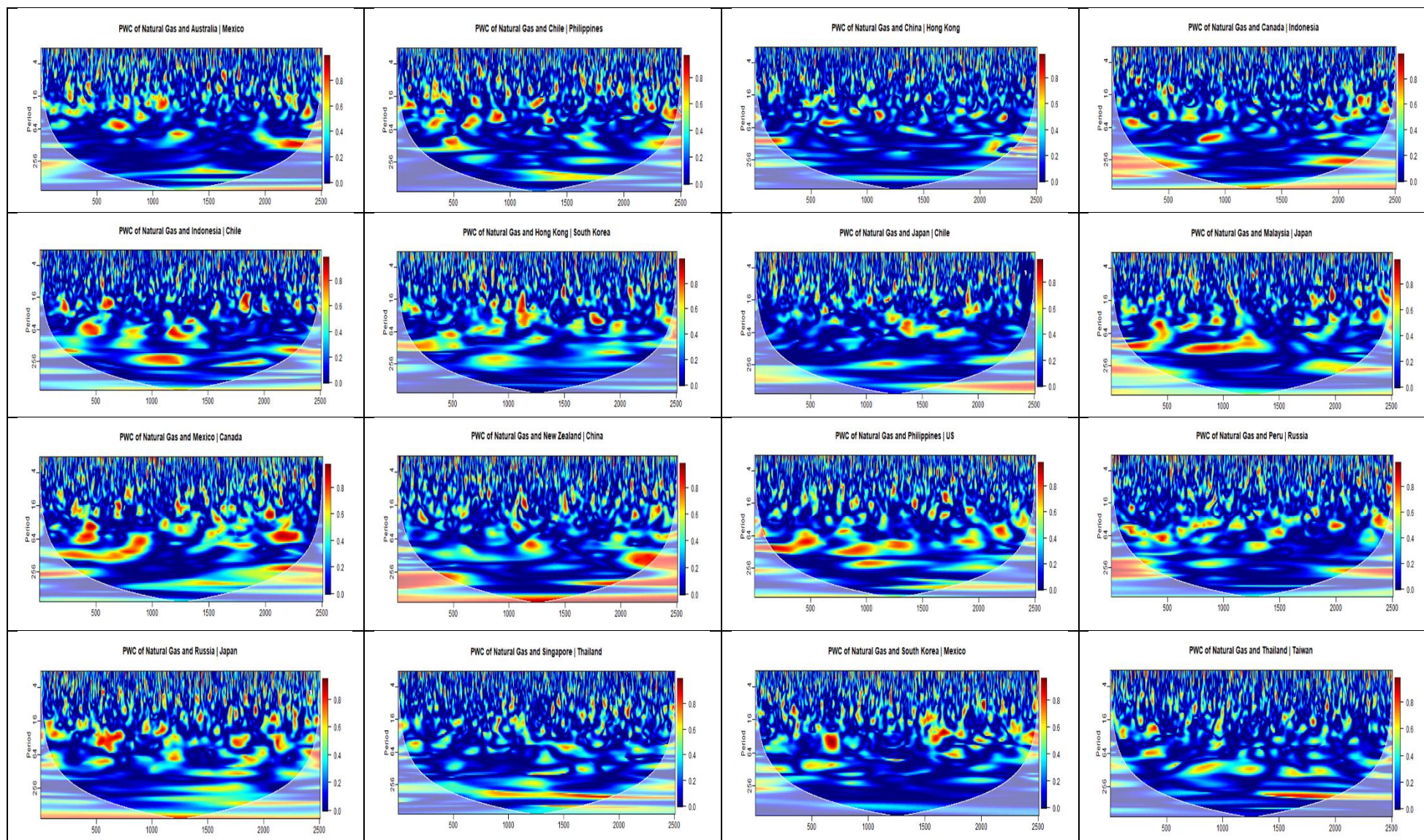
The PWC plots even in the Iran-Israel war (2317-2513), which was more localized, indicate that crude oil continued to lead financially, though to a lesser extent. The short-term coherence with Australia, Chile, New Zealand, and Peru can be observed, which means that the market reacts to the volatility of oil prices quickly. Medium-term impacts in Taiwan and New Zealand, and long-term consistency with Canada, Chile, Indonesia, China, and Peru, all indicate that crude oil is a global risk transmitter even in non-globalized conflicts, particularly in markets that are highly energy-dependent or internationally exposed. The stability of the coherence zones in these markets further confirms that oil co-movement is not spurious but structural and persistent.

In general, the PWC findings are strong corroborations of the previous wavelet coherence results. The omission of third variables (which are probably proxies of global factors or regional shocks) reinforces the conclusion that the co-movements between crude oil and APEC equity markets are direct and significant, and not caused by common influencers. This proves the asymmetric and time-varying interdependence over time scales and justifies the use of crude oil as a top macro-financial variable.

The investor implications are extensive. To short-term traders, especially in oil-sensitive markets, such as Taiwan, Malaysia, and Vietnam, PWC findings affirm that real-time oil

market monitoring must be incorporated into trading algorithms and hedging strategies. The medium-term investors will be interested in the confirmed coherence in the climate and war crises as an indication of the need to consider geopolitical and environmental risk factors in sectoral allocation and regional exposure. To long-term investors, particularly those with exposure to China, Chile, or Malaysia, the long-horizon coherence suggests that crude oil exposure ought to become a permanent component of fundamental analysis, macro overlay, and scenario testing of strategic asset allocation.

To sum up, PWC analysis not only proves the leading position of crude oil during the crisis times but also emphasizes the strength and stability of its impact on the APEC equity markets. Crude oil, therefore, must be considered as a structural co-movement anchor, which has risk transmission potential and diversification insight across time horizons and crisis regimes.



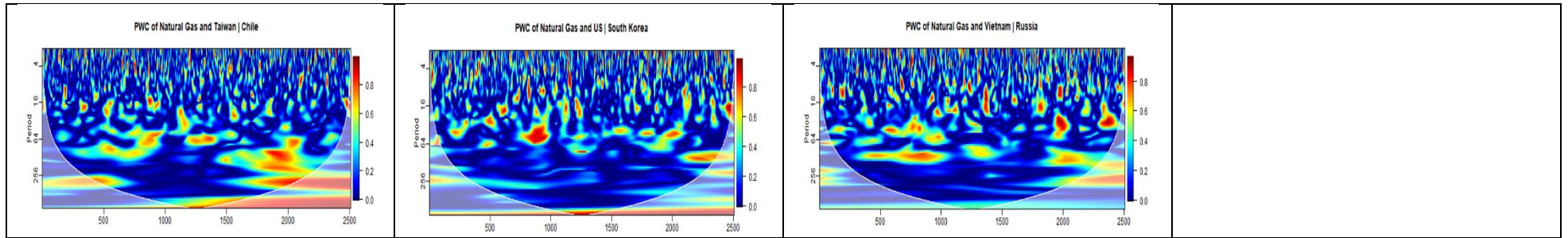


Fig. 4.17: PWC between Natural Gas and APEC

4.5.2.2 Partial Wavelet Coherence Natural Gas and APEC

The fig 4.17 Partial Wavelet Coherence (PWC) results provided on Natural Gas and APEC equity markets provide strong confirmation of the previous wavelet coherence (WC) results by statistically proving the existence of direct co-movement and leadership of natural gas on the selected stock markets despite the removal of the effect of a potential confounding third variable. These findings support the argument that natural gas, despite being more selective than crude oil, remains a non-trivial factor in the determination of equity behavior, especially when energy is volatile and in crisis.

The PWC plots between Australia and Philippines, and Indonesia and Philippines, during the Oil Crisis period (1-195) confirm the previous WC findings of short term leadership in Australia and Indonesia. The plots show that there are visible red and orange areas in the (0-64) time band, which means that there is a lot of coherence that is not caused by third variables. This confirms that the Australian and Indonesian markets were directly affected by the volatility of natural gas in the short-run, probably because they depended on imported gas or were affected by the regional production fluctuations. In the same way, the PWC plot of Peru and Malaysia indicates medium-term coherence (64-128), which confirms the WC finding that Malaysia was medium-term responsive, which may be related to its regional LNG export and pricing behavior.

During the Climate Crisis period (436-695), the PWC plots of China and Mexico, Japan and Hong Kong, and Australia and Philippines have medium-term and short-term high coherence respectively. Specifically, the high red coherence in the medium term between USA and Australia (of the Malaysia pairings) is consistent with the WC result of gas dominating in medium-term frequencies of the USA, Japan, and Australia. This consistency is observed in markets that probably responded to changes in energy policy, carbon pricing, or demand substitution in the climate transition, particularly as natural gas became a strategic fuel as a bridge to the future. The short-term plot of China Mexico also proves that China reacted to gas price volatility in the short run, which supports the argument that natural gas is a signalling mechanism to equity investors in energy-transitioning economies.

In the COVID-19 crisis (1213-1731), PWC plots of Indonesia Philippines, Peru Malaysia, and Mexico USA show evidence of short and medium-term coherence. The short-term areas that can be observed in the PWC pairing of Indonesia support the conclusion that natural gas was the leader of the Indonesian stock market in the short and medium term due to the disruptions in supply chains and energy consumption caused by the pandemic. Also, the plot

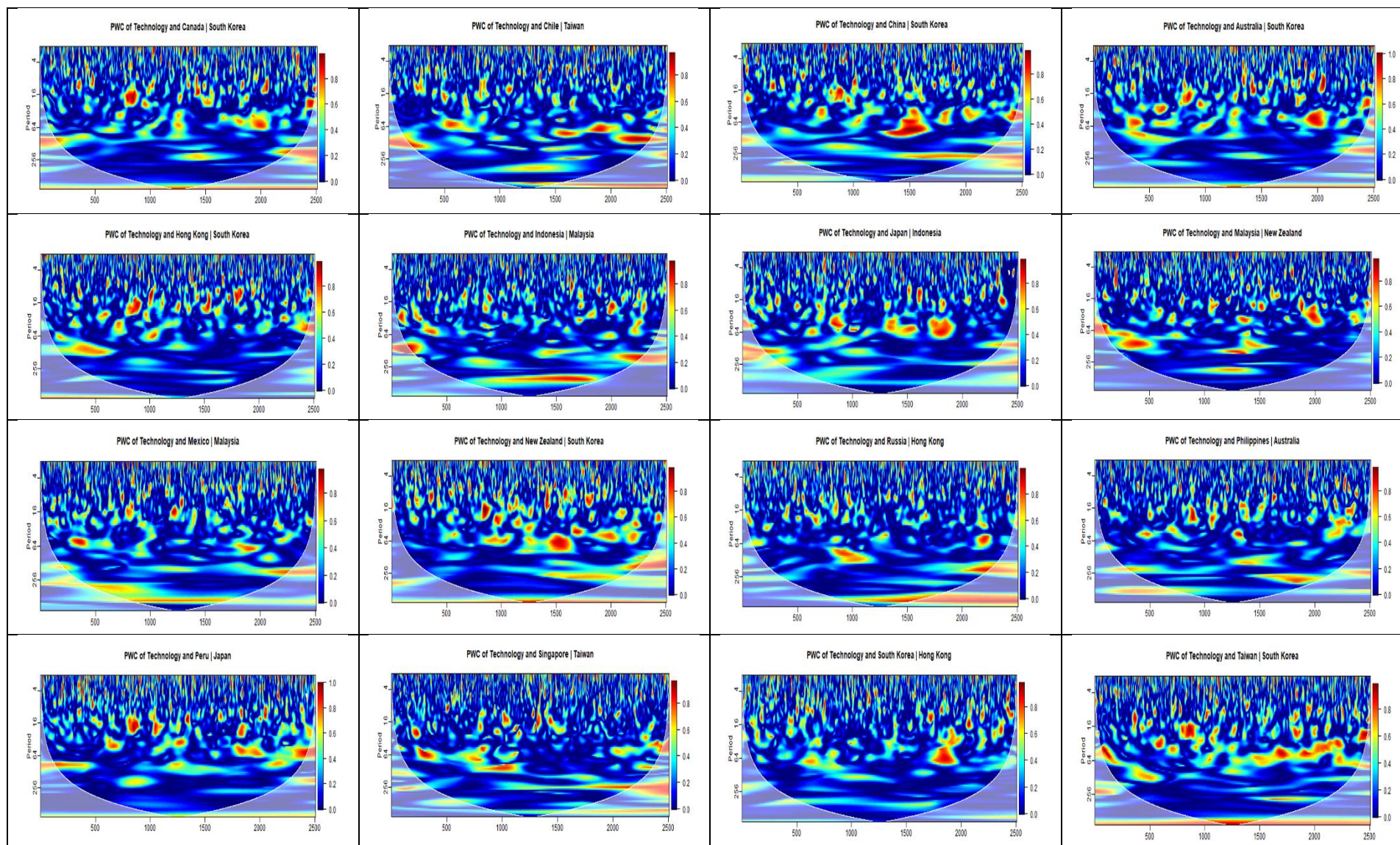
of Mexico with New Zealand and USA shows consistency in the (64-128) time band, which further confirms the medium-term exposure of Mexico, which could be because of the demand-side forces in North America during the lockdown and reopening periods.

During the Russia Ukraine war (1770-2230), gas was a more prevalent concern in Europe, but the PWC plots confirm the WC results with short-term coherence in Chile and medium-term coherence in Vietnam. In particular, the plot between Vietnam and the US indicates a mid-term red patch around the crisis period, which confirms the thesis that the market of Vietnam, despite being less gas-intensive in the region, responded to the global price fluctuations and re-direction of gas flows. The Chile Mexico PWC plot also depicts a strong coherence in the short band, which demonstrates the short-term response of Chile in this energy-inflationary period.

The PWC plots in the Iran-Israel conflict period (2317-2513) shows long-term leadership in Canada and Australia, and medium-term influence in the US, which is exactly what the WC shows. Interestingly, the plots of Canada Peru, Australia Philippines, and USA Malaysia have coherence in the higher frequency bands (>128), which means that even in a more regional geopolitical event, natural gas had strategic, long-term impacts on these markets. This implies that investors probably incorporated risk premiums and long-term energy security dynamics in their responses to natural gas prices.

The confirmed PWC findings confirm that Natural Gas is more selective than crude oil but provides good and stable signals to investors in particular markets at the time of crisis: In Australia, China, and Indonesia, short-term traders are advised to monitor the movement of gas prices, particularly when there is a sudden supply-side shock or uncertainty in demand. Medium-term investors in Malaysia, Mexico, Vietnam, and Japan ought to understand that gas dynamics are linked to infrastructure, geopolitical transitions, and regional production patterns that affect market sentiment in a few weeks or months.

Investors with a long-term horizon in Canada and Australia, where gas demonstrated consistent leadership in localized conflicts, may wish to include gas exposure in strategic portfolio hedging or energy sector tilts, particularly in the event of a sustained geopolitical tension.



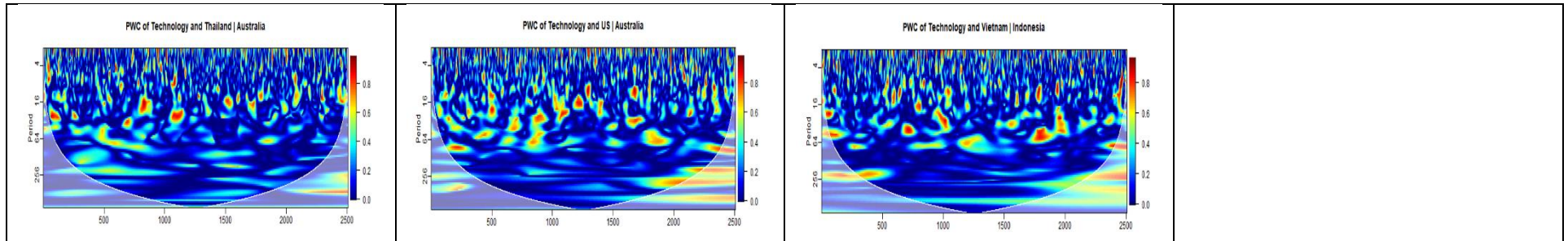


Fig. 4.18: PWC between Technology and APEC

4.5.2.3 Partial Wavelet Coherence Technology and APEC

The fig 4.18 PWC analysis of technology confirms the previous wavelet coherence findings that technology has been selective but significant in terms of leadership in APEC equity markets in times of global crisis. Short-term leadership in Chile, Japan, and Malaysia during the Oil Crisis (1973-1975) is confirmed by red patches in the initial stages of such plots as Japan | China and Philippines | US. The medium-term leadership in Canada and Australia can be observed in the panels of Canada | Malaysia and Australia | China, where the mid-frequency ranges are highly coherent, indicating that even in the energy-related disruptions, the tech-driven expectations contributed to the investor sentiment.

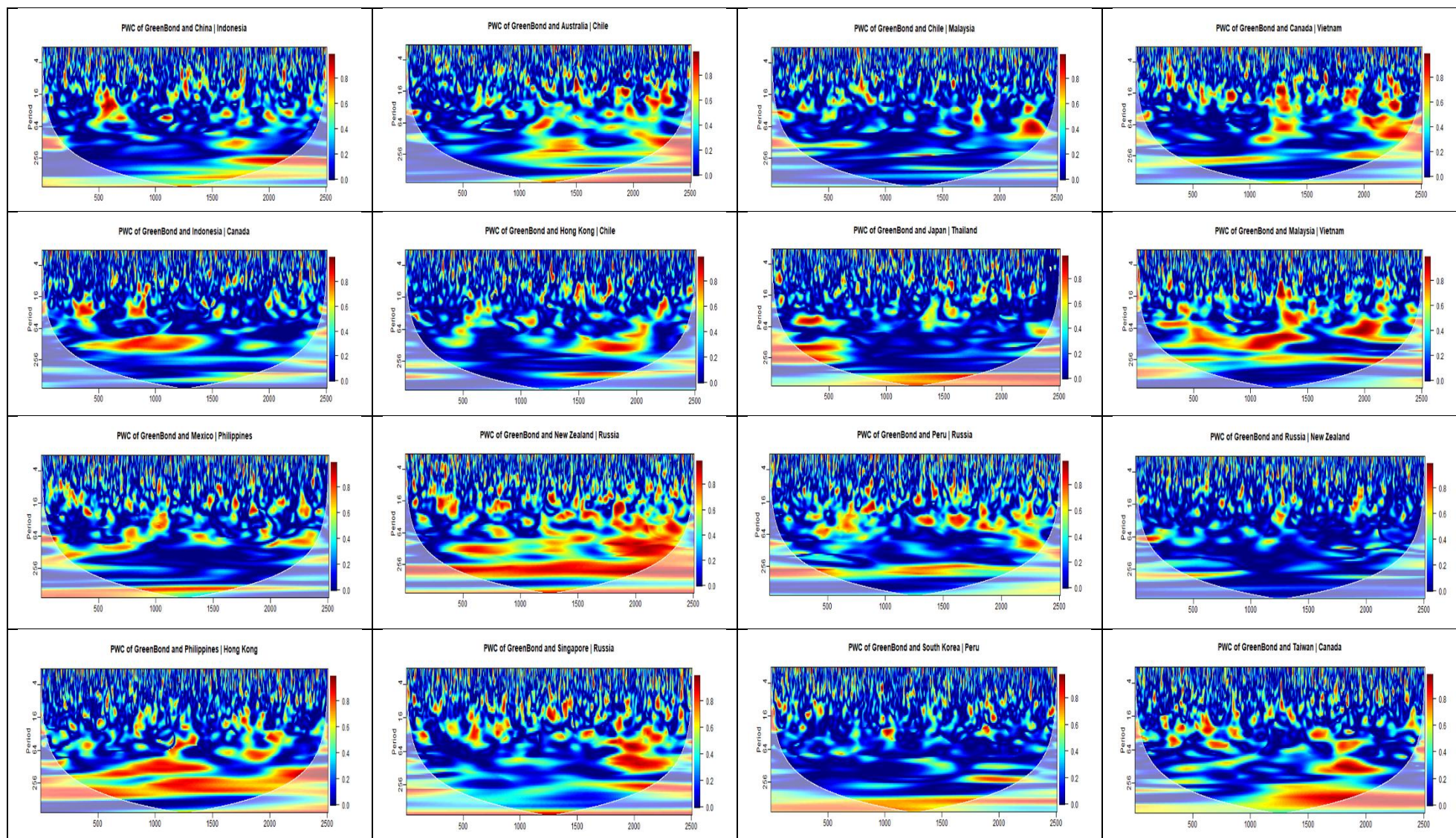
Technology demonstrated a wider leadership during the Climate Crisis (1989-1995). Short-term signals in Chile, Singapore and Hong Kong can be observed in plots like Hong Kong | Singapore where the red areas can be seen around (1990-1995) on the time axis. The panels of the Philippines | US and Thailand | South Korea support medium-term leadership in Australia, USA, and Vietnam, especially in the cases where coherence is higher in mid-frequency bands. These trends highlight that the dynamics of the tech sector, particularly those associated with innovation and climate solutions, served as precursors to the rest of the equity markets.

The role of technology was the most evident in the COVID-19 pandemic (2020-2021). In Canada, Indonesia, and Japan, medium-term leadership is also supported in plots such as Canada | Malaysia and Japan | China, where there are clear red-orange bands between 2020 and 2021. The short-term leadership in Singapore and Indonesia is observed in the “Malaysia | Indonesia” and “Singapore | Philippines”, which proves the importance of tech in indicating the quick changes in the digital adoption and sectoral rotation during the crisis.

Tech leadership was more localized yet significant during the Russia Ukraine War (2022-2023). The short-term leadership in Russia and medium-term impacts in USA can be observed in the panels of Russia | Indonesia and US | Taiwan respectively. The long-term leadership in China and Philippines is particularly noticeable in the plot of Vietnam | Taiwan, where the low-frequency zones are coherent throughout the war time. This indicates the long-term impact of tech in the nations that are vulnerable to geopolitical-tech dependencies.

Lastly, in the Iran-Israel War (2023-2024), technology once more proved long-term leadership in Canada, Australia, and Indonesia, and medium-term leadership in China and Vietnam. The plots Canada | Malaysia and Vietnam | Taiwan demonstrate a high level of coherency that stretches into late 2020s, confirming the perception that tech is a growth and

defense-oriented sector that is forward-looking, particularly in the context of geopolitical tension.



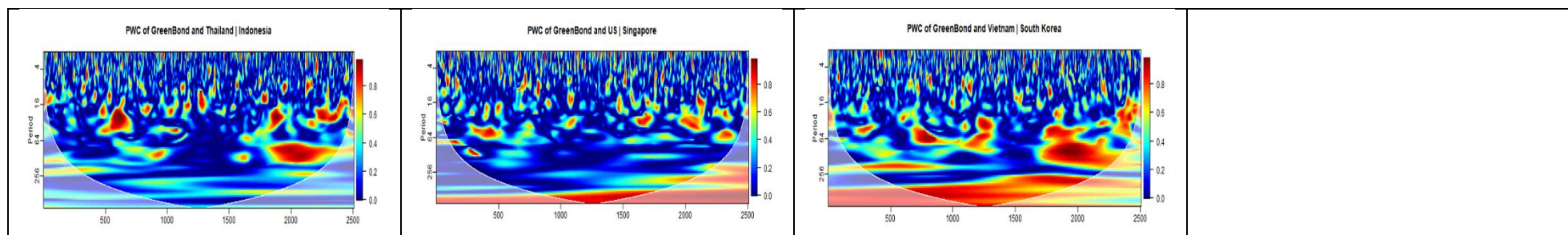


Fig. 4.19 PWC between Green Bonds and APEC

4.5.2.4 Partial Wavelet Coherence Green Bonds with APEC

The fig 4.19 PWC plots of green bonds strongly support the WC findings, which validate the emergence of green bonds as predictive tools in times of global disruptions. Short-term leadership in Chile, Japan and the Philippines is also depicted in the plot such as Japan | Malaysia and Philippines | South Korea in the Oil Crisis (1195). The medium-term leadership in Canada, Australia, Chile, Hong Kong, Taiwan, Thailand, Vietnam, and Malaysia is evident due to the high mid-scale coherence in the “Malaysia | China” and “Canada | Hong Kong” and long-term leadership is clearly evident in Taiwan (Thailand | Taiwan), which confirms the early development of green bonds as macro-financial indicators in energy-sensitive economies.

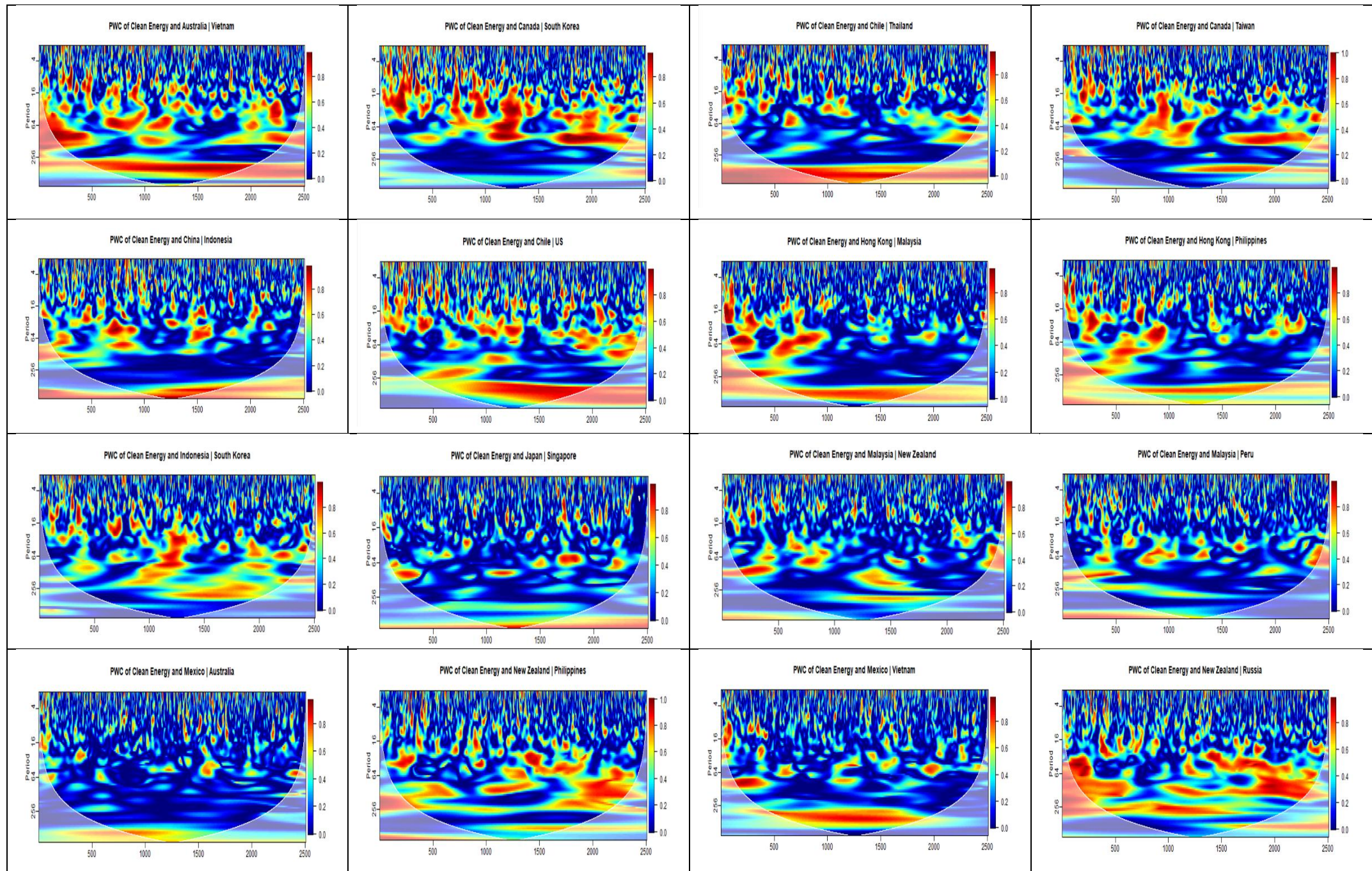
Green bond leadership stabilized during the Climate Crisis (436-695). In the case of China, short-term effects and medium-term leadership in USA, Japan, Malaysia, and China are evident in the US | China and Japan | Malaysia panels. Specifically, the fact that China is a green finance issuer and consumer increases its sensitivity to bond signals. The long-term consistency in Taiwan and Vietnam is also verified in the plot of Vietnam | US, which supports the conclusion of WC that green bonds reflected the market response to the changing sustainability frameworks.

The COVID-19 era (1213-1731) also increased the impact of green bonds. Indonesia | Vietnam and Vietnam | US plots support medium-term leadership in Australia, Indonesia, Vietnam and Malaysia, with strong mid-frequency coherence between 1250 and 1700. The long-term leadership in Malaysia, Vietnam, and New Zealand can also be observed in the case of Russia | New Zealand, which indicates that investors were becoming more interested in green bonds as a source of information about safe, sustainable recovery expectations in the context of the pandemic.

Green bond leadership expanded in time and space during the Russia Ukraine War (1770-2230). The short-term leadership in Singapore, Hong Kong, and Vietnam, and medium-term impacts in Hong Kong, Taiwan, Thailand, Vietnam, and Malaysia are supported by the long-term consistency in Singapore | Japan and Vietnam | China. The long-term leadership in Vietnam, Malaysia, and New Zealand supports the idea that sustainable finance has become a long-term indicator during the energy volatility and global uncertainty caused by war.

Lastly, in the Iran-Israel War (2317-2513), PWC demonstrates widespread green bond leadership in Canada, Australia, Chile, Indonesia, Thailand, Malaysia, Mexico, New Zealand, and the Philippines. Strong, multi-frequency coherence is seen in plots such as Mexico |

China and Philippines | South Korea during this time. This confirms the WC intuition that green bonds have evolved into essential financial tools that can forecast the general equity dynamics under geopolitical pressure, regulatory change, and ESG rebalancing.



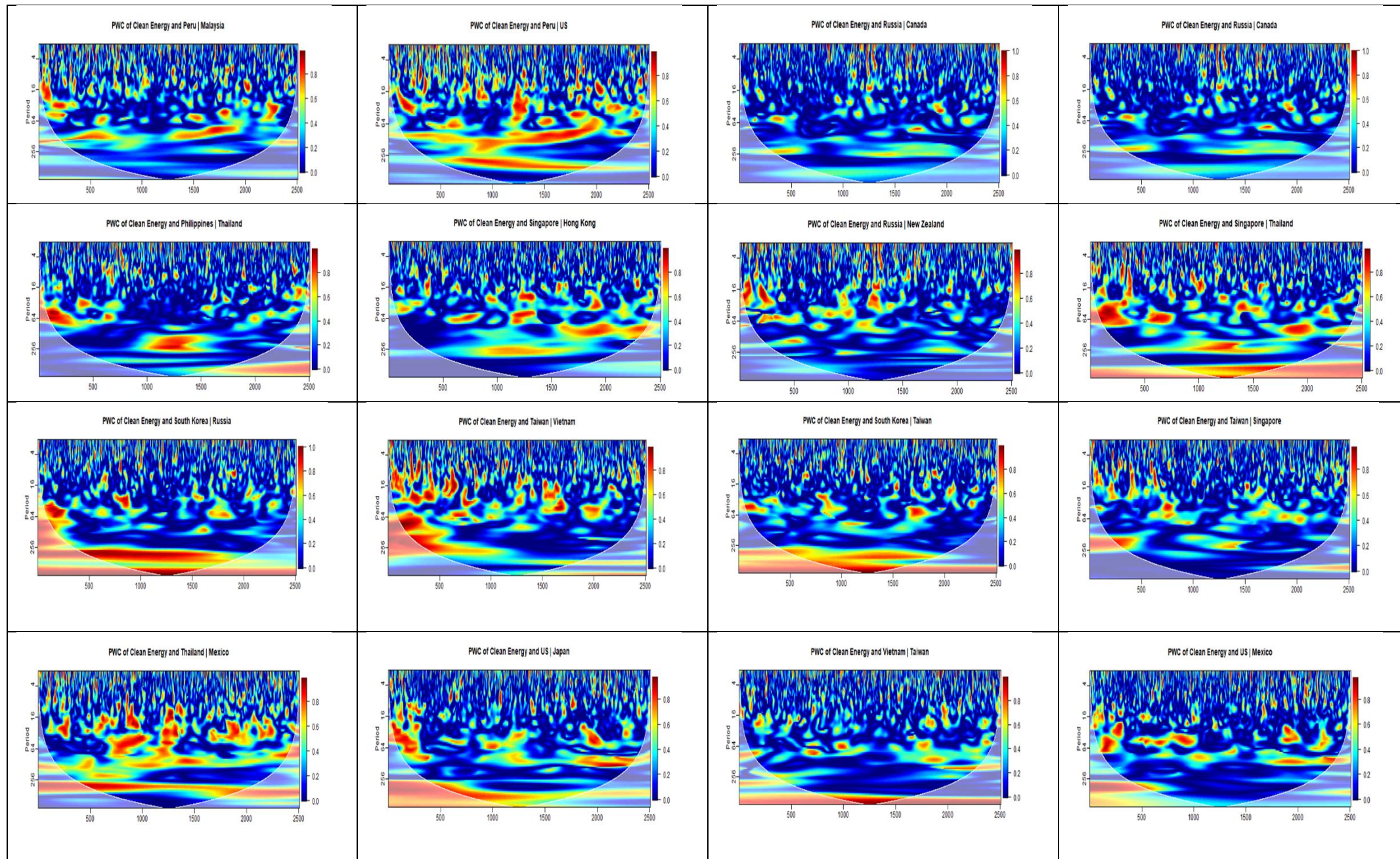


Fig. 4.20: PWC between Clean Energy and APEC

4.5.2.5. Partial Wavelet Coherence Clean Energy and APEC

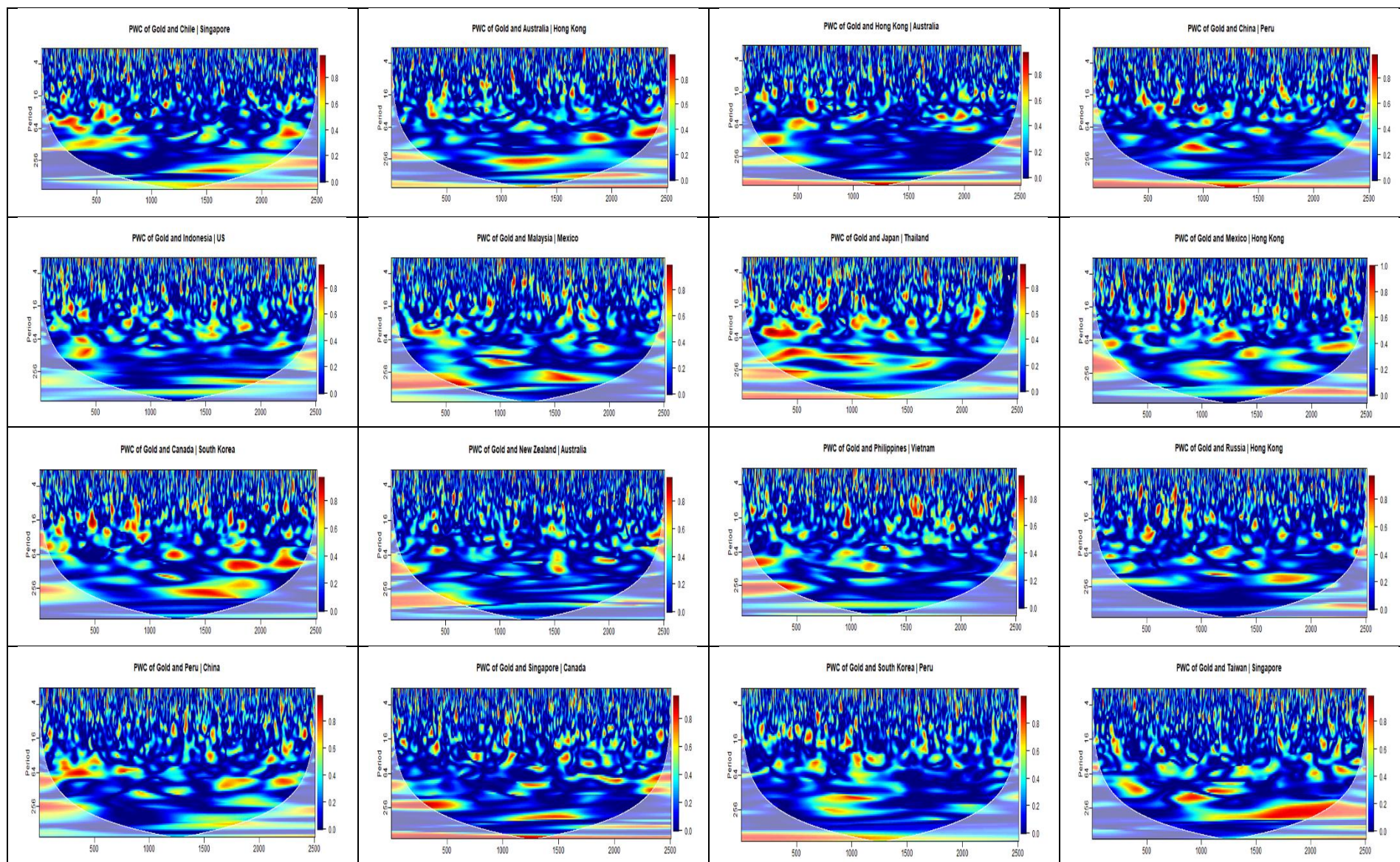
The fig 4.20 PWC plots of clean energy analysis is very supportive of the fact that it is a leading indicator of equity market movements in times of crisis. Clean energy demonstrated short-term and medium-term leadership in Canada, Australia, Hong Kong, Taiwan, Thailand, Malaysia, China, and Vietnam during the Oil Crisis (1-195). Localized coherence is observed in plots like Taiwan | Mexico and Philippines | China early in the sample, indicating early investor interest in clean alternatives in reaction to the volatility of fossil fuels.

During the Climate Crisis (436-695) era, the impact of clean energy became more regular and universal. The short-term coherence in Chile, Singapore, Hong Kong, Taiwan, China, and Vietnam is quite obvious in the Singapore | Vietnam and Vietnam | China PWC panels. The medium-term indicators in China and Vietnam are also still present, which further confirms that clean energy movements gave a solid indication of equity markets as governments stepped up climate efforts and investment in renewables.

In the case of COVID-19 (1213-1731), medium-term clean energy leadership in Australia, China, Indonesia, and Vietnam can be observed in China | Philippines and Vietnam | China. These timeframes coincide with green stimulus plans and increased investor interest in sustainable infrastructure, confirming that clean energy was considered a long-term growth opportunity even in the face of acute health emergencies.

The predictive nature of clean energy was further enhanced during the Russia-Ukraine War (1770-2230) with short, medium and long term leadership in Australia, Chile, Singapore, Hong Kong, Taiwan, Indonesia, China and Vietnam. This is confirmed in such plots as Chile | Australia and Vietnam | China where there is sustained red coherence over all frequencies. These results validate the fact that clean energy markets became central to the measurement of the financial effects of energy geopolitics and the energy transition of the world.

During the Iran-Israel War (2317-2513) era, clean energy continued to lead the pack in Canada, Australia, Chile, Singapore, Hong Kong, Indonesia, China, Mexico, Peru, and the Philippines. In PWC plots such as US | Peru and Vietnam | China, there is a high level of coherence throughout the last time window, which proves that the impact of clean energy has been institutionalized. This confirms the WC finding that clean energy has become a macro-signal globally, including in emerging economies where green financing is becoming popular.



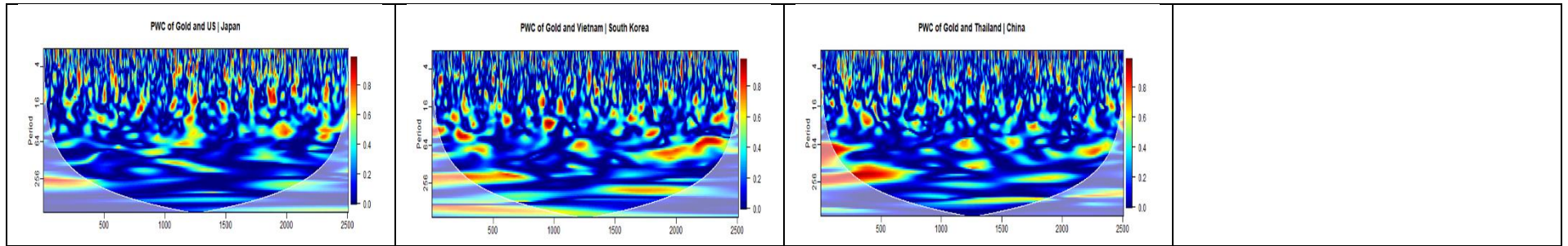


Fig. 4.21: PWC Confirmation of Gold and APEC

The gold-APEC equity relationship in Fig 4.21, often seen as a proxy for safe haven investment behavior, also shows minimal coherence in the PWC results. Coherence is highly localized and appears only during specific windows most notably in the year 2025 for Japan, Malaysia, Mexico, and Thailand. This episodic nature implies that gold's hedging function is activated only under conditions of extreme uncertainty or anticipated market dislocation. Outside of such periods, gold's role in influencing or aligning with APEC equity trends is negligible. The PWC analysis, therefore, reinforces the conventional understanding of gold as a reactive, rather than proactive, asset class one that investors turn to only when market conditions deteriorate significantly. Unlike green bonds or clean energy, gold does not show signs of strategic integration within APEC financial systems but remains a temporary safe-haven instrument.

4.5.2.6 Conclusion

To conclude, the PWC plots are a strong confirmation of the wavelet coherence results, showing that natural gas is a selective yet significant predictor of equity market dynamics in the APEC region. The co-movements are still high even after the third-variable effect is controlled across various crises and time frames. The observed partial coherence is not spurious, but rather based on real world structural energy dependencies, market sentiment reactions to gas price volatility, and the macroeconomic role of natural gas in times of turmoil. Natural gas is therefore a strategic resource to watch to make informed equity investment in energy-dependent, export-sensitive or geopolitically-related APEC economies.

4.5.3 Wavelet correlation

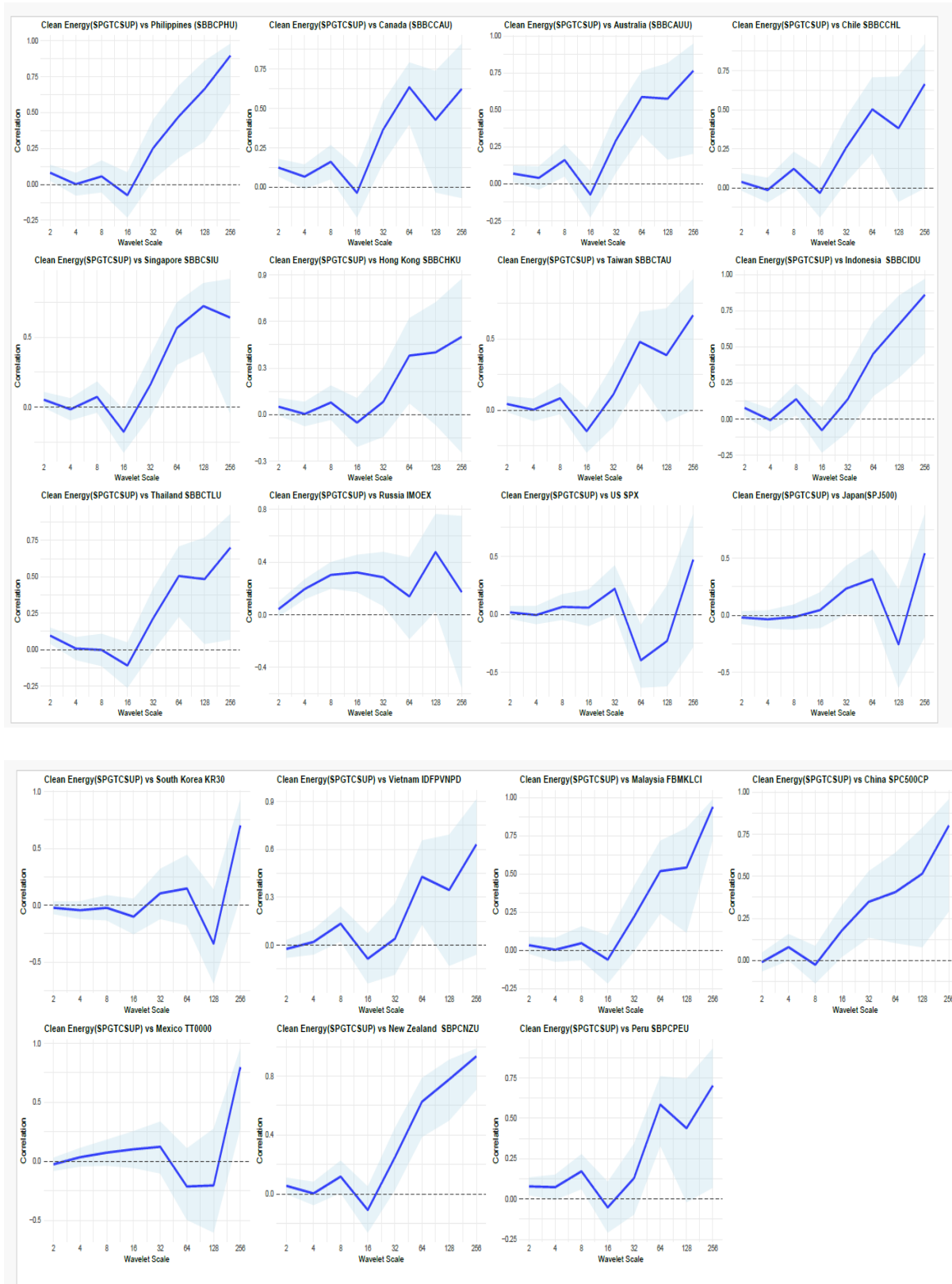


Fig. 4.22: Wavelet correlation between the APEC stock markets and clean energy

4.5.3.1 Wavelet correlation between the APEC stock markets and clean energy

Philippines (SBBCPHU) and Clean Energy: First, at the more minor wavelet scales, correlation is largely absent. For larger scale (scale 8 or above), a stronger positive correlation is obtained, relating the performance of Clean Energy with the Philippine market over larger time or frequency ranges.

Canada (SBBCCAU) and Clean Energy: Like the Philippines, Canada's market begins with a low level of correlation on a smaller scale. This correlation grows with increasing wavelet scale (64, 128, 256). That suggests a more stable relationship between Clean Energy and the Canadian stock market over these extended time frames.

Australia (SBBCAUU) and Clean Energy: A continuous increase in correlation is observed, especially at medium and high wavelet scales. This suggests a more substantial alignment of Clean Energy performance with Australia's market at larger scales and that a similar relationship is more consistently observed and maintained over more extended periods.

Chile (SBBCCHL) and Clean Energy: The relationship is more significant at larger wavelet scales, particularly for scale 8 and larger, where there is a pronounced strengthening. This shows a more robust alignment between Clean Energy and the Chilean market at lower time frequencies.

Singapore (SBBCTSIU) and Clean Energy: The correlation initially appears to be low, but increases significantly at wavelet scales 32 and above. This indicates that at higher time scales, Clean Energy is integrated with the Singaporean market.

Hong Kong (SBBCHKU) and Clean Energy: A similar positive trend is observed in Hong Kong. The correlation is initially noisy, but becomes stronger at larger wavelet scales (32, 64, 128), indicating that the effect of Clean Energy on the Hong Kong market can be observed over longer time scales.

Taiwan (SBBCTAU) and Clean Energy: A steady growth of correlation at higher scales can be observed. Indeed, above scale 64, the correlation becomes more robust, proving that Clean Energy has a greater impact on the Taiwan market at these frequencies.

Indonesia (SBBBCIDU) and Clean Energy: For Indonesia, this relationship exhibits the same increasing trend, and it becomes more pronounced at higher wavelet scales. The relationship also appears to hold more strongly at higher-order scales, indicating that the relationship is more coherent between Clean Energy and the Indonesian market over long periods.

Thailand (SBBCTLU) and Clean Energy: The relationship becomes stronger at the wavelet scales of 32, 64, and so on. This means that the Clean Energy and the Thailand market are closely related at long wavelet scales, which is indicative of a long-term relationship.

Russia (IMOEX) and Clean Energy: While the correlation becomes somewhat noisy, it continues to rise with increasing wavelet scale. This inconsistency could be interpreted as an indication that the link between Clean Energy and the Russian market is not as straightforward as in previous cases, or it may not be linear and could be frequency- or time-dependent.

United States and Clean Energy: The link between the U.S. market and clean energy also experiences a gradual increase with the size of the wavelet scale. This coherence structure at large scales implies that Clean Energy and the U.S. market are strongly and significantly connected at long-time or low-frequency scales.

Japan (SPJ500) and Clean Energy: Japan exhibits a clear, increasing trend of correlation, particularly for scales 8 and above. On larger wavelet scales, the convergence of Clean Energy with Japan's market is stronger and more consistent, indicating a positive relationship over longer horizons.

South Korea (KR30) vs Clean energy (SPGTC SUP): The relationship is seen to become stronger with increasing wavelet scale. The correlation is initially weak (the value is close to zero) but then increases strongly after a certain threshold (a value of about 128), indicating that the variables are more closely related at larger degrees. It can be inferred from this that, at the macro level (in the long term), the impact of the South Korean stock index on clean energy is perhaps more substantial.

Vietnam IDFPVNPVD vs Clean Energy (SPGTC SUP): The agreement is poor at small values and improves with the wavelet scale, eventually reaching a statistically significant value. This stylised fact implies that the relationship between Vietnam's stock market index and clean energy is more apparent at longer horizons, especially at larger scales. The increase might mean that with time, moves in clean energy stocks are becoming increasingly closely correlated with the movement of Vietnam's market.

Malaysia FBMKLCI vs Clean Energy (SPGTC SUP): As with the other countries, the relationship increases with the wavelet scale. The correlation is initially low (negative) but increasing, which means that, similarly to other markets, Malaysia's stock market becomes more (less) correlated with clean energy stocks the longer (shorter) the investment horizon.

CHINA(SPCT SUP vs SPC500CPSPGTC SUP: This has the same stable correlation pattern as the others we've looked at. As the wavelet scale increases, the long-term relationship between China's stock index and clean energy stock returns improves, and therefore, the correlation increases. This suggests that the relation is more robust at larger scales.

Mexico TT000 vs Clean Energy (SPGTC SUP): A more pronounced movement can be observed in the Mexican market index at medium wavelet scales. The relationship strength increases from small to strong positive, indicating that the relationship is more significant at broader scales. However, we cannot discard the possibility that the initially weak relationship is due to short-term market inefficiencies or volatility.

New Zealand SBPCNZU v Clean Energy (SPGTC SUP): In New Zealand, the correlation is a small negative number, which increases less sharply, i.e., the relationship grows less sharply with clean energy stocks. This may suggest that although not an instant connection, it becomes increasingly stronger over the long term.

Peru SBPCPEU vs Clean Energy (SPGTC SUP): The pattern of dependence in Peru rose as the wavelet scales increased; the association between the stock index and clean energy is heightened for larger scales. This implies that, in the long run, the movements in the share prices of clean energy and the Peruvian stock market are more closely related. This suggests that, over more extended periods, the movement in clean energy stocks is more closely tied to Peru's stock market performance.

Table 4.20: Summary of the results of the APEC Stock Market and Clean Energy

S. N o.	Country/In dex	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Strongest (128)	Wavelet Scale Peak (256)
1	Philippines SBBCPHU	Low	Low	Medium	Medium	High	High
2	Canada SBBCCAU	Low	Medium	High	High	High	High
3	Australia SBBCAUU	Low	Medium	High	High	High	High
4	Chile SBBCCHL	Low	Medium	High	High	High	High

5	Singapore SBBCTSIU	Medium	Medium	High	High	High	High
6	Hong Kong SBBCHKU	Medium	Medium	High	High	High	High
7	Taiwan SBBCTAU	Medium	Medium	High	High	High	High
8	Indonesia SBBBCID U	Medium	Medium	High	High	High	High
9	Thailand SBBCTLU	Medium	Medium	High	High	High	High
10	Russia IMOEX	Medium	High	High	High	High	High
11	U.S. (SPX)	Medium	High	High	High	High	High
12	Japan SPJ500	Medium	High	High	High	High	High
13	South Korea KR30	Low	Low	Medium	Medium	High	High
14	Vietnam IDFPVNP VD	Low	Medium	Medium	High	High	High
15	Malaysia FBMKLCI	Low	Low	Medium	Medium	High	High
16	China SPC500CP	Low	Low	Medium	Medium	High	High
17	Mexico TT000	Low	Low	Medium	Medium	High	High
18	New Zealand SBPCNZU	Low	Low	Medium	Medium	High	High
19	Peru SBPCPEU	Low	Low	Medium	Medium	High	High

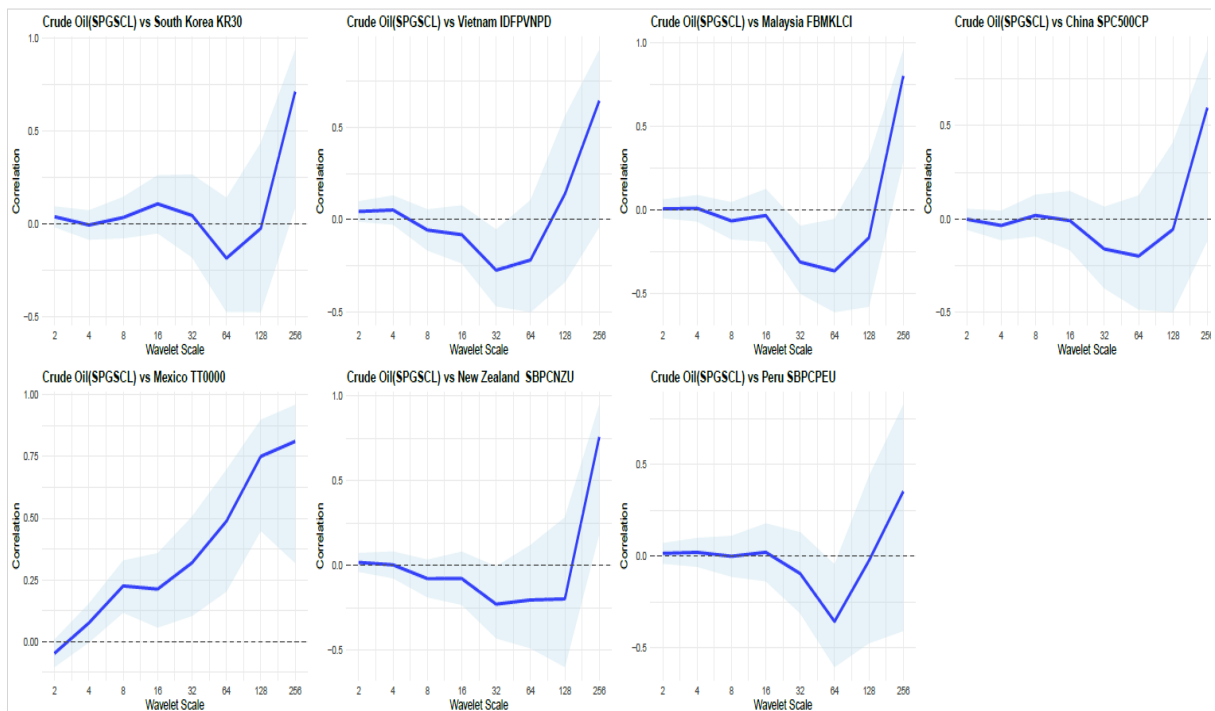
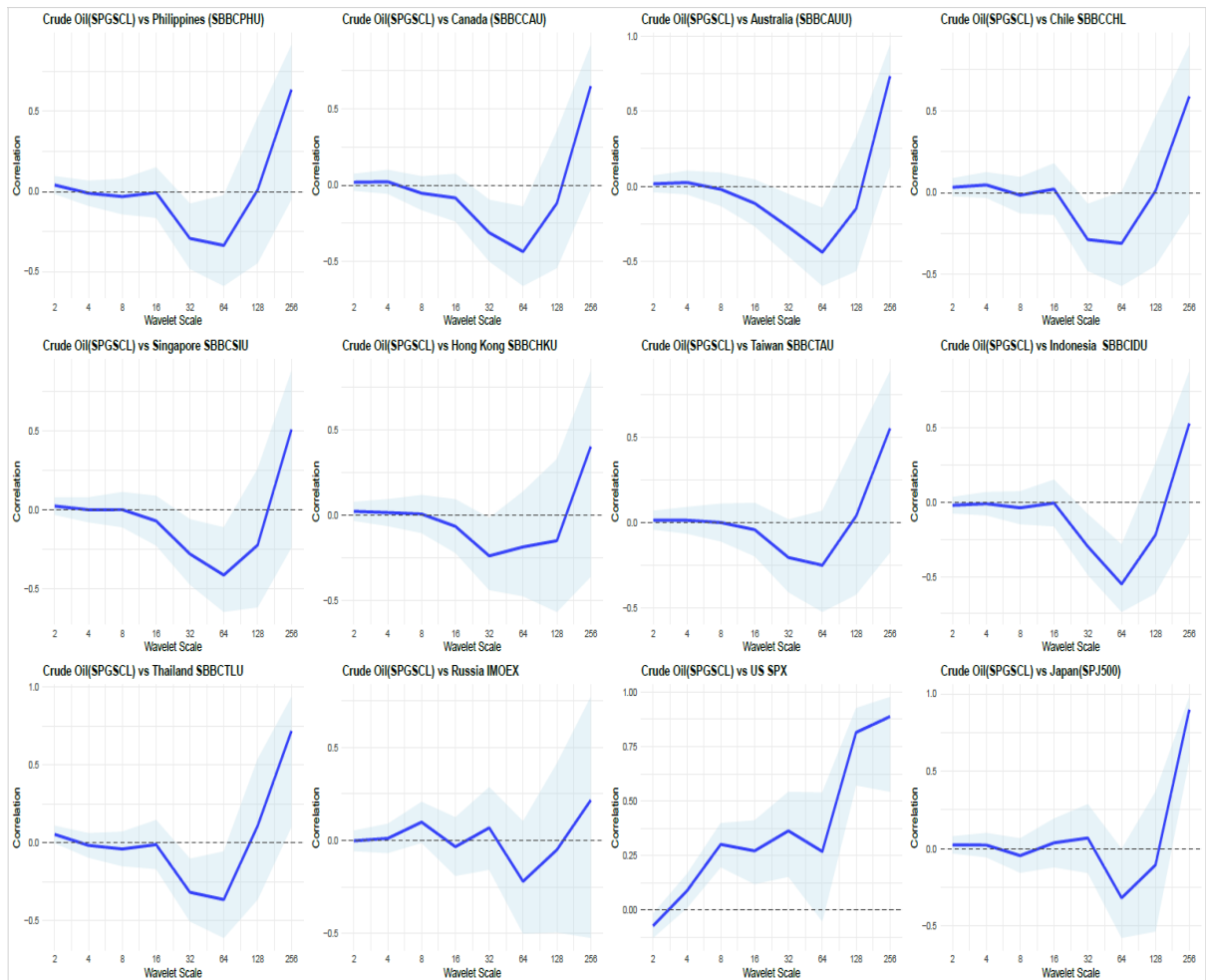


Fig. 4.23 Wavelet correlation countrywide relationship with crude oil

4.5.3.2 Wavelet correlation countrywide relationship with crude oil

Crude Oil (SPGSCL) vs. Philippines (SBBCPHU): Zero or mildly negative correlations are observed from the graph for the minor wavelet scales (low frequencies). At higher scales (high frequency), the correlation increases rapidly, being positive and reaching values of around 0.5 or larger. It implies that Crude Oil and the Philippine market are negatively associated in the short term but positively related in the long run.

SPGSCL vs. Canada (SBCCAU): The correlation is similar to that in the Philippines graph, with a negative trend at lower wavelet scales and a positive trend at higher wavelet scales. This suggests that the Crude also has a short-term negative correlation with the Canadian market, but is positively related over time.

Crude Oil (SPGSCL) / Australia (SBBCAU): Here, the correlation is slightly negative at low frequencies, but with increasing frequencies, the correlation rises steeply. This trend suggests that, over more extended time frames, there is a transition from a weak negative correlation to a strong positive correlation.

Crude Oil (SPGSCL) vs. Chile (SBBCCHL): The situation is quite similar here: one observes a negative correlation at lower wavelet scales, followed by a positive correlation at higher scales. This means that in the short term, the price of Crude Oil and the Chilean market move in opposite directions, but in the medium term, there is a substantial positive trend.

Oil and Crude (SBBCSIUL) vs. Singapore (SBBCSIU): Both countries also have a negative relationship at lower frequencies. There is a high positive correlation at scale factors above this threshold. This means that in the short term, the market moves in the opposite direction, but in the long run, the movement between Crude Oil and Singapore's market is positively correlated.

Crude Oil (SPGSCL) vs Hong Kong (SBBCHKU): Again, we observe a negative correlation at lower scales, which turns positive at larger wavelet scales. Crude Oil and Hong Kong's market initially start moving in opposite directions, but their relationship strengthens and becomes positive over extended periods.

Crude Oil (SPGSCL) vs. Taiwan (SBBCTAUS): A similar pattern was observed, where, at more minor scales, there is a negative correlation and at larger scales, a positive correlation. In the short term, there's an inverse relationship, but in the long term, Crude Oil and Taiwan's market have moved in the same direction.

Crude Oil (SPGSCL) vs Indonesia (SBBCTIDU): The curve at small wavelet scales shows a negative correlation, which turns to positive as the wavelet scale increases. Thus, it can be stated that oil and the Indonesian market are inversely correlated in the short term, and resemble each other more in the long term.

Crude Oil (SPGSCL) Comparative performance Thailand (SBBCTLU): The below negative correlation of minor scales suddenly changes to a positive one at higher wavelet scales. In the short run, the markets diverge, but in the longer term, they align themselves.

Crude Oil (SPGSCL) vs Russia (IMOEX): There is a similar characteristic here with negative correlations at small wavelet scales and a rapid transition to positive values at larger scales. This indicates a short-term inverse relationship, while a positive long-term relationship exists between Crude Oil and the Russian market.

Crude Oil (SPGSCL) Versus US SPX (S&P 500): Wavelet correlation plot. The correlation is initially small but grows, indicating that higher frequencies are positively correlated. In the short term, the Crude Oil market still exhibits a stronger correlation with the U.S. (SPX) market.

SPGSCL vs Japan (SPJ500): The correlation structure is very similar to that of the S&P 500 U.S. market (SPX), with a gradual rise in positive correlations across the multiresolution scales. Crude oil and the Japanese (SPJ500) market have a moderate and positive relationship at all time scales, with high correlation occurring at larger wavelet scales.

Crude Oil vs. South Korea (KR30): The correlation between crude Oil and South Korea's KR30 index is initially small and constant at fine wavelet scales. However, at a scale of approximately 128, the latter starts to increase steeply, and this increase is significantly further at higher scales (256). This indicates that high time scales (longer-term periods) of the crude oil price are highly influenced by South Korea's KR30 index.

Crude Oil vs. Vietnam (IDFPVNPD): This correlation increases monotonically with the wavelet scale from smaller to larger scales, and it increases significantly as the scale approaches 256. This implies that crude oil and the Vietnam index have a high correlation at longer time series, while their dependence is weak for short forecast horizons.

Crude Oil vs. Malaysia (FBMKLCI): As in the other graphs, the correlation initially remains low, but then it increases significantly at scale 128 and peaks at 256. It means that on a longer time horizon, the price movement of crude oil is more correlated with the FBMKLCI index of Malaysia, especially for larger wavelet scales.

Crude Oil vs. China (SPC500CP): For China, the correlation starts at a low level and increases significantly with the wave scale. This suggests a long-term strong correlation between crude oil and China's index.

Crude Oil vs. Mexico (TT0000): This figure demonstrates a growing correlation toward higher scales, originating from a very low value at the most minor wavelet scales. The relationship becomes stronger when considering higher scales, especially from scale 32 and above, which means that Mexico's index and crude oil are more closely related to each other over more extended periods.

Crude Oil vs. New Zealand (SBPCNZU): For New Zealand, we observe the same pattern of correlation, where the relationship between crude oil and the New Zealand index continues to be weak at the more minor wavelet scales. The correlation is striking at higher scales (128 and 256), indicating a more substantial relationship over longer timescales.

Crude Oil vs. Peru (SBPCPEU): The behaviour of the correlation is consistent with that of the other countries, with a curve that starts from a lower value and steeply increases as the wavelet scale is increased. At 256 scales, the best correlation was found, indicating that crude oil and the index from Peru are more closely related over long periods.

Table 4.21: Summary of the wavelet correlation with APEC Stock Market and Crude Oil.

S.No.	Country/Index	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Strongest (128)	Wavelet Scale Peak (256)
1	Australia	Low	Low	Medium	Medium	High	High
2	Canada	Low	Low	Medium	Medium	High	High
3	Chile	Low	Low	Medium	Medium	High	High
4	China (SPC500CP)	Low	Low	Medium	Medium	High	High
5	Hong Kong	Low	Low	Medium	Medium	High	High

6	Indonesia	Low	Low	Medium	Medium	High	High
7	Japan	Medium	Medium	High	High	High	High
8	Malaysia (FBMKLCI)	Low	Low	Medium	Medium	High	High
9	Mexico (TT0000)	Low	Medium	Medium	Medium	High	High
10	New Zealand (SBPCNZU)	Low	Medium	Medium	Medium	High	High
11	Peru (SBPCPEU)	Low	Medium	Medium	Medium	High	High
12	Philippines	Low	Low	Medium	Medium	High	High
13	Russia	Low	Low	Medium	Medium	High	High
14	Singapore	Low	Low	Medium	Medium	High	High
15	South Korea (KR30)	Low	Low	Medium	Medium	High	High
16	Taiwan	Low	Low	Medium	Medium	High	High
17	Thailand	Low	Low	Medium	Medium	High	High
18	US SPX	Medium	Medium	High	High	High	High
19	Vietnam (IDFPVNPD)	Low	Low	Medium	Medium	High	High

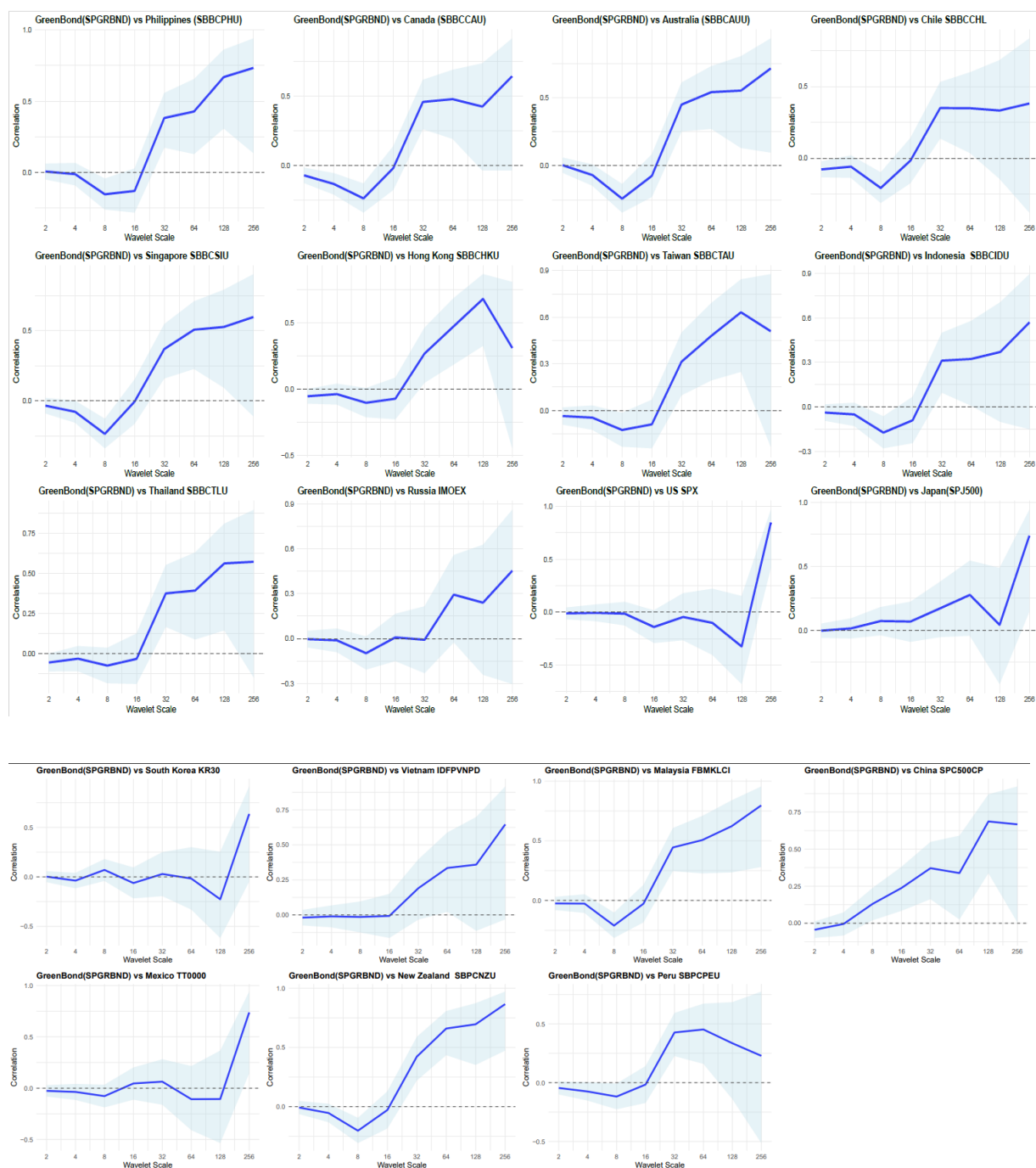


Fig. 4.24: Wavelet correlation countrywide relationship with green bonds

4.5.3.3 Wavelet correlation countrywide relationship with green bonds

Green Bond (SPGRBND) vs Philippines (SBBCPHU): The correlation is minimal in the small wavelet scale and rises when we increase the wavelet scale. On the other hand, a clear positive relationship is evident at intermediate and large scales (wavelet scales of approximately 32 and larger), indicating that the correlation between Green Bonds and the Philippine market increases substantially over longer time horizons.

Green Bond (SPGRBND) vs Canada (SBBCCAUI): The correspondence is not suitable for small wavelet scales and improves after wavelet scale 4. For the larger scales (32 and above), there is a strong positive correlation, indicating that Green Bond is becoming increasingly dependent on the Canadian market over time.

Green Bond (SPGRBND) vs Australia (SBBCAUU): Similar to Canada, the correlation is low at the beginning and increases near the largest scales of wavelet. The strongest correlations were found over the wavelet scales of 64–128, suggesting that Green Bond is most similar to the characteristics in the Australian market over the medium- and long-term.

Green Bond (SPGRBND) vs Chile (SBBCCHL): The correlation is increasing from a very low correlation for the minor wavelet scales to higher with the medium scales (32–64). This suggests a moderate to high correlation between Green Bonds and the Chilean market on these scales.

Green Bond (SPGRBND) vs Singapore (SBBCSIU): The wavelet correlation is increased with increasing wavelet scale. A strong positive dependence is noted from scales greater than 16, and the strongest correlation is reached around scale 128. This suggests that green bond shows a moderate to high degree of correlation with Singapore over longer time horizons.

Green Bond (SPGRBND) vs. Hong Kong (SBBCHKU): The correlation between the Green Bond and the HK market is found to be generally weak and becomes stronger as we increase from a lower wavelet scale to a moderate-higher scale (around 64). Thereafter, the correlation appears stable at a higher level, implying the relationship between the Green Bond and Hong Kong markets converges.

Green Bond (SPGRBND) vs Taiwan (SBBCTAU): The correlations are very weak at small wavelet scales, and they increase gradually. The relationship becomes positive for scales larger than 32, suggesting a robust correlation at medium to large wavelet scales.

Green Bond (SPGRBND) vs Indonesia (SBBBCIDU): The correlation exhibits a significant upward shift at larger wavelet scales. The increase is rapid beyond scale 16, suggesting a long-term to medium-term correlated behaviour between the Green Bond and the Indonesian market.

Green Bond (SPGRBND) vs Russia (IMOEX): Correlation increases from the most minor scale of 1024, followed by a steep growth at higher scales. This strong association indicates that the Green Bond-Russia market is nearly perfectly aligned over the medium to long term.

Green Bond (SPGRBND) vs U.S. (SPX): Correlation is generally high and doesn't vary much over the different wavelet scales, with the maximum correlation obtained at the larger scales, indicating that the U.S. and Green Bond markets are strongly linked in the long run. The

uniform behaviour persists across all scales, perhaps indicating a stable and constant connection.

Green Bond (SPGRBND) vs Japan (SPJ500): The correlation becomes sharper with a larger scale of wavelet, particularly at scale 128 and upwards. The relationship is excellent, especially over longer time horizons.

Green Bond (SPGRBND) vs. South Korea KR30: The results of the wavelet correlation show that the correlation becomes sharper after a particular scale, especially around scale 8. It suggests a low correlation on small scales and an increase on larger wavelet scales. The positive correlation indicates that for longer time horizons, the Green Bond (SPGRBND) is dependent on the South Korean market.

Green Bond (SPGRBND) vs Vietnam IDFPWNP: As in South Korea, the correlation is initially low at the minor wavelet scales and starts to increase somewhere after the scale of 16. The slow performance suggests that the relationship between Green Bond (SPGRBND) and Vietnam becomes stronger as the time frame increases, reaching its highest level at 128 or 256. This suggests that the association is more pronounced at higher frequencies, indicating greater persistence.

Green Bond (SPGRBND) vs Malaysia: In this case, the correlation steadily increases beyond the low wavelet scales. This suggests a significant relationship between Green Bond (SPGRBND) and the Malaysian market at higher time scales, indicating a moderate association between them.

Green Bond (SPGRBND) vs China: Wavelet results demonstrate that the correlation is steadily increasing as the scale of the wavelet increases, with a marked peak at about the 256 scale. Just like in the Malaysia graph, the Green Bond (SPGRBND) – China relationship becomes stronger over time at higher frequencies, hence showing that there is significant dependency between the two entities as time scales increase.

Green Bond (SPGRBND) vs Mexico: The correlation starts low and increases sharply at a higher wavelet scale, similar to the South Korea KR30 plot. That means there is a weaker correlation at smaller scales, but it is significantly enhanced at larger scales. The connection of Green Bond (SPGRBND) with Mexico is particularly enhanced at longer time scales.

Green Bond (SPGRBND) vs New Zealand: The correlation does not change its tendency at lower wavelet scales and then increases at scales in the vicinity of 16, to effectively plateau at larger scales. This indicates a weak relationship at lower scales, with a significant increase at larger scales. This indicates an increasing relationship between Green Bond(SPGRBND) and New Zealand on a longer-term basis.

Green Bond (SPGRBND) vs Peru: The Peru stock market exhibits characteristics similar to those of New Zealand, with a low correlation at small wavelet scales and a steep rise beyond a particular scale (around 32). The relationship between Green Bond (SPGRBND) and Peru is stronger at larger scales, which means the two variables can be connected at higher frequencies over time.

Table 4.22: Summary of the wavelet correlation with APEC Stock Market and Green Bond.

S.No.	Country/Index	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Stronges t (128)	Wavelet Scale Peak (256)
1	Australia (SBBCAUU)	Low	Mediu m	High	High	High	High
2	Canada (SBBCCAUI)	Low	Mediu m	Mediu m	Mediu m	High	High
3	Chile (SBBCCHL)	Low	Mediu m	High	High	High	High
4	China (SPC500CP)	Low	Mediu m	Mediu m	High	High	Stronges t
5	Hong Kong (SBBCHKU)	Low	Mediu m	High	High	High	High
6	Indonesia (SBBCTDU)	Low	Mediu m	Mediu m	Mediu m	High	High
7	Japan (SPJ500)	Low	Low	Mediu m	Mediu m	High	High
8	Malaysia (FBMKLCI)	Low	Mediu m	Mediu m	High	High	Stronges t
9	Mexico (TT000)	Low	Low	Mediu m	High	High	Stronges t
10	New Zealand SBPCNZU	Low	Low	Mediu m	Mediu m	High	Stronges t
11	Peru (SBPCPEU)	Low	Low	Mediu m	High	High	Stronges t

12	Philippines (SBBCPHU)	Low	Low	Medium	High	High	High
13	Russia (IMOEX)	Low	Medium	Medium	Medium	High	Medium
14	Singapore (SBBCSIU)	Low	Medium	High	High	High	High
15	South Korea (KR30)	Low	Low	Medium	Medium	High	Strongest
16	Taiwan (SBBCTAU)	Low	Medium	High	High	High	High
17	Thailand (SBBCTLU)	Low	Medium	High	High	High	High
18	U.S. (SPX)	Low	Low	Medium	Medium	High	Medium
19	Vietnam (IDFPWNP)	Low	Low	Medium	High	High	Strongest

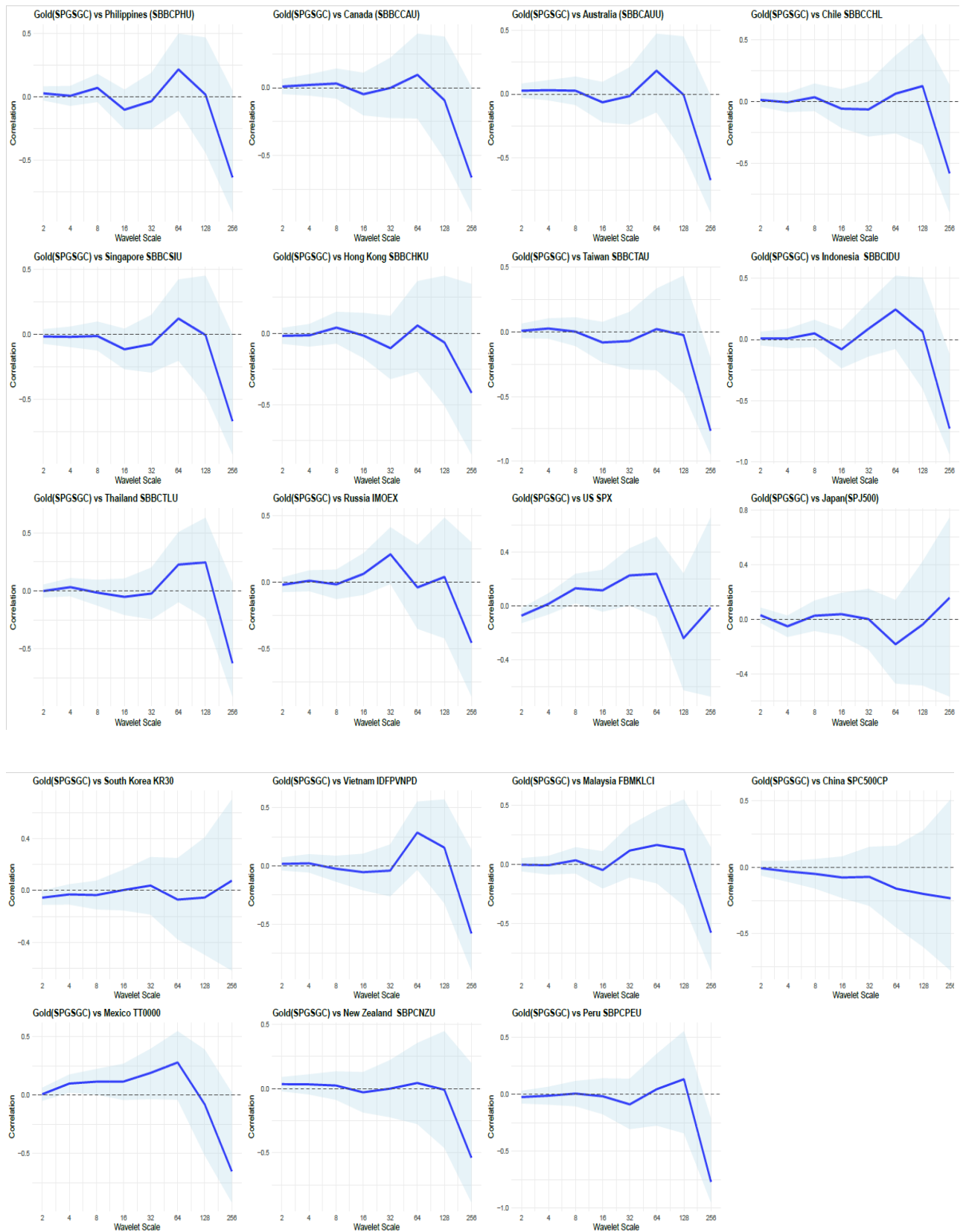


Fig. 2.25: Wavelet correlation countrywide relationship with gold

4.5.3.4 Wavelet correlation countrywide relationship with gold

Gold vs Philippines (SBBCPHU): The wavelet correlation plot begins with a negative anticorrelation at lower wavelet scales, then approximately falls to zero at around the middle scales (which range from 16 to 32), rises to a sharp negative at larger wavelet scales. The latter suggests that for some wavelet scales, the association between gold and the Philippines is very slightly positively (at lower wavelet scales) or negatively (at higher wavelet scales) sloped.

Gold vs Canada (SBBCAUU): There is a tendency (which is generally negative) for the correlation across the wavelet scales. It indicates that the price change of gold is negatively associated with Canada's stock market, particularly in the larger wavelet scale from 128 to 256. At sub-Lagrangian scales, it seems the correlation is close to 0 (or perhaps weak).

Gold vs. Australia (SBBCAUU): As in Canada, the association in the USA is negative at most scales, with the strongest negative associations observed at the larger scales. A significant positive correlation is not observed in any of the wavelet scales.

Gold vs Chile (SBCCCHL): For Chile, the relationship seems relatively neutral to slightly optimistic at low wavelet scales. However, as the scale grows (accepting around 64), a more pronounced inverse relationship becomes apparent, particularly on the larger scale.

Gold vs Singapore (SBBCSIU): It is not easy to see, but it fluctuates, starting very close to 0, placing the model somewhere in the middle, then slightly below a ratio of a hundredth of a per cent, and then slightly above. It indicates an ambivalent relationship between gold and the market in Singapore, ranging from positive to negative.

Gold vs Hong Kong (SBBCHKU): The correlation exhibits a clear negative behaviour, which is preserved across all wavelet scales. The inverse relationship implies that during multiple periods, gold and the Hong Kong market moved in opposite directions.

Gold vs Taiwan (SBBCTAU): A weak negative correlation is observed for all wavelet scales, with fluctuations indicating minor variations. This suggests that there is no robust and consistent relationship between Taiwan's market and gold.

Gold vs. Indonesia (SBBCIDU): The association between gold and Indonesia exhibits a fluctuating correlation, particularly at high wavelet scales. At small wavelet scales, the correlation approaches zero, while as the wavelet scale relaxes, the correlation becomes complex and negative.

Gold vs Thailand: Wavelet Correlation shows an extremely weak or practically neutral correlation, which remains close to zero, at every scale. There is no significant relationship between the price of gold and the stock market in Thailand, regardless of the time frame.

Gold vs Russia: The relationship is generally negative on scales, except for a short period near the middle of the wavelet scales (about 32). However, the broader picture reveals that the Russian market has a historical tendency to run counter to the price of gold.

Gold vs U.S.: The response exhibits a clear positive association, which is more pronounced at higher wavelet scales (128-256). This suggests that gold and the U.S. market (as represented by the SPX) tend to move in the same direction, particularly over extended periods.

Gold vs. Japan: The relationship between Japan and gold is typically positive, but it does not exhibit a high degree of correlation, unlike the U.S. market. The pattern indicates a tendency for higher correlation as the wavelet scales increase, which implies a moderate similarity between the movement of gold and Japan's market in the long run.

Gold(SPGSGC) vs South Korea: The negative correlation is stable from small scales up to a wavelet scale of about 64, where it becomes positive. The peak correlation occurs at wavelet scales of around 64–128, before reverting to a negative value again. It indicates a moderate and unstable correlation at all scales, but a more significant difference in behaviour around the intermediate scale of wavelets.

Gold (SPGSGC) vs. Vietnam: In this case, the correlation is negative at lower scales, quickly turns positive around the wavelet scale of 64, and eventually declines to negative as the scale increases. This suggests that the relationship between gold and the Vietnamese index at various time scales is not a fixed one, and the strongest positive association is observed at the intermediate level.

Gold (SPGSGC) vs Malaysia: The correlation structure is comparable to South Korea, with the exception that between SL and TL, it becomes once negative, then positive, and then again negative across scales. The peak of the positive correlation is at the wavelet scale of 64 and decreases rapidly on further scales. This pattern reveals a short-term coherence between gold and the Malaysian index, especially at moderate and high frequencies.

Gold (SPGSGC) vs China: Across most wavelet scales, the correlation remains closely around zero, but with minor fluctuations. Such a low relationship means that the price of Gold and China's index (SPC500CP) are mostly not related, or in other words, the two variables are relatively independent of each other, at least at most time scales.

Gold (SPGSGC) vs Mexico: Here, the correlation exhibits an intriguing feature with a prominent positive peak at a wavelet scale of 64, followed by a fall-off to the negative. This indicates a weak connection at both low and high frequencies, but also suggests no relation for the mid-frequencies.

Gold (SPGSGC) vs New Zealand: The correlation again exhibits a generic behaviour, being negative at lower scales, which increases rapidly at intermediate scales, and finally becomes negative again. This indicates that, as in the other cases, the association between Gold and the New Zealand Index becomes more evident at intermediate frequencies.

Gold (SPGSGC) vs. Peru: The pattern for Peru is very similar to that of Mexico—a positive correlation that peaks around scale 64 and falls off rapidly. The correlation between Gold and Peru's index is also strongest at mid-range scales, suggesting that short- to medium-term movements in the two instruments are more in sync.

Table 4.23: Summary of the wavelet correlation with APEC Stock Market and Gold.

S. No.	Country/Index	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Strongest (128)	Wavelet Scale Peak (256)
1	Australia(SB BCAUU)	Negative	Negative	Negative	Negative	Strong Negative	Strong Negative
2	Canada(SBB CAUU)	Negative	Negative	Negative	Negative	Strong Negative	Strong Negative
3	Chile (SBCCCHL)	Neutral	Neutral	Neutral	Negative	Negative	Strong Negative
4	China SPC500CP	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
5	Hong Kong(SBBC HKU)	Strong Negative	Strong Negative	Strong Negative	Strong Negative	Strong Negative	Strong Negative
6	Indonesia (SBBCIDU)	Neutral	Fluctuating	Slight Negative	Strong Positive	Negative	Strong Negative
7	Japan (SPJ500)	Weak Positive	Weak Positive	Neutral	Neutral	Slight Positive	Positive

8	Malaysia (FBMKLCI)	Negative	Neutral	Neutral	Positive	Strong Positive	Negative
9	Mexico (TT0000)	Negative	Neutral	Strong Positive	Strong Positive	Neutral	Strong Negative
10	New Zealand (SBPCNZU)	Negative	Neutral	Neutral	Positive	Strong Positive	Negative
11	Peru (SBPCPEU)	Negative	Neutral	Strong Positive	Strong Positive	Neutral	Strong Negative
12	Philippines (SBBCPHU)	Negative	Neutral	Neutral	Negative	Negative	Strong Negative
13	Russia (IMOEX)	Negative	Neutral	Negative	Negative	Strong Negative	Strong Negative
14	Singapore (SBBCSIU)	Neutral	Weak Negative	Slight Positive	Negative	Weak Positive	Fluctuating
15	South Korea KR30	Negative	Neutral	Neutral	Positive	Strong Positive	Negative
16	Taiwan (SBBCTAU)	Neutral	Slight Negative	Weak Negative	Weak Negative	Weak Negative	Weak Negative
17	Thailand (SBBCTLU)	Neutral	Neutral	Neutral	Neutral	Neutral	Neutral
18	U.S. (SPX)	Positive	Positive	Positive	Positive	Strong Positive	Strong Positive
19	Vietnam(ID FPVNPD)	Negative	Neutral	Positive	Strong Positive	Neutral	Strong Negative

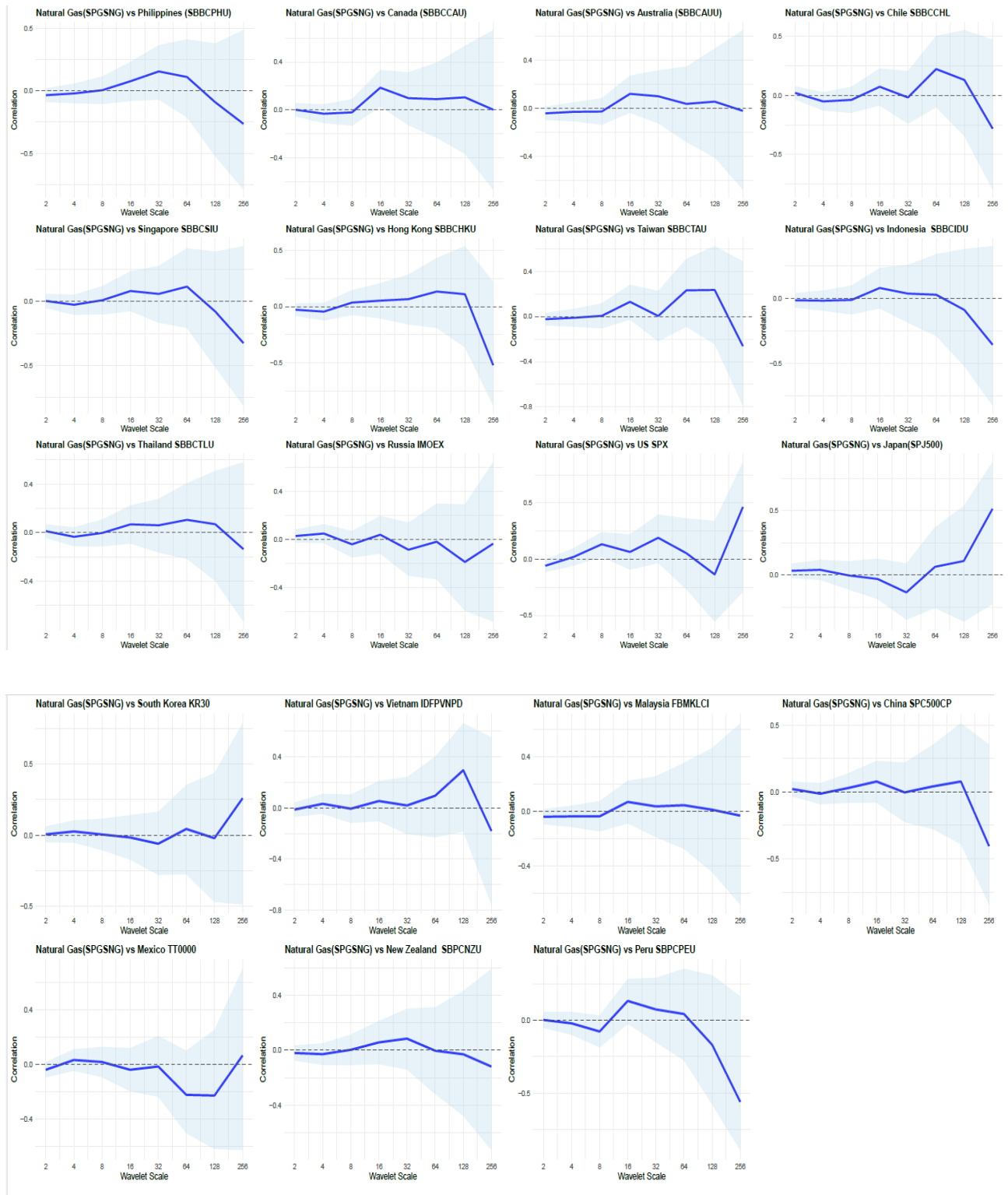


Fig. 4.26: Wavelet correlation countrywide relationship with Natural Gas

4.5.3.5 Wavelet correlation countrywide relationship with Natural Gas

Natural Gas (SPGSNG) vs Philippines (SBBCPHU): A significant correlation does not appear at smaller as well as at larger wavelet scales, indicating that there is no strong, meaningful correlation between the price of natural gas and the Philippines Stock Market

Index (SBBCPHU). The damping is reduced slightly at middle wavelet scales, but remains negative overall.

Natural Gas (SPGSNG) vs Canada (SBBCCAUI): This wavelet correlation appears mostly positively correlated at the middle scales, peaking upward and then returning to zero to drop below zero at the larger scales. This suggests that at medium-term horizons, the Canadian stock markets exhibit positive co-movements with the natural gas price; however, this relationship weakens at more extended periods.

Natural Gas (SPGSNG) vs. Australia (SBBCAUI): The correlation exhibits a similar behaviour to that of Canada; a slightly positive correlation exists at low to mid wavelet scales, and the correlation is negative at large wavelet scales. This suggests a weak short- and medium-term cointegration between the Australian stock market and natural gas prices, which persists in the long run.

Natural Gas (SPGSNG) vs Chile (SBBCHL): The correlation is predominantly negative, and it is most significant at the larger wavelet scales. This indicates a more long-term inverse relationship to Chile's stock market and natural gas prices. There is a weak tendency towards an increase at the scale of intermediate sizes; however, the negative correlation persists.

Natural Gas (SPGSNG) vs Singapore (SBBCSIU): This wavelet correlation results demonstrate a marginal positive correlation at middle scales, then decrease at higher scales. It implies that the short-to-medium-term as well as the long-term stock market of Singapore has a weak positive association with natural gas prices.

Natural Gas (SPGSNG) vs. Hong Kong (SBBCHKU): There is a varying correlation around zero, with a weak positive correlation at intermediate scales. This implies no apparent correlation between the Hong Kong stock market and natural gas prices at most wavelet scales.

Natural Gas (SPGSNG) vs Taiwan (SBBCTAU): The wavelet correlation results indicate a strong positive relation at medium-to-large time scales, which suggests that the Taiwan market could be substantially influenced by natural gas prices at this time frequency. At lower wavelet scales, the degree of correspondence is weaker or even harmful.

Natural Gas (SPGSNG) vs Indonesia (SBBCTDU): Here, the correlation again remains relatively close to zero, with a slight positive or negative bias. There is no significant correlation between the price of natural gas and the Indonesian market index at any time.

Natural Gas (SPGSNG) vs Thailand (SBBCTLU): A weak positive relationship is also found at the medium scales. It implies a loose linkage between the Thai stock market and the natural gas price in the short run.

Natural Gas (SPGSNG) vs. Russia (IMOEX): The correlation oscillates across zero, indicating that there is no stable relationship between Russia's stock market and natural gas prices, and a slight positive correlation exists at small wavelet scales.

Natural Gas (SPGSNG) vs U.S. (SPX): This exhibits a moderate to strong positive correlation, especially at middle to larger wavelet scales. This indicates that the U.S. stock market (SPX) is highly positively correlated with Natural gas in the short to medium run.

Natural Gas (SPGSNG) vs. Japan (SPJ500): The relationship is generally positive, especially at higher wavelet scales, suggesting that Japan's stock market follows the movements of the price of natural gas, with a stronger correlation observed in the long run.

Natural Gas (SPGSNG) vs South Korea KR30: The correlation drifts around zero with no large-scale pattern. It exhibited relatively small fluctuations across the wavelet scales, hence suggesting no relatively strong and consistent relationship between natural gas and the South Korean market index (KR30). The shaded area represents the uncertainty in the correlation values; however, the data generally appears to be weakly correlated.

Natural Gas (SPGSNG) versus Vietnam IDFPVNP: In this plot, it appears that the correlation builds up to a higher value, indicating that there is some (positive) relationship between the two at some level of the wavelet scale. The trend starts negative, then goes positive and peaks before inverting. The association appears to be non-constant here, but could be stronger at some scales. It is suggested that natural gas prices and Vietnam could also be more connected at different scales.

Natural Gas (SPGSNG) vs. Malaysia FBMKLCI: Similar to the first figure, it shows a negative correlation that is strongest at specific wavelet scales but weakens around zero. At medium scales of the wavelet support, there appears to be a stronger correlation; however, at larger scales, the correlation remains flat at around zero.

Natural Gas (SPGSNG) versus China SPC500CP: In this case, the correlation begins positively but becomes increasingly negative as the wavelet scale increases. This may indicate that at some frequencies (longer time scales), natural gas and China's SPC500CP index have a negative relationship with each other. In turn, it may mean that they move in opposite directions at those frequencies.

Natural Gas (SPGSNG) versus Mexico TT0000: This figure reveals a remarkable positive correlation that reaches its maximum at certain wavelet scales. It probably indicates that at specific frequencies, there is a weak to strong positive relationship between Mexican and natural gas prices. This could suggest that in those scales, the market movements of the two assets are correlated.

Natural Gas (SPGSNG) versus New Zealand SBPCNZU: The plot here reveals a weak correlation around zero and minor dissimilarities, implying that there is no decisive and consistent relationship between natural gas and New Zealand's Index along the wavelet scales. This structure exhibits a minimal relationship between the two series.

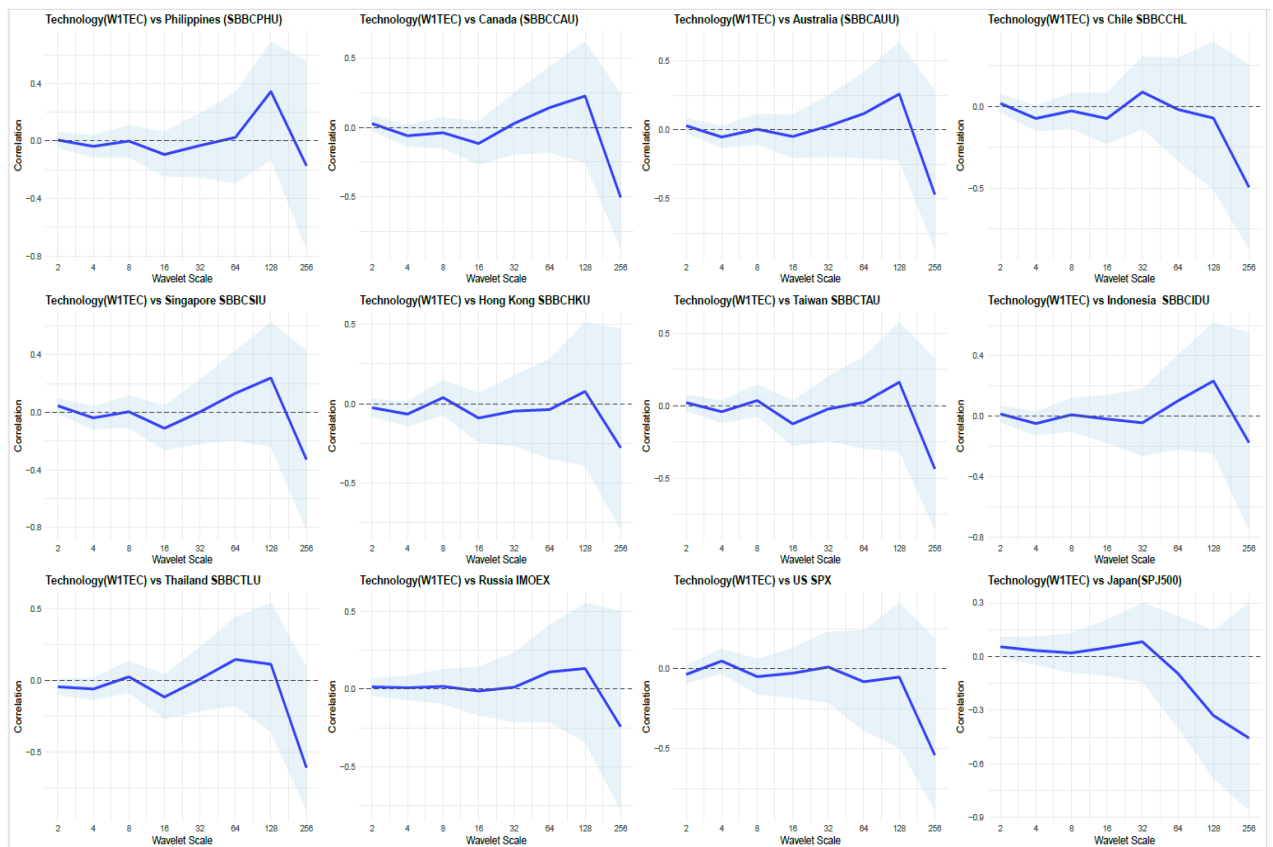
Natural Gas (SPGSNG) versus Peru (SBPCPEU): The association initially starts low and becomes even lower, and after some scales, it becomes negative, indicating a small negative association between natural gas and the Peru index at specific scales. The negative relationship becomes more apparent at increasing wavelet scale, suggesting that at higher frequencies (going back in time), the two assets tend to move in opposite directions.

Table 4.24: Summary of the wavelet correlation with APEC Stock Market and Natural Gas.

S. No.	Country/Index	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Strongest (128)	Wavelet Scale Peak (256)
1	Philippines (SBBCPHU)	Negative	Negative	Negative	Negative	Negative	Negative
2	Canada (SBBCCA U)	Positive	Positive	Positive	Positive	Positive	Negative
3	Australia (SBBCAU U)	Negative	Negative	Negative	Negative	Strong Negative	Strong Negative
4	Chile (SBBCCHL)	Negative	Negative	Negative	Negative	Negative	Mild Positive

5	Singapore (SBBCSI U)	Positive	Positive	Positive	Positive	Positive	Weak Positive
6	Hong Kong (SBBCHK U)	Zero	Zero	Zero	Zero	Zero	Zero
7	Taiwan (SBBCTA U)	Positive	Positive	Positive	Positive	Strong Positive	Strong Positive
8	Indonesia (SBBCTD U)	Zero	Zero	Zero	Zero	Zero	Zero
9	Thailand (SBBCTL U)	Positive	Positive	Positive	Positive	Weak Positive	Weak Positive
10	Russia (IMOEX)	Zero	Zero	Zero	Zero	Mild Positive	Weak Positive
11	U.S. (SPX)	Positive	Positive	Positive	Positive	Strong Positive	Moderate Positive
12	Japan (SPJ500)	Positive	Positive	Positive	Positive	Strong Positive	Strong Positive
13	South Korea (KR30)	Negative	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral
14	Vietnam (IDFPVN P)	Negative	Weak/Neu tral	Moderate Positive	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral
15	Malaysia (FBMKLC I)	Negative	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral

16	China (SPC500C P)	Positive	Weak/Neu tral	Weak/Neu tral	Negative	Negative	Negative
17	Mexico (TT0000)	Weak Positive	Weak/Neu tral	Moderate Positive	Weak/Neu tral	Weak/Neu tral	Moderate Positive
18	New Zealand (SBPCNZ U)	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral	Weak/Neu tral
19	Peru (SBPCPE U)	Weak/Neu tral	Weak/Neu tral	Negative	Negative	Negative	Negative



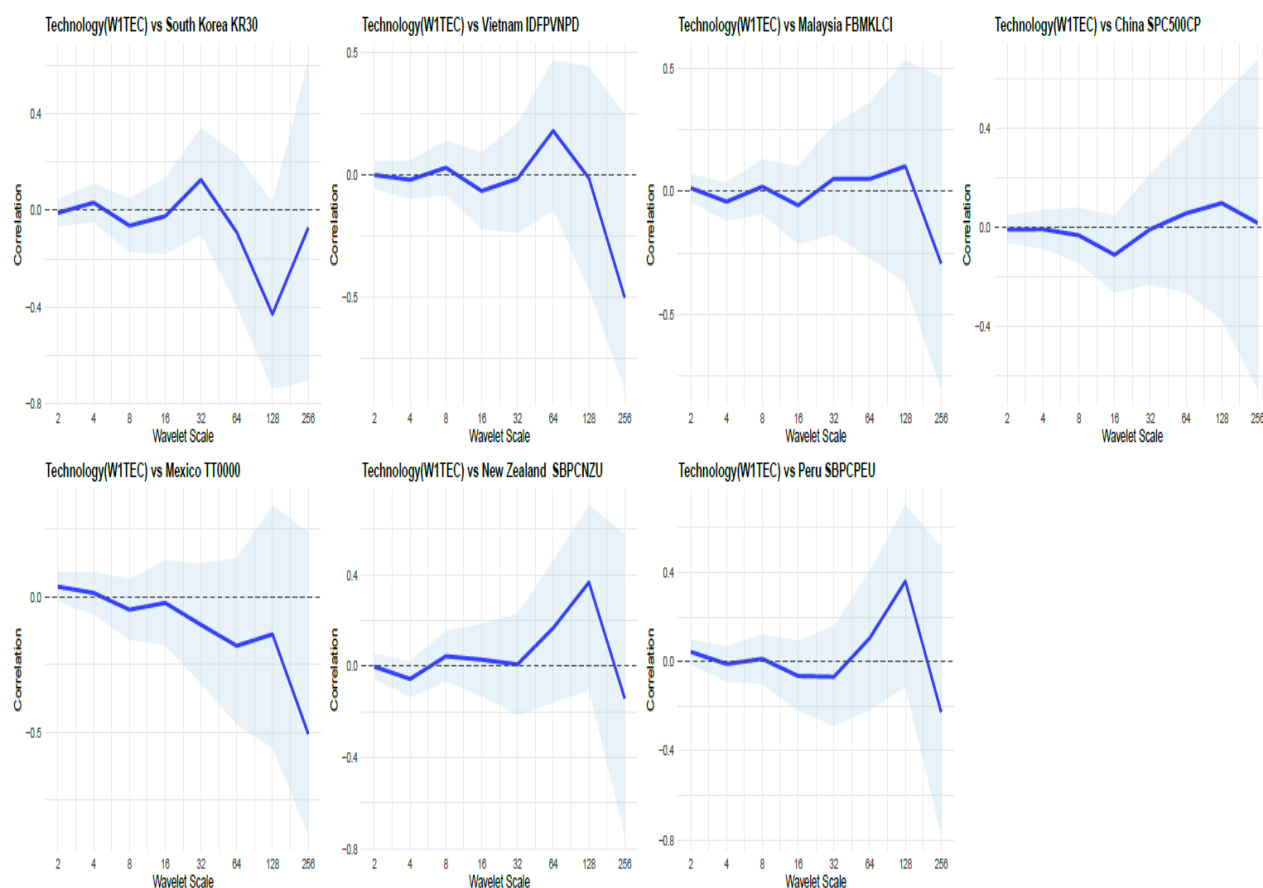


Fig. 4.27: Wavelet correlation Stock Market countrywide relationship with Technology stocks

4.5.3.6 Wavelet correlation Stock Market countrywide relationship with Technology

Philippines (SBBCPHU) V/s Technology: At low wavelet scales, the correlation steeply increases at intermediate scales, a breakthrough occurs, and the correlation steeply decreases again at larger scales. It implies that the link between Technology (WITEC) and the Philippine stock market is variable in time scales, with visible strong volatility behaviour in the short and medium terms and weak correlation in the long term.

Canada (SBCCAU) V/s Technology: The relation is predominantly inverse, especially at intermediate to larger scales, with the maximum inverse relationship around scale 128. It means that, with a negative sign at higher time scales, there is a negative correlation between the Technology index and the Canadian market at most time scales.

Australia (SBBCAUU) V/s Technology: Like Canada, the correlation is negative, but the association does not appear as regular. A strong negative relationship is found mainly at middle scales, which could mean that there is an inverse association between technology improvement and the Australian market, but only at specific time scales and not always.

Chile (SBBCCHL) V/s Technology: There is virtually no correlation for Chile at all scales analysed, indicating probably no significant relationship between Technology(WITEC) and the Chilean stock market within the time scales studied.

Singapore (SBBCSIU) V/s Technology: The correlation is first negative at small scale, positive at scale (32), negative after that. This situation indicates that there may be short-term oscillations within (e.g., with a one-week window) where the two series move in different directions. However, as the time scale increases, they begin to move in the same direction for a while before reverting to a negative trend again.

Hong Kong (SBBCHKU) vs. Technology: The relationship is primarily negative on the majority of the wavelet scales, especially at the larger time scales, which means that the Hong Kong market and Technology (WITEC) are mainly in a negative relationship, and the trend is more reinforced at higher volumes.

Taiwan (SBCTAU) vs. Technology: This plot is characterised by a mostly negative correlation pattern at various scales, with a stronger negative correlation at larger scales. (It suggests that, like Hong Kong, the relationship between the stock market and Technology (WITEC) for Taiwan is negative, especially for longer time horizons.

Indonesia (SBBCTIDU) V/s Technology: The correlation varies between being negative and positive at different wavelet scales. It begins negatively, rises on a minor scale, and declines once again, possibly indicating a complex or counter-veiling dependence as a function of time.

Thailand (SBBCTLU) vs. Technology: The linkage begins in the negative region and remains continuously negative at all wavelet scales, resulting in a negative relationship between the Technology index and the Thai stock market. Experiments show it is extreme at intermediate scales.

Russia (IMOEX) vs. Technology: The connection between Thailand and Russia is also mainly negative, and the most significantly negative correlation can be observed at intermediate scales (approximately scale 64). This means that Russia behaves on average in opposition to Technology (WITEC).

U.S. (SPX) vs. Technology: The dependence on the U.S. stock market is relatively solid; however, it starts from small negative values, but the relation persists for longer wavelet scales. The correlation indicates that in the short term, there is a bearish correlation. Still, in

the longer term, the relationship between Technology (WITEC) and the U.S. is likely to be bullish.

Japan (SPJ500) V/s Technology: Initially, the correlation is positive at small scales but becomes negative at larger scales. These observations indicate a dynamic change in the market over different time scales.

South Korea (KR30) vs. Technology: The relationship exhibits varying positive and negative values across different wavelet scales. At the lower scales (smaller values of the wavelet), we observe a negative correlation, indicating an inverse relationship between W1TEC technology and the South Korean index. As the scale increases, a peak emerges at an intermediate wavelet scale, accompanied by a somewhat stronger positive correlation. But the correlation is reduced again at the most significant momentum. This indicates an oscillating connection, implying that the technology index is affecting (or being affected by) the South Korean market at different time lengths.

Vietnam (IDFPVNPD) V/s Technology: The correlation is initially low (in fact, around zero), then rises to a positive maximum at larger wavelet scales. At some mid-range scales, the correlation remains positive, while at higher scales, it finally decreases. That means that the impact of technology development on Vietnam's market is strengthened at specific time intervals but otherwise weakened.

Malaysia (FBMKLCI) V/s Technology: The relationship varies, hovering at around zero at most wavelet scales. At specific time scales, the correlation becomes negative, indicating that, at these time scales, the technology and Malaysian index are inversely correlated. Taken together, this implies a weak or non-synchronous relation between the two over time with no clear trend at any wavelet scale.

China (SPC500CP) V/s Technology: The dependence is overall positively correlated, with a maximum around the intermediate wavelet scales, while decreasing at the larger scales. This indicates a moderate dependence of the technology sector on the Chinese index at some time scales, and the dependence diminishes at longer time horizons.

Mexico (TT0000) V/s Technology: Correlation initially nasty and negative at small wavelet scales and has a clear little dip at medium-scale wavelets. It is indicative of a negative correlation relationship between technology and the Mexican market at these scales. The correlation begins to move closer to zero but remains negative, suggesting a weak or receding association as the scale increases.

New Zealand (SBPCNZU) V/s Technology: The plot is anti-correlated at more minor wavelet scales but positively correlated at larger wavelet scales. This change implies that, in shorter time horizons, the technology index is negatively related to New Zealand's financial index, while in longer horizons, the relationship becomes positive.

Peru (SBPCPEU) V/s Technology: The relationship is oscillatory, with positive peaks and negative troughs at different wavelet scales. A well-defined positive peak at mid-wavelet scales and a rapid decrease towards large wavelet scales indicate a weak anti-persistent pattern between technology and the Peruvian index in specific time-frequency ranges.

In Conclusion, based on the above results of the wavelet correlation, the APEC stock market has shown a Negative trend with Technology stocks. Interestingly, the Natural gas and Gold indices have shown a mixed relationship with the APEC stocks at different levels. On the other hand, Clean Energy, Green Bonds, and Crude Oil exhibit a strong correlation in the long term and a low correlation at more minor scales, indicating that over the period, APEC Stock is strongly correlated or connected with these variables.

Table 4.25: Summary of the wavelet correlation with APEC Stock Market and Technology.

S. No.	Country/Index	Wavelet Scale Start (2)	Wavelet Scale Increase (8)	Wavelet Scale Strong (32)	Wavelet Scale High (64)	Wavelet Scale Strongest (128)	Wavelet Scale Peak (256)
1	Australia (SBBCAUU)	Negative	Negative	Weak Negative	Weak Negative	Negative	Negative
2	Canada (SBCCAU)	Negative	Negative	Negative	Negative	Strong Negative	Negative
3	Chile (SBBCCHL)	Zero	Zero	Zero	Zero	Negative	Negative
4	China (SPC500CP)	Neutral	Neutral	Positive	Neutral	Positive	Negative
5	Hong Kong (SBBCHKU)	Negative	Negative	Negative	Negative	Strong Negative	Negative
6	Indonesia (SBBCTIDU)	Negative	Positive	Positive	Negative	Negative	Negative

7	Japan (SPJ500)	Positive	Positive	Neutral	Negative	Negative	Negative
8	Malaysia (FBMKLCI)	Neutral	Neutral	Negative	Negative	Neutral	Negative
9	Mexico (TT0000)	Negative	Negative	Negative	Neutral	Weak	Neutral
10	New Zealand (SBPCNZU)	Negative	Negative	Positive	Neutral	Positive	Negative
11	Peru (SBPCPEU)	Negative	Positive	Positive	Negative	Positive	Negative
12	Philippines (SBBCPHU)	Negative	Negative	Positive	Negative	Negative	Negative
13	Russia (IMOEX)	Negative	Negative	Negative	Negative	Strong Negative	Negative
14	Singapore (SBBCSIU)	Negative	Weak Positive	Positive	Negative	Negative	Negative
15	South Korea (KR30)	Negative	Negative	Positive	Negative	Positive	Negative
16	Taiwan (SBCTAU)	Negative	Negative	Weak Negative	Negative	Strong Negative	Negative
17	Thailand (SBBCTLU)	Negative	Negative	Negative	Negative	Strong Negative	Negative
18	U.S. (SPX)	Negative	Weak Negative	Neutral	Positive	Weak Positive	Positive
19	Vietnam (IDFPVNPD)	Negative	Neutral	Positive	Neutral	Positive	Negative

Chapter 5

5 Summary, Conclusion and Suggestions

This final chapter offers a concise synopsis of the preceding analysis, followed by a discussion of the principal insights derived from the investigation of dynamic connectedness, co-movements, and hedging effectiveness across APEC equity markets, energy commodities, technology stocks, gold, and green bonds. It summarizes the research design and empirical results, articulates conclusions, and highlights practical implications for investors, portfolio managers, and policymakers operating in both regional and global arenas. Section 5.1 reviews the entire study, emphasizing how time-varying connectedness metrics, wavelet co-movement techniques, and optimal-portfolio models (MVP, MCP, MCoP) were integrated to evaluate systemic linkages and diversification benefits. Sections 5.2 and 5.3 present the core findings—detailing long-run and short-run spillover patterns among the five asset classes—and the key conclusions regarding their roles in risk transmission and hedge effectiveness. Section 5.4 discusses managerial and policy implications, illustrating how a blended allocation across APEC equities, energy, tech, gold, and green bonds can enhance risk-adjusted performance. Section 5.5 delineates study limitations, including data frequency constraints and model-specific assumptions. Finally, Section 5.6 identifies avenues for future inquiry, such as extending the framework to high-frequency data, alternative sustainable assets, and stress-test scenarios under extreme market conditions.

5.1 Study Overview

This study aims to examine the evolving interconnectedness and co-movement patterns between APEC equity markets and a select group of key global asset classes—namely energy commodities, technology stocks, gold, and green bonds. The study focuses on exploring dynamic connectedness and co-movement among a broad set of asset classes, including equity indices from 19 developed and emerging APEC countries, green bonds, clean and dirty energy assets, gold, and global technology. The selected countries and their respective equity market indices are: Philippines (PSEI - SBBCPHU), Canada (TSX - SBBCCAU), Australia (ASX 200 - SBBCAUU), Chile (SBBCCHL), Singapore (STI - SBBCSIU), Hong Kong (HK50 - SBBCHKU), Taiwan (TWSE - SBBCTAU), Indonesia (JCI - SBBCIDU), Thailand (SET Index - SBBCTLU), Russia (MOEX - IMOEX), USA (S&P 500 - USSPX), Japan (NIKKEI 225 - SPJ500), South Korea (KOSPI - KR30), Vietnam (VNI - IDFPVNPD), Malaysia (KLCI - FBMKLCI), China (SHCOMP - SPC500CP), New Zealand (NZSE50 - SBPCNZU), Mexico (BMV - TT0000), and Peru (BVL - SBPCPEU). In addition to equities,

the analysis includes key global asset classes such as Green Bonds (S&P Green Bond Index - SPGRBND), Clean Energy (S&P Global Clean Energy Select Index - SPGTCSUP), Crude Oil (S&P GSCI Crude Oil - SPGSCL), Natural Gas (S&P GSCI Natural Gas - SPGSNG), Gold (S&P GSCI Gold - SPGSGC), and Technology (Dow Jones Global Technology Index - W1TEC). This diversified selection allows the study to capture intricate co-movements and volatility spillovers among traditional markets, emerging economies, and alternative sustainable investments, making it possible to evaluate systemic interconnectedness, portfolio hedging opportunities, and transmission of global shocks.

The inquiry is novel because it simultaneously spans (a) traditional safe-haven assets (gold), (b) transition commodities (natural gas, crude oil), (c) digital growth proxies (technology), and (d) ESG-aligned instruments (green bonds, clean energy), all set against a heterogeneous mix of developed and emerging APEC bourses. The research addresses critical gaps in the existing literature by investigating how these markets interact over time and across different frequencies, and how such interactions can be strategically leveraged for portfolio diversification and risk management. The study is motivated by the growing complexity and integration of global financial markets, particularly within the Asia-Pacific region, where regional economic growth, policy shifts, and increased investor interest in sustainable and digital assets have reshaped traditional asset dynamics. Prior research has primarily focused on developed markets or individual asset pairs, leaving an important gap in understanding the multilateral, dynamic linkages that exist in more diversified and emerging market contexts. This thesis, therefore, offers a novel contribution by exploring the interdependencies between APEC equities and alternative asset classes using both time-varying and time-frequency analytical frameworks.

To meet the research objectives, three methodological components are explained and justified in detail:

5.1.1 Connectedness Approach TVP-VAR

To estimate the dynamic spillover indices among the chosen asset classes, the Time-Varying Parameter Vector Autoregression (TVP-VAR) model, which is an extension of the framework introduced by Diebold and Yilmaz (2012) by Koop and Korobilis (2014), is

introduced. This model enables directional and total connectedness to be measured and structural breaks and changing relationships over time to be considered. The model provides useful information on price discovery and the spread of systemic risks in interconnected financial systems by identifying net transmitters and receivers of shocks.

5.1.2 Wavelet Analysis of Time-Frequency Co-Movement

The chapter acknowledges that financial time series are non-stationary and describes how wavelet-based methods, such as the Wavelet Power Spectrum, Cross Wavelet Transform, and Wavelet Coherence, can be used to measure time-localized and scale-specific co-movement patterns. These methods allow identifying short-, medium- and long-term synchronization between APEC equities and the other four asset classes. Specifically, wavelet coherence enables the detection of lead-lag relationships and the strength of co-movement across multiple frequency bands that are frequently ignored by traditional time-domain models.

5.1.3 Portfolio Optimization Models: MVP, MCP and MCoP

The study uses three different portfolio optimization frameworks to measure the effectiveness of hedging and diversification strategies:

Minimum Variance Portfolio (MVP): This model, according to Markowitz (1959), seeks to minimize the total portfolio risk (variance) at a specific level of portfolio return, based on asset return covariances.

Minimum Correlation Portfolio (MCP): MCP proposed by Christoffersen et al. (2014) minimizes systemic exposure by building portfolios with the lowest average pairwise correlation of the assets in the portfolio.

Minimum Connectedness Portfolio (MCoP): This model is based on the idea of Broadstock et al. (2020) and employs the pairwise connectedness indices of the TVP-VAR model to choose assets that are less systemically interconnected and thus provide more protection against the risk of contagion.

All these portfolios are measured with Sharpe Ratios to find out the risk-adjusted performance and to compare the effectiveness of each model in reducing exposure in high-volatility or crisis times.

5.2 MAIN FINDINGS BY OBJECTIVES

The empirical findings of this study are interpreted within the framework of three foundational theories. First, the Efficient Market Hypothesis (EMH; Fama, 1970) predicts that information shocks propagate rapidly across integrated markets. The crisis-period TCI spikes exceeding 80% observed in this study confirm EMH's implication that geopolitical and pandemic shocks disrupt price discovery and generate cross-market contagion. Second, Markowitz's (1952) Modern Portfolio Theory provides the foundation for the portfolio constructions. The superior Sharpe Ratio of the MVP during high-connectedness regimes confirms that risk diversification is most valuable when asset correlations rise, and the MCoP's superiority during crisis peaks extends MPT into the dynamic connectedness domain. Third, Solnik's (1974) Theory of International Portfolio Diversification establishes that diversification benefits are horizon-dependent. The wavelet coherence evidence directly confirms this: diversification benefits are strongest at short-to-medium frequency scales (scales 2–32, approximately 1 week to 1.5 months) and diminish at longer horizons as markets achieve sustained alignment.

5.2.1 Description of Descriptive Statistics and Implications

This section gives an in-depth overview of the descriptive statistics of the return series of the chosen asset classes, namely, APEC equity markets, clean energy, green bonds, technology stocks, and commodities, such as crude oil and natural gas. The mean returns are near zero in most series as expected with high-frequency financial data and indicate the overall unpredictability and efficiency of daily market fluctuations. But small positive returns in the U.S. and technology sectors indicate that investors are optimistic about those sectors in the long term. On the other hand, markets such as Philippines, Chile and Hong Kong have a slightly negative returns which could be due to local economic or geopolitical pressures. The values of variance, which is a proxy of volatility, are significantly different with natural gas and crude oil exhibiting high volatility. Conversely, safer investments such as green bonds and gold have lower variance, which supports their potential as safe havens or stabilizing elements in diversified portfolios.

The series distributional properties are significant to modeling and risk assessment. Most series have negative skewness, which means that there is a greater likelihood of extreme downside risk, which is relevant to hedging strategies and risk-averse portfolio construction.

The existence of leptokurtic (fat-tailed) distributions, which is indicated by high kurtosis in assets such as crude oil and Russian equities, is an indicator of exposure to large, rare shocks, which is a major characteristic in markets that are sensitive to geopolitical events and economic crises. The Jarque-Bera test results, which reject the null of normality across all assets, support the need for non-linear, robust econometric models such as TVP-VAR and GARCH frameworks. Additionally, stationarity confirmed by the ADF test validates the use of time series models without differencing. The significant $Q^2(5)$ statistics, indicating autocorrelation in squared residuals, further support the presence of conditional heteroskedasticity, justifying the integration of time-varying models in volatility and spillover analysis. These statistical features not only shape the methodological foundation of the study but also directly inform the portfolio optimization strategies discussed in later sections.

5.2.2 Objective 1: Dynamic Connectedness

5.2.2.1 Findings

High Total Connectedness Index (TCI) Variability: The TCI plot from 2016 to 2024 reveals significant fluctuations, starting near 100% in 2016, declining to a low of 40% during 2020-2022 (COVID-19), and surging above 80% in 2024 (Iran-Israel War). This indicates periods of intense global risk integration, particularly during energy and geopolitical crises.

Crude Oil as Dominant Risk Transmitter: The FROM, TO, and NET spillover plots consistently highlight crude oil's role as the primary volatility driver (NET +13.92%, TO 67.74%, FROM 53.82%), with significant impacts on Russia (7.26%), Vietnam (4.99%), and Malaysia (3.30%), peaking during the 2014-16 Oil Crisis, 2022 Russia-Ukraine War, and 2024 Iran-Israel War. The findings of the present study are consistent with those of Qiang Ji et al., 2018, thereby affirming the information spillovers from crude oil to other markets.

Natural Gas as a Moderately Resilient Contributor: Natural gas exhibits a near-neutral NET spillover (+1.18%, TO 62.62%, FROM 61.44%), transmitting risk to Russia (3.31%), China (2.96%), and Japan (2.75%), with spikes tied to LNG supply disruptions. Its low NET value indicates resilience and potential for diversification during market instability. These results support prior research by Anyikwa, and Phiri, 2023, confirming that natural gas exhibit greater resilience and hence further validate the importance of natural gas in APEC portfolio diversification.

Defensive Assets as Highly Vulnerable Stabilizers: Green bonds (NET -21.47%, FROM 68.00%, TO 46.53%) and gold (NET -19.38%, FROM 65.32%, TO 45.94%) consistently face

substantial spillovers from other assets, marked by stable FROM values and minimal TO contributions. These highly negative NET values indicate significant pressure from external sources, suggesting vulnerability despite their role as safe havens, with contributions in markets like Japan (2.54% from green bonds) and China (2.69% from gold) during volatile periods, though diversification benefits are tempered by this exposure. The analysis aligns with existing literature by Boakye et al., 2024 wherein Gold is emerging as net receiver of shocks.

Clean Energy and Technology with Varying Resilience: Clean energy (NET -0.77%, FROM 61.20%, TO 60.43%) demonstrates resilience with its relatively low negative NET value, gaining modest spillovers and showing potential for diversification, particularly with notable FROM spikes in China (3.99%). In contrast, technology (NET -19.14%, FROM 53.75%, TO 34.61%) is highly vulnerable, with significant FROM spikes in South Korea (1.92%) and China (2.23%), reflecting severe exposure to policy and macro-financial shifts, limiting its diversification potential due to heavy reliance on external pressures. **Equity Market Vulnerability:** High-FROM markets like Australia (82.67%), Singapore (81.48%), and Canada (75.87%) show significant external risk exposure, with volatility spikes in 2020 and 2024, while low-FROM markets like South Korea (48.91%) demonstrate greater resilience to global shocks the results align with findings by Attarzadeh, A., & Balcilar, M. (2022) proving clean energy as diversifiers.

Geopolitical and Event-Driven Spikes: The 2020 COVID-19 dip and 2024 Iran-Israel War surge in TCI and spillover plots underscore the influence of oil related conflicts, amplifying crude oil and natural gas spillovers. Empirical evidence from this study parallels earlier findings by Maher, 2025, highlighting the robustness of Geopolitical and Oil Event-Driven Spikes across different markets.

Dynamic Transmission Patterns: Russia and China emerge as net transmitters (>66% TO), while Japan, Thailand, and New Zealand act as net absorbers, with NET spillover plots showing distinct positive and negative trends aligned with global events. The results align with Arzoumanian, S. (2023), wherein it is established how output fluctuations in Russia are transmitted internationally.

5.2.2.2 Implications

Equity Market Selection: Prioritize investment in low-FROM markets like South Korea, Hong Kong, and Peru for resilience, while minimizing exposure to high-FROM markets like Australia and Singapore during volatile phases, adjusting based on dynamic FROM spillover trends.

Dynamic Portfolio Adjustment: Regularly monitor TCI and spillover plots to adjust allocations, increasing gold and green bond weights during geopolitical tensions (e.g., 2024) and reducing crude oil and natural gas during energy price surges, ensuring alignment with event-driven risk patterns.

Risk Management Focus: Implement derivatives or pair trades (e.g., oil futures) to offset crude oil's impact and diversify across asset classes and geographies to leverage the stabilizing influence of net absorbers like Japan and Thailand, enhancing overall portfolio resilience.

Long-Term ESG Integration: Focus on clean energy to achieve sustainable growth, leveraging their stabilizing NET trends (-0.77%) and increasing importance in the context of the climate crisis, especially in such markets as China and Mexico.

Geopolitical Sensitivity: Plan to be more connected in times of conflicts (e.g., 2024 Iran-Israel War) by preferring safe havens and minimizing exposure to transmitter markets such as Russia and China, so that it can adapt to sudden spillover increases.

5.2.3 Objective 2: Optimal hedging and portfolio allocation

The aim of this paper was to analyze the performance of three sophisticated portfolio optimization techniques Minimum Variance Portfolio (MVP), Minimum Correlation Portfolio (MCP), and Minimum Connectedness Portfolio (MCoP) to determine their effectiveness in risk management and in producing returns in volatile financial markets. All these portfolios are alternative ways of constructing a portfolio based on contemporary financial theory and sound empirical techniques. By performing a comparative analysis using mean return, standard deviation, Sharpe ratio, and hedge effectiveness (HE), we have been able to determine different risk-return profiles and the suitability of these strategies in different market conditions.

Minimum Variance Portfolio (MVP) is based on the pioneering research of Markowitz (1959) and seeks to minimize the overall portfolio risk by choosing assets that when

combined yield the minimum variance. Empirical findings indicated that MVP had the highest Sharpe ratio (0.0300) compared to the other two portfolios, although it had the lowest mean return. Such high risk-adjusted performance can be explained by the fact that MVP includes assets with low individual volatilities and positive hedge effectiveness, including clean energy, technology and gold (HE 0.93-0.98). These commodities play a major role in lowering the volatility of portfolios. In addition, other assets such as gold stocks were also regularly included, providing moderate returns and good hedging characteristics. Green bonds had high weightage and positive hedge effectiveness and therefore were likely to be included in higher percentages as compared to MCP and MCoP portfolios. The portfolio construction is a clear indication of a conservative, stability-seeking approach, which is appropriate to risk-averse investors and can work in times of macroeconomic shocks or global crises.

Minimum Correlation Portfolio (MCP) is a conceptualized portfolio by Christoffersen et al. (2014) that aims to reduce systemic exposure by choosing assets with low pairwise correlation. Although MCP showed a better average return compared to MVP, it was also more volatile (standard deviation = 0.0042). As a result, its Sharpe ratio was a bit lower (0.0256), which means that its risk-adjusted performance decreased slightly. The MCP had a more geographically diversified asset base with a broad range of APEC equities and commodities. The diversification effect is seen by the incorporation of markets like crude oil, Natural Gas and Peru which all helped to increase the portfolio returns. But the higher volatility seen indicates that although MCP can be used to decrease systemic exposure, it might not provide the same degree of protection against extreme downside risk as the MVP. MCP is, thus, most suitable to the investment goals of moderately risk-averse investors who want a globally diversified portfolio with better return potential and some degree of risk containment.

The Minimum Connectedness Portfolio (MCoP) is constructed based on the connectedness indices calculated by the Time-Varying Parameter Vector Autoregression (TVP-VAR) model suggested by Broadstock et al. (2020) and aims at minimizing the systemic spillover effects among financial assets. MCoP had the highest mean return of the three portfolios, which indicated a return-seeking strategy, but at the expense of the highest volatility (standard deviation = 0.0047). Consequently, its Sharpe ratio (0.0260) was between MVP and MCP. The portfolio mix is a balanced one that picks assets with moderate returns potential and low systemic interconnectedness, including clean energy, technology, crude oil, and gold. MCoP

is especially appropriate to investors who are worried about market contagion and systemic shocks because it seeks to decouple the portfolio against inter-market linkages that are extremely strong during crisis periods. Although it is not as stable as MVP, it has a higher potential of returns and dynamic immunity to contagion, which makes it a good choice to investors with moderate to high risk tolerance who expect increased systemic volatility.

5.2.3.1 Investor Implications

These results have significant implications to different types of investors:

- **Risk-Averse Investors:** The Minimum Variance Portfolio (MVP) is the best option to those who want to preserve their capital and have low volatility, particularly when there is financial instability. It has low variance and high hedge effectiveness, which makes it resistant to global shocks and appropriate to long-term, passive investment strategies.
- **Diversification-Oriented Investors:** Investors seeking exposure to a wide range of international markets without sacrificing risk control too much should look at the Minimum Correlation Portfolio (MCP). It offers a moderate protection against volatility and permits modest returns due to its capacity to decrease internal portfolio correlations.
- **Crisis-Sensitive or Systemic Risk-Aware Investors:** Investors that are worried about global contagion and the propagation of shocks across interconnected markets would find the Minimum Connectedness Portfolio (MCoP) most useful. It is perfect in times of geopolitical turmoil, pandemics, or systemic financial crises, when conventional diversification might not provide adequate protection.

Table-5.1: Comparative Portfolio Performance and Suitability

Criteria	Minimum Variance Portfolio (MVP)	Minimum Correlation Portfolio (MCP)	Minimum Connectedness Portfolio (MCoP)
Objective	Minimize total variance	Minimize pairwise correlation	Minimize systemic connectedness
Mean Return	7.39E-05	0.000108	0.000123
Standard Deviation	0.0025 (lowest)	0.0042	0.0047 (highest)
Sharpe Ratio	0.0300 (highest)	0.0256	0.0260

Volatility Reduction Strategy	High HE assets (Oil, Gas, Clean Energy)	Globally diversified low-correlation assets	Assets with low TVP-VAR connectedness
Geographic Diversification	Moderate	Broad	Balanced
Systemic Contagion Shield	Moderate	Moderate	Strongest
Return Orientation	Conservative	Balanced	Growth-oriented
Suitable For	Highly risk-averse investors	Moderate-risk investors seeking diversification	Investors anticipating systemic risks

Overall, this discussion confirms that various optimization strategies address the needs of different investors and their risk tolerance. The MVP is unique in its risk-reducing characteristics and risk-adjusted performance, which makes it the most appropriate strategy in turbulent times. MCP provides a moderate trade-off with low-correlation diversification, whereas MCoP is a dynamic portfolio option to overcome financial contagion. The success of both models, as evidenced by empirical performance and theoretical rationale, supports the notion that portfolio strategies should be customized to the macroeconomic environment and investor type.

5.2.4 Objective 3: Wavelet Coherence

5.2.4.1 Findings

5.2.4.1.1 Gold and APEC Equity Markets

Wavelet coherence results demonstrate that gold consistently acts as a leading indicator of equity market movements across most APEC countries during multiple global crises as demonstrated in Table 5. 1. Notably, during the Oil Crisis, countries such as Chile, Japan, Vietnam, New Zealand, and Canada exhibited short- to medium-term coherence with gold leading. This trend continues during the Climate Crisis, where China and Australia saw medium- and long-term leadership. During COVID-19, gold led equity markets in Taiwan, Russia, USA, Japan, Vietnam, and New Zealand across all three-time scales.

In the Russia–Ukraine War, gold's leadership was evident in Canada, Chile, Russia, USA, and Japan, mostly at medium and long horizons. Lastly, during the Iran–Israel War, gold was a medium- to long-horizon leader in Canada, Australia, and Malaysia.

Gold's leading role implies that it functions as a classic hedge and safe haven, with its pricing adjusting quickly to global uncertainties before equity markets can internalize the same. Countries with large exposure to commodities, geopolitically sensitive trade balances, or strong currency fluctuations (e.g., Canada, Russia, and Australia) exhibit stronger coherence.

Table 5.2: Gold as a Leading Indicator for APEC Equity Markets During Global Crises

Crisis	Countries Where Gold Leads (by Time Horizon)
Oil Crisis	S: Chile, Japan, Vietnam, NZ; M: Canada, Australia, etc.
Climate Crisis	M: China; L: Australia
COVID-19	S/M/L: Taiwan, Russia, USA, Japan, Vietnam, NZ
Russia–Ukraine	M/L: Canada, Chile, Russia, USA, Japan
Iran–Israel War	M: Canada, Australia, Malaysia; L: Malaysia

Source: Author's calculations

Implication: Investors should monitor gold for early risk-off signals, especially in markets like Vietnam, New Zealand, and Russia, where gold leads equity market responses during global uncertainty.

5.2.4.1.2 Natural Gas and APEC Equity Markets

Wavelet coherence results for natural gas reveal its strategic importance, especially for economies that are net energy importers or exporters (see Table 5.2). During the Oil Crisis, Australia, Indonesia, Japan, and Malaysia showed coherence with gas markets, with gas leading equity returns at short and medium horizons. During the Climate Crisis, countries such as USA, Japan, Malaysia, and China exhibited short- and medium-term coherence.

The COVID-19 period again showed gas leading in Australia, Indonesia, and Mexico, primarily at medium horizons. A notable increase in coherence during the Russia–Ukraine War appeared in Chile and Vietnam, while in the Iran–Israel War, gas significantly led equities in Canada, Australia, New Zealand, USA, Malaysia, and China, particularly in the long term.

This reflects natural gas’s role as a real-time barometer of energy security, industrial cost structure, and geopolitical tension. Import-heavy economies like Japan, and LNG-exporters like Australia and Malaysia, respond quickly to changes in gas prices.

Table 5.3: Natural Gas Leading APEC Equity Market Movements by Crisis

Crisis	Countries Where Gas Leads (by Time Horizon)
Oil Crisis	S: Australia; M: Indonesia, Japan, Malaysia
Climate Crisis	S: Australia, Indonesia, China; M: USA, Japan, Malaysia
COVID-19	M: Australia, Indonesia, Mexico
Russia–Ukraine	S: Chile; M: Vietnam
Iran–Israel War	M/L: Canada, Australia, USA, Malaysia, China, NZ

Source: Author’s calculations

Implication: Investors in energy-intensive economies should watch natural gas market signals to forecast input-cost pressures on equities. Particularly in Malaysia, Vietnam, and Australia, natural gas trends precede equity market realignments.

5.2.4.1.3 Green Bonds and APEC Equity Markets

Wavelet coherence between green bonds and equity markets underscores the growing financialization of environmental concerns (see Table 5.3). During the Oil Crisis, green bonds led equity markets in Chile, Japan, Philippines, Taiwan, Vietnam, and Malaysia—predominantly at medium and long horizons.

During the Climate Crisis, coherence was found across USA, Japan, Malaysia, China, and Vietnam, where green bonds were leading indicators. In the COVID-19 era, countries like Australia, Indonesia, Malaysia, Vietnam, and New Zealand showed strong green bond leadership, particularly at medium and long horizons.

The Russia–Ukraine War reinforced this relationship, with long-horizon leadership seen in Vietnam, Malaysia, and New Zealand, while in the Iran–Israel War, Canada, Australia, Chile, Indonesia, China, and Malaysia again witnessed medium- and long-term coherence.

Green bond movements often precede equity shifts due to faster responses to ESG fund flows, sustainability-linked debt issuance, and policy interventions (like green subsidies or carbon pricing). The depth of bond markets allows earlier integration of policy shocks than equity markets.

Table 5.4: Green Bonds Leading APEC Equity Index Movements Across Global Shock Periods

Crisis	Countries Where Green Bonds Lead (by Time Horizon)
Oil Crisis	S: Chile, Japan, Philippines; M: Malaysia, Taiwan, etc.
Climate Crisis	M: USA, Japan, Malaysia, China; L: Taiwan, Vietnam
COVID-19	M/L: Australia, Indonesia, Malaysia, Vietnam, NZ
Russia–Ukraine	S/M/L: Vietnam, Malaysia, NZ, HK, Singapore
Iran–Israel War	M/L: Canada, Australia, Chile, Indonesia, China, Malaysia

Source: Author’s calculations

Implication: Green bond yield movements are an early warning system for ESG-heavy equity sectors. Investors in Malaysia, Vietnam, and New Zealand can use green bond spreads to preempt equity inflows into renewables and clean infrastructure.

5.2.4.1.4 Technology Sector and APEC Equity Markets

Wavelet coherence analysis shows that technology stocks are effective medium-term leaders of equity movements, especially in innovation-driven or export-heavy markets (see Table 5.4). During the Oil Crisis, tech led equity markets in Canada, Australia, Japan, Chile, and

Malaysia. The Climate Crisis saw leadership in Chile, Singapore, Hong Kong, Australia, and Vietnam.

During COVID-19, Singapore, Indonesia, Canada, and Japan showed coherence with technology, while in the Russia–Ukraine War, USA, China, Philippines, and Russia followed technology sector signals. The Iran–Israel War showed long-horizon coherence in Canada, Australia, Indonesia, China, and Vietnam.

These results confirm that technology markets internalize signals related to digital transformation, semiconductor geopolitics, and innovation policy faster than broader equity indices.

Table 5.5: Technology Sector as a Predictor of APEC Equity Market Dynamics During Crisis Episodes

Crisis	Countries Where Tech Leads (by Time Horizon)
Oil Crisis	M: Canada, Australia, Japan; S: Chile, Malaysia
Climate Crisis	S/M: Chile, Singapore, HK, Australia, Vietnam
COVID-19	S/M: Singapore, Indonesia, Canada, Japan
Russia–Ukraine	M/L: USA, China, Philippines, Russia
Iran–Israel War	L: Canada, Australia, Indonesia, China, Vietnam

Source: Author's calculations

Implication: Tech sector prices provide critical foresight into macro and supply chain risks. Investors in Singapore, Vietnam, and Indonesia can benefit by tracking technology ETFs and digital innovation benchmarks for portfolio rotation cues.

5.2.4.1.5 Clean Energy and APEC Equity Markets

Wavelet coherence between clean energy and equity markets revealed the strongest and most widespread leadership relationships, particularly during climate, geopolitical, and oil-related crises (see Table 5.5). During the Oil Crisis, Australia, Canada, Hong Kong, and Taiwan were significantly led by clean energy. The Climate Crisis saw clean energy lead in Australia, China, Singapore, and Vietnam across all time horizons.

During COVID-19, leadership was strong in Australia, China, Indonesia, Vietnam, and New Zealand. The Russia–Ukraine War brought clear leadership in Australia, Chile, Singapore, Hong Kong, Vietnam, Taiwan, and Malaysia. Lastly, during the Iran–Israel War, long-term leadership emerged in Canada, Australia, Chile, Singapore, Indonesia, China, Mexico, Peru, and Philippines.

This reflects the reallocation of capital towards green and sustainable sectors, often in response to global energy shocks, policy shifts, and international climate commitments.

Table 5.6: Clean Energy as a Structural Lead Asset for APEC Equity Markets Across Major Crises

Crisis	Countries Where Clean Energy Leads (by Time Horizon)
Oil Crisis	S/M: Australia, Canada, HK, Vietnam; M: Malaysia, Thailand
Climate Crisis	S/M/L: Australia, China, Vietnam, Singapore, HK
COVID-19	M/L: Australia, China, Indonesia, Vietnam, NZ
Russia–Ukraine	S/M/L: Australia, HK, Vietnam, Taiwan, Malaysia
Iran–Israel War	L: Canada, Australia, China, Mexico, Peru, Philippines

Source: Author's calculations

Implication: Clean energy markets provide stable leadership indicators to nations in green transitions. When investing in Vietnam, China, Australia, and Canada, investors must keep an eye on clean energy ETFs and indices, especially when there is a conflict or carbon policy change in the energy sector.

In general, Wavelet coherence analysis of five key asset classes proves that each asset offers unique and complementary insights into equity market dynamics in the context of global crises.

Gold and Green Bonds are traditional risk-off and ESG sentiment indicators.

Natural Gas provides a real time measure of energy inflation and supply shocks particularly in industrializing markets.

Technology is expected to foresee structural innovation, digital change, and supply-chain risk.

Clean Energy is the most encompassing forward-looking sustainability-oriented portfolio indicator. For APEC market participants and global investors, understanding these dynamic relationships empowers timelier and crisis-sensitive asset allocation, particularly in geopolitically exposed or energy-transitioning economies.

5.2.4.1.6 Crude Oil–APEC Market Co-Movement and Investment Implications

This study presents strong arguments that crude oil was always a top asset that affected the APEC equity markets during different global crises. Through the analysis of the Oil Crisis (Period 1-195), Climate Crisis (436-695), COVID-19 Pandemic (1213-1731), Russia-Ukraine War (1770-2230), and the Iran-Israel War (2317-2513), it was noted that crude oil did not operate in a vacuum but was dynamically connected to the equity performance of the emerging and developed economies in APEC. These co-movement patterns were identified in the short, medium-, and long-term horizons, which supports the macro-financial significance of crude oil.

In the Oil Crisis, crude oil demonstrated temporary leadership of markets like Vietnam, Malaysia, Taiwan, and Peru, probably because of their exposure to imported energy or oil-related exports. The medium-term structural dependencies were more apparent in the case of China and Malaysia, which are industrial and manufacturing-intensive economies. Markets such as Chile and China still showed the impact of crude oil in the long run, which meant that oil prices determined the overall economic stories and long-term investor sentiment.

The Climate Crisis era showed an expansion of the leadership of crude oil. Even in the short-run, oil price shocks were sensitive in the financial developed economies such as Australia, Singapore, and Hong Kong, as well as Taiwan, Malaysia, and China, which is a sign of how environmental and regulatory uncertainty can increase the macro-financial role of oil. The medium-term impacts could be observed in Thailand and the United States, probably because of the policy-induced anticipations regarding the energy transition. The long-term implication of the dominance of crude oil over Australia, Chile, Malaysia, and Taiwan implies that the economies will continue to be exposed to the dynamics of fossil fuels in the face of changing climate policy regimes.

The scope of the impact of crude oil was even wider in the case of the COVID-19 pandemic. The short-run impacts were observed in Indonesia, Malaysia, New Zealand, and China, which were the first countries to be affected by the supply chain breakdown and the shrinking of global demand (Zahraee et al., 2022). The medium-term co-movement covered a large cluster of countries such as Canada, Australia, Chile, Hong Kong, Russia, Mexico, and Peru, which shows the importance of oil as a key global macroeconomic variable in recovery and uncertainty. The fact that these patterns persisted over long periods of time implies that there was a long-run consistency between investor expectations and macroeconomic fundamentals and energy price paths, particularly during portfolio rebalancing under crisis conditions (H & Rishad, 2020; Fischer et al., 2021; Potts & Yerger, 2024)

During the Russia Ukraine war, crude oil still maintained its impact, especially in the short and medium term in Canada, Australia, Chile, Taiwan, Japan, and Indonesia, among others. This was a reaction of the global investors to geopolitical risks such as supply shocks and inflationary fears (Bilal et al., 2023; Sun et al., 2024). The historical control in Chile, Indonesia, Malaysia, and Peru highlights the entrenched power of crude oil in the economy of countries that are prone to energy price pass-throughs and trade shocks (Saari et al., 2016; César et al., 2021; Rahman et al., 2021)

The Iran Israel war, though more localized in character, also confirmed the role of crude oil as a systemic financial indicator. Markets like Australia, Chile, New Zealand and Peru were quick in responding in the short term, whereas Taiwan and New Zealand were sensitive in the medium term. In Canada, Indonesia, China, and Peru, long-run leadership persisted. This once more demonstrates the ability of oil prices to pass through international financial markets, especially in commodity-exporting or energy-intensive economies, even in the case of regional wars. All these findings are systemic in the sense that crude oil is a time-varying leader of equity market performance across APEC economies in times of global crisis (O'Neill et al., 2009; Yao & Kuang, 2019). The strength and length of the effect of oil depends on the crisis and on structural characteristics of individual economies, including trade openness, industrial structure, and energy dependence (Alfalih, 2024; Pea-Assounga et al., 2025)

These observations have important implications to investors. Short-term investors ought to be cautious of the changes in oil prices, particularly in very sensitive markets such as Taiwan, Malaysia, and Peru where transmission of oil shocks is immediate in case of a crisis onset. Dynamic portfolio management techniques, such as stop-loss policies or tactical allocation to

energy hedges, can be useful. Medium-term investors should understand that oil has an impact not only on direct energy markets but also on the wider equity indices due to policy changes, inflationary transmission, and risk appetite. Portfolio resilience can be improved by diversification using commodities or volatility-hedged instruments. Long-term investors should consider the structural significance of crude oil in the economy of such countries as China, Malaysia, and Chile. In these countries, the cost of energy determines the cost of production, export competitiveness, and valuation fundamentals (Gupta, 2016; Karanfil & Omgba, 2022). It is therefore important to include oil-related macro factors in long-term projections and strategic asset allocation (Rubio-Varas & Muñoz-Delgado, 2019).

Moreover, the fact that crude oil has always been the most dominant commodity during crisis times confirms its position not only as a commodity but also as a macro-financial indicator (Kolodziej et al., 2014; Aladwani, 2024). It captures investor sentiment, global demand conditions, geopolitical tensions, and structural transitions- which makes it essential to multi-asset class investors, risk managers, and policy-sensitive asset allocation models working within the APEC region (Bouri et al., 2023; Bossman et al., 2023). To sum up, this co-movement analysis shows that the oil markets and APEC equity markets are becoming increasingly interconnected in a way that is sensitive to global shocks and structural dependencies (Chien et al., 2021; Abdou et al., 2024; Mensi et al., 2025). In the case of portfolio strategies that are responsive to crisis events, tracking the dynamics of crude oil provides a prospective benefit and a vital contribution to investment decision-making models.

The three objectives converge logically. High TVP-VAR connectedness peaks coincide with episodes where wavelet coherence reveals an asset leading at multiple scales (e.g., gold during COVID-19). In those windows, MCP and MCoP portfolios—which explicitly down-weight correlated or highly connected assets—out-perform because they translate early cross-asset warnings into lower ex-post volatility. Conversely, when connectedness subsides and wavelet phase arrows point to synchronous rather than leading relationships, the simple MVP or even Equal-Weight structures suffice. Thus, the dynamic spillover map (Objective 1) informs which hedging engine (Objective 2) should be favoured, while phase-specific leadership (Objective 3) explains *why* particular assets (e.g., clean energy) deliver outsized diversification gains during certain geopolitical shocks.

5.3 Policy Implications and Investor Advice Based on Optimal Portfolio Strategies and Related Findings

The findings from the analysis of dynamic connectedness, optimal hedging and portfolio allocation, and wavelet coherence across APEC equity markets and strategic asset classes (Gold, Natural Gas, Green Bonds, Technology, and Clean Energy) provide a robust foundation for shaping policy frameworks and guiding investment decisions. Below are detailed policy implications and tailored advice for investors, justified by the empirical results and their implications for managing risk and capitalizing on opportunities in a volatile global landscape as of 01:25 PM IST on Wednesday, July 09, 2025.

5.3.1 Implications for Institutional Investors and Portfolio Managers

The empirical results provide concrete, actionable guidance for institutional investors managing multi-asset portfolios with exposure to APEC equity markets.

First, during high-connectedness regimes ($TCI > 70\%$), which this study identifies as occurring during all five crisis episodes, the Minimum Connectedness Portfolio (MCoP) should be the preferred portfolio construction framework, as it explicitly accounts for the time-varying interdependence structure. The MVP may be substituted during low-connectedness tranquil periods when variance minimization alone is sufficient.

Second, Green Bonds should constitute a core defensive allocation of 30–42% in variance-minimizing portfolios, as evidenced by the MVP's 42% Green Bond weight achieving the highest Sharpe Ratio (0.0306). Despite their low weight in MCP and MCoP, green bonds retain positive hedging effectiveness ($HE = 0.59$ in MVP), confirming their risk-reduction role even in modest allocations.

Third, Clean Energy warrants strategic over-weighting relative to traditional energy commodities. Despite its very low MVP weight (0.02%), Clean Energy achieves the highest hedge effectiveness ($HE = 0.98$), meaning that even marginal allocations deliver substantial risk reduction. Investors in Australia, Vietnam, and China should track clean energy indices as leading portfolio rotation signals, particularly during climate or geopolitical crises.

Fourth, bivariate hedge ratios confirm that Natural Gas, Crude Oil, Technology, Green Bonds, and Gold all provide positive hedging efficiency across multiple APEC markets. A dynamic hedging overlay adjusting these ratios using TVP-VAR connectedness signals will outperform static hedging in volatile regimes.

5.3.2 Implications for Regulatory Bodies and Policymakers

The persistent dominance of crude oil as a net transmitter of systemic risk (NET = +13.92%) and the sharp TCI surges during geopolitical conflicts (exceeding 80% during the 2024 Iran-Israel War) have direct implications for financial regulators across APEC economies.

Regulatory authorities in high-FROM markets particularly Australia (FROM > 80%) and Singapore should implement countercyclical capital buffers and enhanced foreign currency risk disclosure requirements during periods of elevated geopolitical tension. These measures can contain the amplification of incoming volatility shocks and preserve domestic financial stability.

Policymakers responsible for energy sector oversight should prioritize flexible LNG infrastructure investment, given that Natural Gas displays balanced spillover (TO 62.6%, FROM 61.4%), acting as a conduit rather than a shock initiator. Strategic LNG infrastructure allows both importing economies (Japan, South Korea) and exporting economies (Australia, Malaysia) to cushion against global gas supply disruptions.

To deepen the market for green bonds and gold both persistent shock absorbers governments should expand sovereign green bond issuance, establish transparent reserve disclosure frameworks, and introduce sustainable investment tax incentives. Larger and more liquid green bond markets will strengthen their role as stabilizing instruments during financial stress.

5.3.3 Implications for Sustainable Finance and ESG Policy

The wavelet coherence evidence demonstrates that clean energy and green bond markets provide forward-looking signals of equity market direction particularly during climate,

geopolitical, and energy crisis windows. This has significant implications for ESG-oriented investment policy.

Regulators and standard-setting bodies (e.g., APEC Finance Ministers' Process, FSB) should advocate for consistent environmental policy frameworks including stable feed-in tariffs, predictable carbon pricing, and harmonized green taxonomy standards to ensure that clean energy and green bond markets remain reliable early-warning indicators. Policy discontinuity in ESG regulation disrupts the leadership signal these markets provide, undermining their utility for portfolio managers and central bank macro-financial monitoring.

For ESG fund managers and impact investors, the finding that Green Bonds led equity markets in Malaysia and New Zealand during ESG transition periods reinforces the case for dedicated green bond allocations as a source of both return diversification and forward-looking market intelligence. Clean energy markets provide the most comprehensive crisis-period leadership (confirmed in 14 of 19 APEC markets), making clean energy ETF exposure essential in any climate-aware APEC portfolio strategy.

5.4 Theoretical Contributions of the Study

Beyond its empirical contributions, this study makes three original theoretical advances to the literature on financial market integration, portfolio optimization, and sustainable asset allocation.

5.4.1 Theoretical Contribution 1 (TC-1) Extension of TVP-VAR Connectedness to a Multi-Asset, Multi-Crisis APEC Framework

This study is the first to apply the Antonakakis et al. (2020) TVP-VAR connectedness framework simultaneously to 19 APEC equity markets and six asset classes (Clean Energy, Crude Oil, Natural Gas, Gold, Technology, and Green Bonds) across a 10-year, five-crisis window (2015–2024). Prior applications are largely confined to bilateral or tri-variate systems and single-crisis windows. By extending the TVP-VAR to a 25-variable system with systematic crisis-period decomposition, this study advances the methodological boundary of dynamic connectedness analysis and provides the most comprehensive connectedness mapping of the APEC financial ecosystem to date. This directly addresses the limitation

identified by Gabauer and Gupta (2018) regarding the scalability of connectedness methods to large, heterogeneous financial systems.

5.4.2 Theoretical Contribution 2 (TC-2) First Integration of Green Bonds into the Minimum Connectedness Portfolio for APEC Crisis-Period Analysis

The Minimum Connectedness Portfolio (MCoP) framework has not previously been applied to include Green Bonds and Clean Energy as explicit asset classes in an APEC-wide crisis context. This study demonstrates that incorporating connectedness-based weights produces portfolios that are structurally resilient to systemic shock propagation, particularly when Green Bonds are included as a low-NET-transmitter anchor. This finding advances Modern Portfolio Theory (Markowitz, 1952) by demonstrating that connectedness-adjusted allocation decisions generate superior risk-adjusted outcomes during crisis regimes, a dimension that variance-minimizing approaches inherently ignore.

5.4.3 Theoretical Contribution 3 (TC-3) Frequency-Domain Extension of International Portfolio Diversification Theory to 19 APEC Markets

Solnik's (1974) Theory of International Portfolio Diversification established that cross-border diversification yields risk-reduction benefits depending on correlation structures. This study advances this theory into the frequency domain by demonstrating, through wavelet coherence analysis, that diversification benefits in the APEC context are systematically horizon-dependent and crisis-contingent. Clean Energy and Gold provide the most consistent short-to-medium horizon leadership (scales 2–32, approximately 1 week to 1.5 months) the time frames most relevant to active portfolio rebalancing while diversification at longer horizons (scales 64–256) diminishes as markets achieve sustained co-movement. This frequency-stratified extension of Solnik's framework provides portfolio managers with rebalancing-horizon-specific guidance that static correlation-based strategies cannot offer.

5.5 Limitations

1. Daily Frequency – Higher-frequency (intra-day) data could uncover micro-structure spillovers invisible at the daily level.

2. Index Proxies – Composite equity and asset-class indices may mask intra-sector dispersion; future work could use granular industry or firm-level data.
3. Model Dependence – TVP-VAR assumes linear relationships; extreme-value or regime-switching methods might capture tail-driven contagion more effectively.
4. ESG Data Maturity – Green-bond and clean-energy indices are still evolving; back history is shorter than for traditional commodities, potentially biasing long-horizon estimates.

5.6 Future Research Directions

High-Frequency Network Analytics – Employ minute-by-minute connectedness to test real-time shock transmission during flash-crash or cyber-attack scenarios.

Alternative Sustainable Assets – Incorporate carbon-credit futures, biodiversity indices or hydrogen benchmarks to broaden the ESG opportunity set.

Stress-Test Frameworks – Embed the TVP-VAR–wavelet pipeline in macroprudential stress tests, simulating extreme war or pandemic scenarios beyond the historical sample.

Machine-Learning-Enhanced Portfolios – Integrate neural-network estimators of dynamic correlations into the MCoP engine to automate allocation shifts.

Behavioral Overlay – Combine sentiment indices (e.g., Google Trends) with wavelet coherence to measure how attention shocks amplify or dampen the physical spillover network.

References:

- Abakah, E. J. A., Trabelsi, N., Tiwari, A. K., & Nasreen, S. (2024). Bitcoin, Fintech stocks and Asian Pacific equity markets: a dependence analysis with implications for portfolio management. *Journal of Risk Finance*, 25(5), 792–839. <https://doi.org/10.1108/JRF-04-2024-0095>
- Abbas, J., Mubeen, R., Iorember, P. T., Raza, S., & Mamirkulova, G. (2021). Exploring the impact of COVID-19 on tourism: transformational potential and implications for a sustainable recovery of the travel and leisure industry. *Current Research in Behavioral Sciences*, 2, 100033. <https://doi.org/10.1016/j.crbeha.2021.100033>
- Abbass, K., Qasim, M. Z., Song, H., Murshed, M., Mahmood, H., & Younis, I. (2022). A review of the global climate change impacts, adaptation, and sustainable mitigation measures. *Environmental Science and Pollution Research*, 29(28), 42539–42559. <https://doi.org/10.1007/s11356-022-19718-6>
- Abdou, H. A., Elamer, A. A., Abedin, M. Z., & Ibrahim, B. A. (2024). The impact of oil and global markets on Saudi stock market predictability: A machine learning approach. *Energy Economics*, 132, 107416. <https://doi.org/10.1016/j.eneco.2024.107416>
- About APEC. (2024, January 1). APEC. Retrieved July 1, 2025, from <https://www.apec.org/about-us/about-apec>
- Acharya, V. V., Pedersen, L. H., Philippon, T., & Richardson, M. (2017). Measuring systemic risk. *Review of Financial Studies*, 30(1), 2–47. <https://doi.org/10.1093/rfs/hhw088>
- ADB. (2009). The Economics of Climate Change in Southeast Asia: A Regional Review. In Asian Development Bank. Asian Development Bank. Retrieved July 2, 2025, from https://www.preventionweb.net/files/9212_EconomicsClimateChange.pdf
- Adekoya, O. B., Badmus, J. O., & Al-Faryan, M. a. S. (2025). Geopolitical Risks and the Predictability of Green Investments: A GARCH-Based Mixed Data Sampling approach. *International Journal of Finance & Economics*. <https://doi.org/10.1002/ijfe.3124>
- Advani, N. (2025, June 15). Stocks, Bonds & Correlation Chaos: Rethinking the 60/40 strategy. *The Economic Times*. <https://economictimes.indiatimes.com/markets/stocks/news/stocks-bonds-correlation-chaos-rethinking-the-60/40-strategy/articleshow/121860651.cms?from=mdr>
- Agboola, E., Chowdhury, R., & Yang, B. (2024). Oil price fluctuations and their impact on oil-exporting emerging economies. *Economic Modelling*, 106665. <https://doi.org/10.1016/j.econmod.2024.106665>
- Ahmad, N., Jawadi, F., & Azam, M. (2022). Do Multi-Market institutions and renewable energy matter for sustainable Development: A panel data investigation. *Computational Economics*, 62(4), 1393–1411. <https://doi.org/10.1007/s10614-022-10302-1>
- Ahmad, T., & Zhang, D. (2020). A critical review of comparative global historical energy consumption and future demand: The story told so far. *Energy Reports*, 6, 1973–1991.

<https://doi.org/10.1016/j.egy.2020.07.020>

Ahmad, W., & Rais, S. (2018). Time-Varying Spillover and the Portfolio Diversification Implications of Clean Energy Equity with Commodities and Financial Assets. *Emerging Markets Finance and Trade*, 54(8), 1837–1855.

<https://doi.org/10.1080/1540496x.2018.1467314>

Ahmad, W., Mishra, A. V., & Daly, K. (2018). Heterogeneous dependence and dynamic hedging between sectors of BRIC and global markets. *International Review of Financial Analysis*, 59, 117–133. <https://doi.org/10.1016/j.irfa.2018.07.005>

Ahmed, A. D., & Huo, R. (2020). Volatility transmissions across international oil market, commodity futures and stock markets: Empirical evidence from China. *Energy Economics*, 93, 104741. <https://doi.org/10.1016/j.eneco.2020.104741>

Ahmed, R., Yusuf, F., & Ishaque, M. (2023). Green bonds as a bridge to the UN sustainable development goals on environment: A climate change empirical investigation. *International Journal of Finance & Economics*. <https://doi.org/10.1002/ijfe.2787>

Akhtaruzzaman, M., Boubaker, S., & Sensoy, A. (2020). Financial contagion during COVID–19 crisis. *Finance Research Letters*, 38, 101604. <https://doi.org/10.1016/j.frl.2020.101604>

Akorsu, P. K., Kumordzie, M., Agyei, S. K., Woode, J. K., & Adjei, A. F. (2025). Dynamic interdependence between crude oil and the automobile equities amid uncertainties. *Future Business Journal*, 11(1). <https://doi.org/10.1186/s43093-025-00526-6>

Al-Mulali, U., & Ozturk, I. (2015). The effect of energy consumption, urbanization, trade openness, industrial output, and the political stability on the environmental degradation in the MENA (Middle East and North African) region. *Energy*, 84, 382–389. <https://doi.org/10.1016/j.energy.2015.03.004>

Al-Yahyaee, K. H., Mensi, W., Al-Jarrah, I. M. W., Hamdi, A., & Kang, S. H. (2019). Volatility forecasting, downside risk, and diversification benefits of Bitcoin and oil and international commodity markets: A comparative analysis with yellow metal. *The North American Journal of Economics and Finance*, 49, 104–120. <https://doi.org/10.1016/j.najef.2019.04.001>

Al-Yahyaee, K. H., Mensi, W., Ko, H., Yoon, S., & Kang, S. H. (2019). Why cryptocurrency markets are inefficient: The impact of liquidity and volatility. *The North American Journal of Economics and Finance*, 52, 101168. <https://doi.org/10.1016/j.najef.2020.101168>

Al-Yahyaee, K. H., Mensi, W., Sensoy, A., & Kang, S. H. (2019). Energy, precious metals, and GCC stock markets: Is there any risk spillover? *Pacific-Basin Finance Journal*, 56, 45–70. <https://doi.org/10.1016/j.pacfin.2019.05.006>

Aladwani, J. (2024). Oil volatility uncertainty: Impact on fundamental macroeconomics and the stock index. *Economies*, 12(6), 140. <https://doi.org/10.3390/economies12060140>

Alfalih, A. A. (2024). The impact of oil prices, foreign direct investment and trade openness

on unemployment rates in an oil-exporting country: The case of Saudi Arabia. *Heliyon*, 10(3), e25094. <https://doi.org/10.1016/j.heliyon.2024.e25094>

Alam, A., Banna, H., Alam, A. W., Bhuiyan, M. B. U., & Mokhtar, N. B. (2024). Climate change and geopolitical conflicts: The role of ESG readiness. *Journal of Environmental Management*, 353, 120284. <https://doi.org/10.1016/j.jenvman.2024.120284>

Alamgir, M., & Cheng, M. (2023). Do green bonds play a role in achieving sustainability? *Sustainability*, 15(13), 10177. <https://doi.org/10.3390/su151310177>

Alappatt, M., & Shaikh, J. M. (2014). Forthcoming Procedure of Goods and Service Tax (GST) in Malaysia. In *Issues in Business Management and Economics* (Vols. 2–12, pp. 210–213). *Journal Issues*. <https://doi.org/10.15739/IBME.2014.008>

Alexander, C., Choi, J., Park, H., & Sohn, S. (2019). BitMEX bitcoin derivatives: Price discovery, informational efficiency, and hedging effectiveness. *Journal of Futures Markets*, 40(1), 23–43. <https://doi.org/10.1002/fut.22050>

Alfar, A. J., Elheddad, M., & Doytch, N. (2023). Impact of political conflict on foreign direct investments in the mining sector: Evidence from the event study and spatial estimation. *Journal of Environmental Management*, 350, 119590. <https://doi.org/10.1016/j.jenvman.2023.119590>

Ali, O., Murray, P. A., Momin, M., Dwivedi, Y. K., & Malik, T. (2024). The effects of artificial intelligence applications in educational settings: Challenges and strategies. *Technological Forecasting and Social Change*, 199, 123076. <https://doi.org/10.1016/j.techfore.2023.123076>

Aljohani, T. M., Assolami, Y. O., Alrumayh, O., Mohamed, M. A., & Almutairi, A. (2025). Sustainable Energy Systems In a Post-Pandemic World: A Taxonomy-Based Analysis of Global Energy-Related Markets Responses and Strategies following COVID-19. *Sustainability*, 17(5), 2307. <https://doi.org/10.3390/su17052307>

Allied Market Research. (2025, January). Green Bonds Market Size, Share, Competitive Landscape and Trend Analysis Report, by investor type, by issuer, by application : Global Opportunity Analysis and Industry Forecast, 2023 - 2033. Retrieved July 2, 2025, from <https://www.alliedmarketresearch.com/green-bonds-market-A325534#:~:text=On%20the%20basis%20of%20region,to%20climate%20action%20and%20sustainability.>

Almeida, D., Ferreira, P., Dionísio, A., & Aslam, F. (2024). Exploring the connection between geopolitical risks and energy markets. *Energy Economics*, 108113. <https://doi.org/10.1016/j.eneco.2024.108113>

Alqaralleh, H., & Canepa, A. (2021). The role of precious metals in portfolio diversification during the COVID-19 pandemic: A wavelet-based quantile approach. *Resources Policy*, 75, 102532. <https://doi.org/10.1016/j.resourpol.2021.102532>

Amadi, L. (2020). Globalization and the changing liberal international order: A review of the literature. *Research in Globalization*, 2, 100015. <https://doi.org/10.1016/j.resglo.2020.100015>

Amin, S. B., Chowdhury, M. I., Ehsan, S. A., & Iqbal, S. Z. (2021). Solar energy and natural disasters: Exploring household coping mechanisms, capacity, and resilience in Bangladesh. *Energy Research & Social Science*, 79, 102190. <https://doi.org/10.1016/j.erss.2021.102190>

Amir, M., Deshmukh, R. G., Khalid, H. M., Said, Z., Raza, A., Muyeen, S., Nizami, A., Elavarasan, R. M., Saidur, R., & Sopian, K. (2023). Energy storage technologies: An integrated survey of developments, global economic/environmental effects, optimal scheduling model, and sustainable adaption policies. *Journal of Energy Storage*, 72, 108694. <https://doi.org/10.1016/j.est.2023.108694>

Ang, T., Salem, M., Kamarol, M., Das, H. S., Nazari, M. A., & Prabakaran, N. (2022). A comprehensive study of renewable energy sources: Classifications, challenges and suggestions. *Energy Strategy Reviews*, 43, 100939. <https://doi.org/10.1016/j.esr.2022.100939>

ANI. (2025, March 7). Continued geo-economic uncertainty is playing in favour of Gold: WGC. *The Economic Times*. <https://economictimes.indiatimes.com/industry/cons-products/fashion/-/cosmetics/-/jewellery/continued-geo-economic-uncertainty-is-playing-in-favour-of-gold-wgc/articleshow/118777906.cms?from=mdr>

APEC Secretariat. (2024a). APEC Capacity Building Workshop on APEC's goals of doubling the renewable energy share in the energy mix and reducing energy intensity. In APEC (EWG 08 2021S). APEC Energy Working Group.

APEC Secretariat. (2024b). APEC Regional Trends Analysis, February 2024. In APEC. Retrieved July 1, 2025, from <https://apec.sitefinity.cloud/publications/2024/03/apec-regional-trends-analysis-february-2024#:~:text=APEC%20GDP%20is%20estimated%20to,ago%20level%20of%205.9%20percent.>

APEC. (2023, June). Free trade Agreements and regional trading agreements | APEC. Retrieved July 1, 2025, from https://www.apec.org/groups/other-groups/fta_rta

Arouri, M. E. H. (2011). Does crude oil move stock markets in Europe? A sector investigation. *Economic Modelling*, 28(4), 1716–1725. <https://doi.org/10.1016/j.econmod.2011.02.039>

Arouri, M. E. H., & Nguyen, D. K. (2010). Oil prices, stock markets and portfolio investment: Evidence from sector analysis in Europe over the last decade. *Energy Policy*, 38(8), 4528–4539. <https://doi.org/10.1016/j.enpol.2010.04.007>

Asia Pacific Energy Research Centre (APEREC) & The Institute of Energy Economics, Japan (IEEJ). (2019). APEC ENERGY DEMAND AND SUPPLY OUTLOOK. In APEC (APEC#219-RE-01.9). APEC Secretariat.

Asia-Pacific Economic Cooperation [APEC]. (2020). APEC Regional Trends Analysis: New virus, old challenges and rebuilding a better Asia-Pacific APEC amid COVID-19: Navigating Risks and Opportunities towards resilience. In APEC Policy Support Unit. Asia-Pacific Economic Cooperation.

Asia-Pacific Economic Cooperation. (2022). APEC in Charts 2022 Policy Support Unit. In

Asia-Pacific Economic Cooperation. Asia-Pacific Economic Cooperation Policy Support Unit.

Asian Development Bank. (2024). Asia-Pacific Climate Report 2024. In Asian Development Bank. <https://doi.org/10.22617/sgp240498-2>

Asl, M. G., Jabeur, S. B., Nammouri, H., & Miled, K. B. H. (2024). Dynamic connectedness of quantum computing, artificial intelligence, and big data stocks on renewable and sustainable energy. *Energy Economics*, 108017. <https://doi.org/10.1016/j.eneco.2024.108017>

Attarzadeh, A., & Balcilar, M. (2022). On the Dynamic Connectedness of the Stock, Oil, Clean Energy, and Technology Markets. *Energies*, 15(5), 1893. <https://doi.org/10.3390/en15051893>

Attarzadeh, A., & Balcilar, M. (2022c). On the dynamic return and volatility connectedness of cryptocurrency, crude oil, clean energy, and stock markets: a time-varying analysis. *Environmental Science and Pollution Research*, 29(43), 65185–65196. <https://doi.org/10.1007/s11356-022-20115-2>

Attia, E. F., Aly, S. M., ElRawas, A. S., & Awad, E. O. (2023). Portfolio diversification benefits before and during the times of COVID-19: evidence from USA. *Future Business Journal*, 9(1). <https://doi.org/10.1186/s43093-023-00205-4>

Awartani, B., & Maghyreh, A. I. (2013). Dynamic spillovers between oil and stock markets in the Gulf Cooperation Council Countries. *Energy Economics*, 36, 28–42. <https://doi.org/10.1016/j.eneco.2012.11.024>

Babalos, V., Balcilar, M., & Gupta, R. (2015). Herding behavior in real estate markets: Novel evidence from a Markov-switching model. *Journal of Behavioral and Experimental Finance*, 8, 40–43. <https://doi.org/10.1016/j.jbef.2015.10.004>

Baele, L. (2005). Volatility spillover effects in European equity markets. *Journal of Financial and Quantitative Analysis*, 40(2), 373–401. <https://doi.org/10.1017/s0022109000002350>

Bakhsh, S., Zhang, W., Ali, K., & Oláh, J. (2024). Strategy towards sustainable energy transition: The effect of environmental governance, economic complexity and geopolitics. *Energy Strategy Reviews*, 52, 101330. <https://doi.org/10.1016/j.esr.2024.101330>

Balcilar, M., Ozdemir, Z. A., & Shahbaz, M. (2018). On the time-varying links between oil and gold: New insights from the rolling and recursive rolling approaches. *International Journal of Finance & Economics*, 24(3), 1047–1065. <https://doi.org/10.1002/ijfe.1704>

Bardi, U. (2018). Peak oil, 20 years later: Failed prediction or useful insight? *Energy Research & Social Science*, 48, 257–261. <https://doi.org/10.1016/j.erss.2018.09.022>

Baruník, J., & Hlínková, M. (2016). Revisiting the long memory dynamics of the implied–realized volatility relationship: New evidence from the wavelet regression. *Economic Modelling*, 54, 503–514. <https://doi.org/10.1016/j.econmod.2016.01.014>

Baruník, J., & Křehlík, T. (2018). Measuring the frequency dynamics of financial

connectedness and systemic risk*. *Journal of Financial Econometrics*, 16(2), 271–296. <https://doi.org/10.1093/jjfinec/nby001>

Basuony, M. a. K., Bouaddi, M., Ali, H., & EmadEldeen, R. (2021). The effect of COVID-19 pandemic on global stock markets: Return, volatility, and bad state probability dynamics. *Journal of Public Affairs*, 22(S1). <https://doi.org/10.1002/pa.2761>

Batool, I. (2025). Israel-Hamas conflict: impacts on world economy [RESEARCH PAPER]. *Journal of Development and Social Sciences*, 6(1), 269–281. [https://doi.org/10.47205/jdss.2025\(6-1\)24](https://doi.org/10.47205/jdss.2025(6-1)24)

Battiston, S., Rodrigues, J. F., & Zeytinoglu, H. (2007). THE NETWORK OF INTER-REGIONAL DIRECT INVESTMENT STOCKS ACROSS EUROPE. *Advances in Complex Systems*, 10(01), 29–51. <https://doi.org/10.1142/s0219525907000933>

Baur, D. G., & Lucey, B. M. (2010). Is gold a hedge or a safe haven? An analysis of stocks, bonds and gold. *Financial Review*, 45(2), 217–229. <https://doi.org/10.1111/j.1540-6288.2010.00244.x>

Baur, D., & McDermott, T. (2012, February 1). *Safe haven assets and investor behaviour under uncertainty*. <https://econpapers.repec.org/RePEc:iis:dispap:iiisd392>

Bednarski, L., Roscoe, S., Blome, C., & Schleper, M. C. (2023). Geopolitical disruptions in global supply chains: a state-of-the-art literature review. *Production Planning & Control*, 1–27. <https://doi.org/10.1080/09537287.2023.2286283>

Bekaert, G., Harvey, C. R., & Ng, A. (2005). Market integration and contagion. *The Journal of Business*, 78(1), 39–69. <https://doi.org/10.1086/426519>

Belguith, R., Alnafisah, H., Manzli, Y. S., & Jeribi, A. (2025). Can Bitcoin and Gold Have Dynamic Hedging and Safe Haven Capabilities Against the BRICS Plus Stock Market Indices During Global Crises? An Evidence from a Time-Varying Copula Approach. *Emerging Markets Finance and Trade*, 1–24. <https://doi.org/10.1080/1540496x.2025.2486677>

Benati, L. & Bank of England. (2006). Investigating inflation persistence across monetary regimes. CREI – Centre De Recerca En Economia Internacional. <https://crei.cat/wp-content/uploads/2016/09/benati.pdf>

Bende-Nabende, A. (2003). International trade, capital flows and Economic development in East Asia: the Challenge in the 21st century. In *Routledge & CRC Press* (1st Edition). Routledge.

Benlagha, N., Karim, S., Naeem, M. A., Lucey, B. M., & Vigne, S. A. (2022). Risk connectedness between energy and stock markets: Evidence from oil importing and exporting countries. *Energy Economics*, 115, 106348. <https://doi.org/10.1016/j.eneco.2022.106348>

Benton, M., Davidoff-Gore, S., Batalova, J., Huang, L., Zong, J., Migration Policy Institute, & International Organization for Migration. (2022). COVID-19 and the state of global mobility in 2021. International Organization for Migration.

https://www.migrationpolicy.org/sites/default/files/publications/mpi-COVID-19-impact-global-mobility-2021_final.pdf

Bhaduri, S. N., & Durai, S. R. S. (2008). Optimal hedge ratio and hedging effectiveness of stock index futures: evidence from India. *Macroeconomics and Finance in Emerging Market Economies*, 1(1), 121–134. <https://doi.org/10.1080/17520840701859856>

Biehl, H., Bleibtreu, C., & Stefani, U. (2023). The real effects of financial reporting: Evidence and suggestions for future research. *Journal of International Accounting Auditing and Taxation*, 54, 100594. <https://doi.org/10.1016/j.intaccaudtax.2023.100594>

Bilal, M., Aamir, M., Abdullah, S., & Khan, F. (2023). Impacts of crude oil market on global economy: Evidence from the Ukraine-Russia conflict via fuzzy models. *Heliyon*, 10(1), e23874. <https://doi.org/10.1016/j.heliyon.2023.e23874>

Billah, M., Balli, F., & Balli, H. O. (2022). Spillovers on sectoral sukuk returns: evidence from country level analysis. *Applied Economics*, 54(38), 4402–4432. <https://doi.org/10.1080/00036846.2022.2030049>

Billah, M., Hoque, M. E., Hadhri, S., & Xuan, H., DO. (2024). Tail Risk Connectedness between DeFi and Islamic Assets and their determinants. *International Review of Economics & Finance*, 103789. <https://doi.org/10.1016/j.iref.2024.103789>

Billio, M., Casarin, R., Costola, M., & Pasqualini, A. (2016). An entropy-based early warning indicator for systemic risk. *Journal of International Financial Markets Institutions and Money*, 45, 42–59. <https://doi.org/10.1016/j.intfin.2016.05.008>

Blanc, J., & Z. Brown, F. (2020, December 17). Conflict zones in the time of coronavirus: War and war by other means. Carnegie Endowment for International Peace. Retrieved July 2, 2025, from <https://carnegieendowment.org/research/2020/12/conflict-zones-in-the-time-of-coronavirus-war-and-war-by-other-means?lang=en>

Bloom, N., Schankerman, M. A., & Van Reenen, J. (2013). Identifying technology spillovers and product market rivalry. *Econometrica*, 81(4), 1347–1393. <https://doi.org/10.3982/ecta9466>

Bloomberg, M., & Pope, C. (2017). How we invest. *Journal of Applied Corporate Finance*, 29(2), 10–15. <https://doi.org/10.1111/jacf.12228>

Bohi, D. R. (1991). On the macroeconomic effects of energy price shocks. *Resources and Energy*, 13(2), 145–162. [https://doi.org/10.1016/0165-0572\(91\)90012-r](https://doi.org/10.1016/0165-0572(91)90012-r)

Bondia, R., Ghosh, S., & Kanjilal, K. (2016). International crude oil prices and the stock prices of clean energy and technology companies: Evidence from non-linear cointegration tests with unknown structural breaks. *Energy*, 101, 558–565. <https://doi.org/10.1016/j.energy.2016.02.031>

Bora, G. (2023, October 19). Investments in solar to reach \$380 billion this year: International Solar Alliance's Mathur. *The Economic Times*. <https://economictimes.indiatimes.com/small-biz/sustainability/ahead-of-6th-session-of-isa->

[assembly-international-solar-alliance-puts-focus-on-affordable-finance/articleshow/104527295.cms?from=mdr](https://www.assembly-international-solar-alliance-puts-focus-on-affordable-finance/articleshow/104527295.cms?from=mdr)

Bosch, D., & Pradkhan, E. (2015). The impact of speculation on precious metals futures markets. *Resources Policy*, 44, 118–134. <https://doi.org/10.1016/j.resourpol.2015.02.006>

Bossmann, A., Gubareva, M., & Teplova, T. (2023). EU sectoral stocks amid geopolitical risk, market sentiment, and crude oil implied volatility: An asymmetric analysis of the Russia-Ukraine tensions. *Resources Policy*, 82, 103515. <https://doi.org/10.1016/j.resourpol.2023.103515>

Bouri, E. (2020). A broadened causality in variance approach to assess the risk dynamics between crude oil prices and the Jordanian stock market. *Energy Policy*, 85, 271–279. <https://doi.org/10.1016/j.enpol.2015.06.001>

Bouri, E., & Jalkh, N. (2023). Spillovers of joint volatility-skewness-kurtosis of major cryptocurrencies and their determinants. *International Review of Financial Analysis*, 90, 102915. <https://doi.org/10.1016/j.irfa.2023.102915>

Bouri, E., Demirer, R., Gabauer, D., & Gupta, R. (2021). Financial market connectedness: The role of investors' happiness. *Finance Research Letters*, 44, 102075. <https://doi.org/10.1016/j.frl.2021.102075>

Bouri, E., Demirer, R., Gupta, R., & Nel, J. (2021). COVID-19 pandemic and investor herding in international stock markets. *Risks*, 9(9), 168. <https://doi.org/10.3390/risks9090168>

Bouri, E., Hammoud, R., & Kassim, C. A. (2023). The effect of oil implied volatility and geopolitical risk on GCC stock sectors under various market conditions. *Energy Economics*, 120, 106617. <https://doi.org/10.1016/j.eneco.2023.106617>

Bouri, E., Iqbal, N., & Klein, T. (2022). Climate policy uncertainty and the price dynamics of green and brown energy stocks. *Finance Research Letters*, 47, 102740. <https://doi.org/10.1016/j.frl.2022.102740>

Bouri, E., Nekhili, R., & Todorova, N. (2023). Dynamic co-movement in major commodity markets during crisis periods: A wavelet local multiple correlation analysis. *Finance Research Letters*, 55, 103996. <https://doi.org/10.1016/j.frl.2023.103996>

Boyer, M. M., & Filion, D. (2006). Common and fundamental factors in stock returns of Canadian oil and gas companies. *Energy Economics*, 29(3), 428–453. <https://doi.org/10.1016/j.eneco.2005.12.003>

Boza, P., & Evgeniou, T. (2021). Artificial intelligence to support the integration of variable renewable energy sources to the power system. *Applied Energy*, 290, 116754. <https://doi.org/10.1016/j.apenergy.2021.116754>

Breaking Into Wall Street. (2024). What is the Dow Jones Industrial Average (DJIA), and why does it matter to traders at banks? Retrieved July 2, 2025, from <https://breakingintowallstreet.com/kb/finance/dow-jones-industrial-average-djia/#:~:text=Selection%20Criteria%20The%20S&P%20500%20uses%20quantitative,at%20>

[least%2010%25%20of%20its%20shares%20outstanding.](#)

Buehler, H., Gonon, L., Teichmann, J., & Wood, B. (2019). Deep hedging. *Quantitative Finance*, 19(8), 1271–1291. <https://doi.org/10.1080/14697688.2019.1571683>

Cao, J., Chen, J., Hull, J., & Poulos, Z. (2020). Deep hedging of derivatives using reinforcement learning. *The Journal of Financial Data Science*, 3(1), 10–27. <https://doi.org/10.3905/jfds.2020.1.052>

Cao, L., Ahmad, S. F., Wang, Y., Shah, S. J., Ibrahim, M., Alhamdi, F. M., Allaham, M. I., & Abbas, A. (2025). Examining the relationship of inflation, gross domestic product, oil price, foreign direct investment, and trade openness on unemployment in Saudi Arabia. *Humanities and Social Sciences Communications*, 12(1). <https://doi.org/10.1057/s41599-025-05059-5>

Capie, F., Mills, T. C., & Wood, G. (2005). Gold as a hedge against the dollar. *Journal of International Financial Markets Institutions and Money*, 15(4), 343–352. <https://doi.org/10.1016/j.intfin.2004.07.002>

Cappelli, F., Carnazza, G., & Vellucci, P. (2023). Crude oil, international trade and political stability: Do network relations matter? *Energy Policy*, 176, 113479. <https://doi.org/10.1016/j.enpol.2023.113479>

Cecchetti, S. G., Cumby, R. E., & Figlewski, S. (1988). Estimation of the optimal futures hedge. *The Review of Economics and Statistics*, 70(4), 623. <https://doi.org/10.2307/1935825>

César, A., Falcone, G., & Gasparini, L. (2021). Costs and benefits of trade shocks: Evidence from Chilean local labor markets. *Labour Economics*, 73, 102075. <https://doi.org/10.1016/j.labeco.2021.102075>

Chakraborty, S. (2020, August 19). Global merchandise trade volumes fell 14% in first half of 2020: WTO. [www.business-standard.com. https://www.business-standard.com/article/international/global-merchandise-trade-volumes-fell-14-in-first-half-of-2020-wto-120081900967_1.html](https://www.business-standard.com/article/international/global-merchandise-trade-volumes-fell-14-in-first-half-of-2020-wto-120081900967_1.html)

Chang, C., Chung, S., & Yu, M. (2001). Valuation and hedging of differential swaps. *Journal of Futures Markets*, 22(1), 73–94. <https://doi.org/10.1002/fut.2208>

Chang, C., McAleer, M., & Wang, Y. (2020). Herding behaviour in energy stock markets during the Global Financial Crisis, SARS, and ongoing COVID-19*. *Renewable and Sustainable Energy Reviews*, 134, 110349. <https://doi.org/10.1016/j.rser.2020.110349>

Chang, X. (2024). Gold price inflation and its implications for financial markets: Strategies for mitigation. *Advances in Economics Management and Political Sciences*, 119(1), 189–194. <https://doi.org/10.54254/2754-1169/119/20242530>

Chatziantoniou, I., Abakah, E. J. A., Gabauer, D., & Tiwari, A. K. (2022). Quantile time–frequency price connectedness between green bond, green equity, sustainable investments and clean energy markets. *Journal of Cleaner Production*, 361, 132088. <https://doi.org/10.1016/j.jclepro.2022.132088>

Chatziantoniou, I., Colak, G., Filippidis, M., Filis, G., & Tzouvanas, P. (2025). Systemic risk and oil price volatility shocks. *Journal of Financial Stability*,

101432. <https://doi.org/10.1016/j.jfs.2025.101432>

Chatziantoniou, I., Gabauer, D., & Marfatia, H. A. (2021). Dynamic connectedness and spillovers across sectors: Evidence from the Indian stock market. *Scottish Journal of Political Economy*, 69(3), 283–300. <https://doi.org/10.1111/sjpe.12291>

Chen, G., & Wang, M. (2023). Stock market liberalization and earnings management: Evidence from the China–Hong Kong Stock Connects. *Finance Research Letters*, 58, 104417. <https://doi.org/10.1016/j.frl.2023.104417>

Chen, J., & Wang, X. (2021). Asymmetric risk spillovers between China and ASEAN stock markets. *IEEE Access*, 9, 141479–141503. <https://doi.org/10.1109/access.2021.3119932>

Chen, L., Yu, W., & Qian, L. (2024). Green credit policy and ESG performance for promoting sustainable economic system. *Journal of Infrastructure Policy and Development*, 8(4), 3392. <https://doi.org/10.24294/jipd.v8i4.3392>

Chen, X. H., Tee, K., Elnahass, M., & Ahmed, R. (2023). Assessing the environmental impacts of renewable energy sources: A case study on air pollution and carbon emissions in China. *Journal of Environmental Management*, 345, 118525. <https://doi.org/10.1016/j.jenvman.2023.118525>

Chen, X., & Long, W. (2023). To Enhance the Credibility of the Green Bond Market through Regulating GBERs: The Case of China. *Laws*, 12(6), 91. <https://doi.org/10.3390/laws12060091>

Chen, X., Yao, Y., Wang, L., & Huang, S. (2024). How EPU, VIX, and GPR interact with the dynamic connectedness among commodity and financial markets: Evidence from wavelet analysis. *The North American Journal of Economics and Finance*, 74, 102217. <https://doi.org/10.1016/j.najef.2024.102217>

Cheng, F., Gao, H., Pan, X., Qian, M., & Zhou, Q. C. (2025). China's debt market: Evolution, regulation, and global integration. *Pacific-Basin Finance Journal*, 102751. <https://doi.org/10.1016/j.pacfin.2025.102751>

Cherp, A., & Jewell, J. (2014). The concept of energy security: Beyond the four As. *Energy Policy*, 75, 415–421. <https://doi.org/10.1016/j.enpol.2014.09.005>

Chiang, T. C., & Zheng, D. (2010). An empirical analysis of herd behavior in global stock markets. *Journal of Banking & Finance*, 34(8), 1911–1921. <https://doi.org/10.1016/j.jbankfin.2009.12.014>

Chiang, T. C., Jeon, B. N., & Li, H. (2007). Dynamic correlation analysis of financial contagion: Evidence from Asian markets. *Journal of International Money and Finance*, 26(7), 1206–1228. <https://doi.org/10.1016/j.jimonfin.2007.06.005>

Chien, F., Sadiq, M., Kamran, H. W., Nawaz, M. A., Hussain, M. S., & Raza, M. (2021). Co-movement of energy prices and stock market return: environmental wavelet nexus of COVID-19 pandemic from the USA, Europe, and China. *Environmental Science and Pollution Research*, 28(25), 32359–32373. <https://doi.org/10.1007/s11356-021-12938-2>

- Chkili, W., & Nguyen, D. K. (2013). Exchange rate movements and stock market returns in a regime-switching environment: Evidence for BRICS countries. *Research in International Business and Finance*, 31, 46–56. <https://doi.org/10.1016/j.ribaf.2013.11.007>
- Chofreh, A. G., Goni, F. A., & Klemeš, J. J. (2017). A roadmap for Sustainable Enterprise Resource Planning systems implementation (part III). *Journal of Cleaner Production*, 174, 1325–1337. <https://doi.org/10.1016/j.jclepro.2017.10.285>
- Chofreh, A. G., Goni, F. A., Klemeš, J. J., Malik, M. N., & Khan, H. H. (2020). Development of guidelines for the implementation of sustainable enterprise resource planning systems. *Journal of Cleaner Production*, 244, 118655. <https://doi.org/10.1016/j.jclepro.2019.118655>
- Choubey, A., & Balaraman, K. (2025). Geopolitical tensions nudge oil outlook higher, but demand concerns persist: Reuters poll. Reuters. <https://www.reuters.com/business/energy/geopolitical-tensions-nudge-oil-outlook-higher-demand-concerns-persist-2025-06-30/>
- Chowdhury, E. K. (2022). Strategic approach to analyze the effect of COVID-19 on the stock market volatility and uncertainty: a first and second wave perspective. *Journal of Capital Markets Studies*, 6(3), 225–241. <https://doi.org/10.1108/jcms-05-2022-0015>
- Christophers, B. (2021). Fossilised Capital: Price and profit in the energy transition. *New Political Economy*, 27(1), 146–159. <https://doi.org/10.1080/13563467.2021.1926957>
- Chung, W., & Li, C. (2024). Performance evaluations of the goal of APEC’s doubling the modern renewables proportion in 2021. *Renewable Energy*, 121994. <https://doi.org/10.1016/j.renene.2024.121994>
- Ciner, C., Gurdgiev, C., & Lucey, B. M. (2012). Hedges and safe havens: An examination of stocks, bonds, gold, oil and exchange rates. *International Review of Financial Analysis*, 29, 202–211. <https://doi.org/10.1016/j.irfa.2012.12.001>
- Cludius, J., Galster, H., Healy, S., Noka, V., & Lam, L. (2022). The role of financial operators in the ETS market and the incidence of their activities in determining the allowances’ price. In Policy Department for Economic, Scientific and Quality of Life Policies, Policy Department for Economic, Scientific and Quality of Life Policies (Report PE 740.052). European Parliament. <http://www.europarl.europa.eu/supporting-analyses>
- Convoy of Hope. (2025). Largest wildfires in U.S. History. In Convoy of Hope. Retrieved July 2, 2025, from <https://convoyofhope.org/articles/largest-wildfires-in-us-history/>
- Creti, A., Joëts, M., & Mignon, V. (2013). On the links between stock and commodity markets’ volatility. *Energy Economics*, 37, 16–28. <https://doi.org/10.1016/j.eneco.2013.01.005>
- Cugno, M., Castagnoli, R., & Büchi, G. (2021). Openness to Industry 4.0 and performance: The impact of barriers and incentives. *Technological Forecasting and Social Change*, 168, 120756. <https://doi.org/10.1016/j.techfore.2021.120756>
- Cui, J., Goh, M., Li, B., & Zou, H. (2020). Dynamic dependence and risk connectedness

among oil and stock markets: New evidence from time-frequency domain perspectives. *Energy*, 216, 119302. <https://doi.org/10.1016/j.energy.2020.119302>

Cui, Y., Geobey, S., Weber, O., & Lin, H. (2018). The impact of green lending on credit risk in China. *Sustainability*, 10(6), 2008. <https://doi.org/10.3390/su10062008>

Cui, Z., Feng, R., & MacKay, A. (2017). Variable Annuities with VIX-Linked Fee Structure under a Heston-Type Stochastic Volatility Model. *North American Actuarial Journal*, 21(3), 458–483. <https://doi.org/10.1080/10920277.2017.1307765>

Cumming, D., Duppati, G., Fernando, R., Singh, S. P., & Tiwari, A. K. (2024). Dynamics of carbon risk, cost of debt and leverage adjustments. *The British Accounting Review*, 101353. <https://doi.org/10.1016/j.bar.2024.101353>

Dagher, L., & Hasanov, F. J. (2022). Oil market shocks and financial instability in Asian countries. *International Review of Economics & Finance*, 84, 182–195. <https://doi.org/10.1016/j.iref.2022.11.008>

Dai, Z., Zhu, H., & Zhang, X. (2022). Dynamic spillover effects and portfolio strategies between crude oil, gold and Chinese stock markets related to new energy vehicle. *Energy Economics*, 109, 105959. <https://doi.org/10.1016/j.eneco.2022.105959>

Darnall, N., Henriques, I., & Sadorsky, P. (2008). Do environmental management systems improve business performance in an international setting? *Journal of International Management*, 14(4), 364–376. <https://doi.org/10.1016/j.intman.2007.09.006>

Dawar, I., Dutta, A., Bouri, E., & Saeed, T. (2020). Crude oil prices and clean energy stock indices: Lagged and asymmetric effects with quantile regression. *Renewable Energy*, 163, 288–299. <https://doi.org/10.1016/j.renene.2020.08.162>

De Perthuis, C., & Trotignon, R. (2014). Governance of CO2 markets: Lessons from the EU ETS. *Energy Policy*, 75, 100–106. <https://doi.org/10.1016/j.enpol.2014.05.033>

Demiralay, S., Gencer, H. G., & Bayraci, S. (2021). How do Artificial Intelligence and Robotics Stocks co-move with traditional and alternative assets in the age of the 4th industrial revolution? Implications and Insights for the COVID-19 period. *Technological Forecasting and Social Change*, 171, 120989. <https://doi.org/10.1016/j.techfore.2021.120989>

Demski, J., Dong, Y., McGuire, P., & Mojon, B. (2025). Growth of the green bond market and greenhouse gas emissions. *BIS Quarterly Review*, 58–71. https://www.bis.org/publ/qtrpdf/r_qt2503d.htm

Denisov, I., Paramonov, O., Arapova, E., & Safranchuk, I. (2021). Russia, China, and the concept of Indo-Pacific. *Journal of Eurasian Studies*, 12(1), 72–85. <https://doi.org/10.1177/1879366521999899>

Deshmukh, C. S. D. (2021). Supply chain shift from China: Is it Vietnam's gain and India's loss? *Electronic Journal of Social and Strategic Studies*, 02(01). <https://doi.org/10.47362/ejsss.2021.2110>

- Devold, H. & ABB Oil and Gas. (2013). Oil and gas production handbook (3.0).
- Di Tommaso, C., Pacelli, V., & Povia, M. M. (2025). Green Loans and Bank Risk: Navigating the path to Sustainable finance. *International Review of Economics & Finance*, 104138. <https://doi.org/10.1016/j.iref.2025.104138>
- Didier, T., Huneus, F., Larrain, M., & Schmukler, S. L. (2021). Financing firms in hibernation during the COVID-19 pandemic. *Journal of Financial Stability*, 53, 100837. <https://doi.org/10.1016/j.jfs.2020.100837>
- Didier, T., Love, I., & Pería, M. S. M. (2011). What explains comovement in stock market returns during the 2007–2008 crisis? *International Journal of Finance & Economics*, 17(2), 182–202. <https://doi.org/10.1002/ijfe.442>
- Diebold, F. X., & Yilmaz, K. (2009). Measuring financial asset return and volatility spillovers, with application to global equity markets. *The Economic Journal*, 119(534), 158–171. <https://doi.org/10.1111/j.1468-0297.2008.02208.x>
- Diebold, F. X., & Yilmaz, K. (2011). Better to give than to receive: Predictive directional measurement of volatility spillovers. *International Journal of Forecasting*, 28(1), 57–66. <https://doi.org/10.1016/j.ijforecast.2011.02.006>
- Dieter, H. (1997). APEC and the WTO: Collision or co-operation? *The Pacific Review*, 10(1), 19–38. <https://doi.org/10.1080/09512749708719208>
- Dincer, I. (2000). Renewable energy and sustainable development: a crucial review. *Renewable and Sustainable Energy Reviews*, 4(2), 157–175. [https://doi.org/10.1016/s1364-0321\(99\)00011-8](https://doi.org/10.1016/s1364-0321(99)00011-8)
- Doğan, B., Jabeur, S. B., Tiwari, A. K., & Abakah, E. J. A. (2024). Asymmetry in returns and volatility between green financial assets, sustainable investments, clean energy, and international stock markets. *Research in International Business and Finance*, 73, 102626. <https://doi.org/10.1016/j.ribaf.2024.102626>
- Doğan, B., Radulescu, M., Nassani, A. A., Mohammed, K. S., Benlagha, N., & Baldan, C. F. (2025). Spillovers across the crude oil and major currencies exchange rates using dynamic-quantile-frequency analysis. *International Review of Economics & Finance*, 104065. <https://doi.org/10.1016/j.iref.2025.104065>
- Dorfleitner, G., & Zhang, R. (2024). ESG news sentiment and stock price reactions: A comprehensive investigation via BERT. *Schmalenbach Journal of Business Research*, 76(2), 197–244. <https://doi.org/10.1007/s41471-024-00185-3>
- Dorigoni, S., & Anzalone, G. A. (2024). Production of energy from renewable sources and financial performance of European utilities: A panel-data analysis. *Energy Policy*, 194, 114323. <https://doi.org/10.1016/j.enpol.2024.114323>
- Du, L., & He, Y. (2015). Extreme risk spillovers between crude oil and stock markets. *Energy Economics*, 51, 455–465. <https://doi.org/10.1016/j.eneco.2015.08.007>
- Du, L., & He, Y. (2015). Extreme risk spillovers between crude oil and stock

markets. *Energy Economics*, 51, 455–465. <https://doi.org/10.1016/j.eneco.2015.08.007>

Fischer, A. M., Greminger, R. P., Grisse, C., & Kaufmann, S. (2021). Portfolio rebalancing in times of stress. *Journal of International Money and Finance*, 113, 102360. <https://doi.org/10.1016/j.jimonfin.2021.102360>

Dubois, E., Yuan, X., Gayle, D. B., Khurana, P., Knight, T., Laforce, S., Turetsky, D., & Wild, D. (2022). Socially vulnerable populations adoption of technology to address lifestyle changes amid COVID-19 in the US. *Data and Information Management*, 6(2), 100001. <https://doi.org/10.1016/j.dim.2022.100001>

Durand-Lasserve, O., & Pierru, A. (2021). Modeling world oil market questions: An economic perspective. *Energy Policy*, 159, 112606. <https://doi.org/10.1016/j.enpol.2021.112606>

Dutta, A. (2017). Oil price uncertainty and clean energy stock returns: New evidence from crude oil volatility index. *Journal of Cleaner Production*, 164, 1157–1166. <https://doi.org/10.1016/j.jclepro.2017.07.050>

Dutta, A., Bouri, E., Dutta, P., & Saeed, T. (2021). Commodity market risks and green investments: Evidence from India. *Journal of Cleaner Production*, 318, 128523. <https://doi.org/10.1016/j.jclepro.2021.128523>

Ebach, E. M., Hertel, M., Lindermeir, A., & Tränkler, T. (2016). Toward an optimal hedging strategy considering earnings volatility through fair value accounted financial derivatives. *The Journal of Risk Finance*, 17(3), 310–327. <https://doi.org/10.1108/jrf-07-2015-0064>

Ebi, K. L., Vanos, J., Baldwin, J. W., Bell, J. E., Hondula, D. M., Errett, N. A., Hayes, K., Reid, C. E., Saha, S., Spector, J., & Berry, P. (2021). Extreme Weather and Climate Change: population health and health system implications. *Annual Review of Public Health*, 42(1), 293–315. <https://doi.org/10.1146/annurev-publhealth-012420-105026>

Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Minx, J. C., Potsdam Institute for Climate Impact Research, Centro de Investigaciones de la Economía Mundial, & South Centre. (2014). *Climate Change 2014: Mitigation of Climate change*. Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_frontmatter.pdf

Ederington, L., & Guan, W. (2004). The information frown in option prices. *Journal of Banking & Finance*, 29(6), 1429–1457. <https://doi.org/10.1016/j.jbankfin.2004.05.037>

Ehlers, T., & Packer, F. (2017). *Green bond finance and certification*. <https://econpapers.repec.org/RePEc:bis:bisqtr:1709h>

Ehsan, F., Habib, S., Gulzar, M. M., Guo, J., Muyeen, S., & Kamwa, I. (2024). Assessing policy influence on electric vehicle adoption in China: An in-depth study. *Energy Strategy Reviews*, 54, 101471. <https://doi.org/10.1016/j.esr.2024.101471>

Elbayar, M., Mezghani, T., & Abbes, M. B. (2025). Fear and greed amid market turmoil : Impact on stock markets, ESG assets, and green fintech. *Journal of Chinese Economic and Business Studies*, 1–34. <https://doi.org/10.1080/14765284.2025.2492919>

- Elsayed, A. H., Nasreen, S., & Tiwari, A. K. (2020). Time-varying co-movements between energy market and global financial markets: Implication for portfolio diversification and hedging strategies. *Energy Economics*, 90, 104847. <https://doi.org/10.1016/j.eneco.2020.104847>
- Elyasiani, E., Mansur, I., & Odusami, B. (2011). Oil price shocks and industry stock returns. *Energy Economics*, 33(5), 966–974. <https://doi.org/10.1016/j.eneco.2011.03.013>
- Errunza, V. (2001). Foreign portfolio equity investments, financial liberalization, and economic development. *Review of International Economics*, 9(4), 703–726. <https://doi.org/10.1111/1467-9396.00308>
- Erten, B., & Ocampo, J. A. (2013). Super cycles of commodity prices since the Mid-Nineteenth century. *World Development*, 44, 14–30. <https://doi.org/10.1016/j.worlddev.2012.11.013>
- Escario, J., Rodriguez-Sanchez, C., Valero-Gil, J., & Casaló, L. V. (2022). COVID-19 related policies: The role of environmental concern in understanding citizens' preferences. *Environmental Research*, 211, 113082. <https://doi.org/10.1016/j.envres.2022.113082>
- Fama, E. F. (1970). Efficient Capital Markets: A review of theory and Empirical work. *The Journal of Finance*, 25(2), 383. <https://doi.org/10.2307/2325486>
- Fan, S., & Shahbaz, M. (2023). Carbon neutrality and green finance. In Elsevier eBooks (pp. 217–238). <https://doi.org/10.1016/b978-0-443-15936-7.00010-4>
- Fang, X., & Ju, C. (2024). Digital transformation and corporate financialization in emerging markets: Evidence from China. *Heliyon*, 10(2), e24616. <https://doi.org/10.1016/j.heliyon.2024.e24616>
- FAO. (2000). Environment and Natural Resources Working Paper No. 4. In Agenda 21 and other energy-related international agreements. Commission on Sustainable Development (CSD). <https://www.fao.org/4/x8054e/x8054e04.htm>
- Farghali, M., Osman, A. I., Chen, Z., Abdelhaleem, A., Ihara, I., Mohamed, I. M. A., Yap, P., & Rooney, D. W. (2023). Social, environmental, and economic consequences of integrating renewable energies in the electricity sector: a review. *Environmental Chemistry Letters*, 21(3), 1381–1418. <https://doi.org/10.1007/s10311-023-01587-1>
- Farid, S., Kayani, G. M., Naeem, M. A., & Shahzad, S. J. H. (2021). Intraday volatility transmission among precious metals, energy and stocks during the COVID-19 pandemic. *Resources Policy*, 72, 102101. <https://doi.org/10.1016/j.resourpol.2021.102101>
- Fatica, S., Panzica, R., & Rancan, M. (2021). The pricing of green bonds: Are financial institutions special? *Journal of Financial Stability*, 54, 100873. <https://doi.org/10.1016/j.jfs.2021.100873>
- Fernandes, G., Teixeira, P., & Santos, T. A. (2023). The impact of the Ukraine conflict in internal and external grain transport costs. *Transportation Research Interdisciplinary*

Perspectives, 19, 100803. <https://doi.org/10.1016/j.trip.2023.100803>

Fernández, A., Schmitt-Grohé, S., Uribe, M., & National Bureau of Economic Research. (2020). *Does the commodity super cycle matter?* (Working Paper 27589). https://www.nber.org/system/files/working_papers/w27589/w27589.pdf

Ferrer, R., Shahzad, S. J. H., & Soriano, P. (2021). Are green bonds a different asset class? Evidence from time-frequency connectedness analysis. *Journal of Cleaner Production*, 292, 125988. <https://doi.org/10.1016/j.jclepro.2021.125988>

Ferrer, R., Shahzad, S. J. H., & Soriano, P. (2021b). Are green bonds a different asset class? Evidence from time-frequency connectedness analysis. *Journal of Cleaner Production*, 292, 125988. <https://doi.org/10.1016/j.jclepro.2021.125988>

Ferrer, R., Shahzad, S. J. H., López, R., & Jareño, F. (2018). Time and frequency dynamics of connectedness between renewable energy stocks and crude oil prices. *Energy Economics*, 76, 1–20. <https://doi.org/10.1016/j.eneco.2018.09.022>

Filippi, E., Bannò, M., & Trento, S. (2023). Automation technologies and their impact on employment: A review, synthesis and future research agenda. *Technological Forecasting and Social Change*, 191, 122448. <https://doi.org/10.1016/j.techfore.2023.122448>

Flaherty, M., Gevorkyan, A., Radpour, S., & Semmler, W. (2016). Financing climate policies through climate bonds – A three stage model and empirics. *Research in International Business and Finance*, 42, 468–479. <https://doi.org/10.1016/j.ribaf.2016.06.001>

Foglia, M., & Angelini, E. (2020). From me to you: Measuring connectedness between Eurozone financial institutions. *Research in International Business and Finance*, 54, 101238. <https://doi.org/10.1016/j.ribaf.2020.101238>

Foglia, M., Maci, G., & Pacelli, V. (2024). FinTech and fan tokens: Understanding the risks spillover of digital asset investment. *Research in International Business and Finance*, 68, 102190. <https://doi.org/10.1016/j.ribaf.2023.102190>

Forbes, K. J., & Rigobon, R. (2002). No contagion, only interdependence: Measuring stock market comovements. *The Journal of Finance*, 57(5), 2223–2261. <https://doi.org/10.1111/0022-1082.00494>

François, P., Gauthier, G., & Godin, F. (2014). Optimal hedging when the underlying asset follows a regime-switching Markov process. *European Journal of Operational Research*, 237(1), 312–322. <https://doi.org/10.1016/j.ejor.2014.01.034>

Fuentes, F., & Herrera, R. (2020). Dynamics of connectedness in clean energy stocks. *Energies*, 13(14), 3705. <https://doi.org/10.3390/en13143705>

Gad, A. G., Mosa, D. T., Abualigah, L., & Abohany, A. A. (2022). Emerging Trends in Blockchain Technology and Applications: A Review and outlook. *Journal of King Saud University - Computer and Information Sciences*, 34(9), 6719–6742. <https://doi.org/10.1016/j.jksuci.2022.03.007>

- Gai, P., & Kapadia, S. (2010). Contagion in financial networks. *Proceedings of the Royal Society a Mathematical Physical and Engineering Sciences*, 466(2120), 2401–2423. <https://doi.org/10.1098/rspa.2009.0410>
- Gallagher, B. (2010). Peak oil analyzed with a logistic function and idealized Hubbert curve. *Energy Policy*, 39(2), 790–802. <https://doi.org/10.1016/j.enpol.2010.10.053>
- Gao, R., Li, Y., Bai, Y., & Hong, S. (2019). Bayesian inference for optimal risk hedging strategy using PUT options with stock liquidity. *IEEE Access*, 7, 146046–146056. <https://doi.org/10.1109/access.2019.2946260>
- Gao, T., Gupta, A., Gulpinar, N., & Zhu, Y. (2014). Optimal hedging strategy for risk management on a network. *Journal of Financial Stability*, 16, 31–44. <https://doi.org/10.1016/j.jfs.2014.10.005>
- Gao, Y., Gao, X., & Zhang, X. (2017). The 2 °C global temperature target And the evolution of the Long-Term Goal of Addressing Climate Change—From the United Nations Framework Convention on Climate Change to the Paris Agreement. *Engineering*, 3(2), 272–278. <https://doi.org/10.1016/j.eng.2017.01.022>
- García, C. J., Herrero, B., Miralles-Quirós, J. L., & Del Mar Mirallles-Quirós, M. (2023). Exploring the determinants of corporate green bond issuance and its environmental implication: The role of corporate board. *Technological Forecasting and Social Change*, 189, 122379. <https://doi.org/10.1016/j.techfore.2023.122379>
- Garcia, O. a. L., & Landeros, E. R. B. (2020). Analysis of IT and industry 4.0 technologies as facilitators of internationalization and business performance. *Ingeniería E Investigación*, 40(3), 88–99. <https://doi.org/10.15446/ing.investig.v40n3.81696>
- Gatfaoui, H. (2016). Linking the gas and oil markets with the stock market: Investigating the U.S. relationship. *Energy Economics*, 53, 5–16. <https://doi.org/10.1016/j.eneco.2015.05.021>
- Geng, J., Chen, F., Ji, Q., & Liu, B. (2021). Network connectedness between natural gas markets, uncertainty and stock markets. *Energy Economics*, 95, 105001. <https://doi.org/10.1016/j.eneco.2020.105001>
- Ghabri, Y., Guesmi, K., & Zantour, A. (2020). Bitcoin and liquidity risk diversification. *Finance Research Letters*, 40, 101679. <https://doi.org/10.1016/j.frl.2020.101679>
- Ghallabi, F., Souissi, B., Du, A. M., & Ali, S. (2024). ESG stock markets and clean energy prices prediction: Insights from advanced machine learning. *International Review of Financial Analysis*, 103889. <https://doi.org/10.1016/j.irfa.2024.103889>
- Gharbi, O., Trichilli, Y., & Boujelbéne, M. (2023). Risk spillovers connectedness between the US Fintech industry VaR, behavioural biases and macroeconomic instability factors: COVID-19 implications. *China Finance Review International*, 13(3), 410–443. <https://doi.org/10.1108/cfri-12-2022-0277>
- Ghorbani, Y., Zhang, S. E., Nwaila, G. T., Bourdeau, J. E., & Rose, D. H. (2023). Embracing

a diverse approach to a globally inclusive green energy transition: Moving beyond decarbonisation and recognising realistic carbon reduction strategies. *Journal of Cleaner Production*, 434, 140414. <https://doi.org/10.1016/j.jclepro.2023.140414>

Ghosal, S. (2024, November 23). AI driving industrial gold demand, says World Gold Council report. *The Economic Times*. <https://economictimes.indiatimes.com/industry/cons-products/fashion/-/cosmetics/-/jewellery/ai-driving-industrial-gold-demand-says-world-gold-council-report/articleshow/115605467.cms?from=mdr>

Gibson, K. (2025, January 21). The Trump administration's retreat from global climate leadership. *CAP*. <https://www.americanprogress.org/article/the-trump-administrations-retreat-from-global-climate-leadership/>

Giulazian, P. (Director). (2021). Protection of intellectual property rights in digital content trade. In APEC (APEC#221-CT-04.5). Russian State Academy of Intellectual Property. Retrieved July 1, 2025, from https://www.apec.org/docs/default-source/publications/2021/9/protection-of-intellectual-property-rights-in-digital-content-trade/221_cti_protection-of-intellectual-property-rights-in-digital-content-trade.pdf?sfvrsn=b15de010_1

Gómez-Martínez, R., & Medrano-Garcia, M. L. (2024). AI technology for developing Bitcoin investment strategies based on altcoin trends. *Sustainable Technology and Entrepreneurship*, 4(1), 100087. <https://doi.org/10.1016/j.stae.2024.100087>

Gonçalves, A. C. R., Costoya, X., Nieto, R., & Liberato, M. L. R. (2024). Extreme weather events on energy systems: a comprehensive review on impacts, mitigation, and adaptation measures. *Sustainable Energy Research*, 11(1). <https://doi.org/10.1186/s40807-023-00097-6>

Gong, X., & Liao, Q. (2024). Physical climate risk attention and dynamic volatility connectedness among new energy stocks. *Energy Economics*, 136, 107711. <https://doi.org/10.1016/j.eneco.2024.107711>

Gong, X., Chen, L., & Lin, B. (2020). Analyzing dynamic impacts of different oil shocks on oil price. *Energy*, 198, 117306. <https://doi.org/10.1016/j.energy.2020.117306>

Goodell, J. W., & Corbet, S. (2024). The evolving landscape of energy finance: challenges and opportunities during global uncertainty. In *Edward Elgar Publishing eBooks* (pp. 172–191). <https://doi.org/10.4337/9781803926377.00014>

Gregersen, A., & Ørmen, J. (2024). The platform behind the curtain: Obfuscated brokerage on retail trading platforms. *Internet Policy Review*, 13(2). <https://doi.org/10.14763/2024.2.1777>

Griffith Asia Institute. (2024, May 6). China green finance status and trends 2023-2024. Griffith Asia Insights. <https://blogs.griffith.edu.au/asiainsights/china-green-finance-status-and-trends-2023-2024/>

Gubareva, M., Shafiullah, M., & Teplova, T. (2024). Cross-quantile risk assessment: The interplay of crude oil, artificial intelligence, clean tech, and other markets. *Energy Economics*, 108085. <https://doi.org/10.1016/j.eneco.2024.108085>

Guild, J. (2017). Fintech and the Future of Finance. *Asian Journal of Public Affairs*, Lee Kuan Yew School of Public Policy Research(Paper No. 17-20). <https://ssrn.com/abstract=3021684>

Guimarães-Filho, R., & Hong, G. H. (2016). Dynamic connectedness of Asian equity markets. *IMF Working Paper*, 16(57), 1. <https://doi.org/10.5089/9781513572451.001>

Gupta, K. (2016). Oil price shocks, competition, and oil & gas stock returns — Global evidence. *Energy Economics*, 57, 140–153. <https://doi.org/10.1016/j.eneco.2016.04.019>

H, H. P., & Rishad, A. (2020). An empirical examination of investor sentiment and stock market volatility: evidence from India. *Financial Innovation*, 6(1). <https://doi.org/10.1186/s40854-020-00198-x>

Gyamerah, S. A., Owusu, B. E., & Akwaa-Sekyi, E. K. (2022). Modelling the mean and volatility spillover between green bond market and renewable energy stock market. *Green Finance*, 4(3), 310–328. <https://doi.org/10.3934/gf.2022015>

Gyönyör, L. S., & Horváth, M. (2024). Does ESG affect stock market dependence? An empirical exploration of S&P 1200 companies shows the divergent nature of E–S–G pillars. *Research in International Business and Finance*, 69, 102230. <https://doi.org/10.1016/j.ribaf.2024.102230>

Ha, D., Le, P., & Nguyen, D. K. (2025). Financial inclusion and fintech: a state-of-the-art systematic literature review. *Financial Innovation*, 11(1). <https://doi.org/10.1186/s40854-024-00741-0>

Habiba, U. E., Peilong, S., Hamid, K., & Shahzad, F. (2021). Stock returns and asymmetric volatility spillover dynamics between Asian emerging markets. *Global Business Review*, 22(5), 1131–1145. <https://doi.org/10.1177/0972150919838433>

Hall, R. E. (2001). The stock market and capital accumulation. *Hoover Institution and Department of Economics, Stanford University*.

Haman, O. B. (2025). Women and intersectional barriers in social exclusion. *Women S Studies International Forum*, 112, 103142. <https://doi.org/10.1016/j.wsif.2025.103142>

Hameed, A., Kang, W., & Viswanathan, S. (2010). Stock market declines and liquidity. *The Journal of Finance*, 65(1), 257–293. <https://doi.org/10.1111/j.1540-6261.2009.01529.x>

Hammoudeh, S., Ajmi, A. N., & Mokni, K. (2020). Relationship between green bonds and financial and environmental variables: A novel time-varying causality. *Energy Economics*, 92, 104941. <https://doi.org/10.1016/j.eneco.2020.104941>

Hariram, N. P., Mekha, K. B., Suganthan, V., & Sudhakar, K. (2023). Sustainalism: an integrated Socio-Economic-Environmental model to address sustainable development and sustainability. *Sustainability*, 15(13), 10682. <https://doi.org/10.3390/su151310682>

Hasan, M. B., Hassan, M. K., Gider, Z., Rafia, H. T., & Rashid, M. (2023). Searching hedging instruments against diverse global risks and uncertainties. *The North American*

Journal of Economics and Finance, 66, 101893. <https://doi.org/10.1016/j.najef.2023.101893>

Hassan, K., Hoque, A., Wali, M., & Gasbarro, D. (2022). Islamic stocks, conventional stocks, and crude oil: Directional volatility spillover analysis in BRICS. *Energy Economics*, 92, 104985. <https://doi.org/10.1016/j.eneco.2020.104985>

Hassan, Q., Viktor, P., Al-Musawi, T. J., Ali, B. M., Algburi, S., Alzoubi, H. M., Al-Jiboory, A. K., Sameen, A. Z., Salman, H. M., & Jaszczur, M. (2024). The renewable energy role in the global energy Transformations. *Renewable Energy Focus*, 48, 100545. <https://doi.org/10.1016/j.ref.2024.100545>

Haushalter, G. D. (2000). Financing Policy, Basis Risk, and Corporate Hedging: Evidence from Oil and Gas Producers. *The Journal of Finance*, 55(1), 107–152. <https://doi.org/10.1111/0022-1082.00202>

He, F., Ma, F., Wang, Z., & Yang, B. (2021). Asymmetric volatility spillover between oil-importing and oil-exporting countries' economic policy uncertainty and China's energy sector. *International Review of Financial Analysis*, 75, 101739. <https://doi.org/10.1016/j.irfa.2021.101739>

Heaney, R., & Hooper, V. (1999). World, regional and political risk influences upon Asia Pacific equity market returns. *Australian Journal of Management*, 24(2), 131–142. <https://doi.org/10.1177/031289629902400203>

Henriques, I., & Sadorsky, P. (2007). Oil prices and the stock prices of alternative energy companies. *Energy Economics*, 30(3), 998–1010. <https://doi.org/10.1016/j.eneco.2007.11.001>

Henriques, I., & Sadorsky, P. (2008). Oil prices and the stock prices of alternative energy companies. *Energy Economics*, 30(3), 998–1010. <https://doi.org/10.1016/j.eneco.2007.11.001>

Henriques, I., & Sadorsky, P. (2024). Connectedness and systemic risk between FinTech and traditional financial stocks: Implications for portfolio diversification. *Research in International Business and Finance*, 73, 102629. <https://doi.org/10.1016/j.ribaf.2024.102629>

Hernando, R. C., Vasquez, G. N. A., & Jeju, C. K. (2025, May 15). Navigating uncertainty: Transforming tensions into policy priorities | APEC. APEC. Retrieved July 2, 2025, from <https://www.apec.org/press/blogs/2025/navigating-uncertainty--transforming-tensions-into-policy-priorities>

Hillier, D., Draper, P., & Faff, R. (2006). Do Precious Metals shine? An investment perspective. *Financial Analysts Journal*, 62(2), 98–106. <https://doi.org/10.2469/faj.v62.n2.4085>

Hoang, A. T., Nižetić, N. S., Olcer, A. I., Ong, H. C., Chen, W., Chong, C. T., Thomas, S., Bandh, S. A., & Nguyen, X. P. (2021). Impacts of COVID-19 pandemic on the global energy system and the shift progress to renewable energy: Opportunities, challenges, and policy implications. *Energy Policy*, 154, 112322. <https://doi.org/10.1016/j.enpol.2021.112322>

Hoque, M. E., Billah, M., Alam, M. R., & Tiwari, A. K. (2024). Gold-backed cryptocurrencies: A hedging tool against categorical and regional financial stress. *Global*

Finance Journal, 60, 100964. <https://doi.org/10.1016/j.gfj.2024.100964>

Horky, F., Mutascu, M., & Fidrmuc, J. (2022). Oil and renewable energy returns during pandemic. *Environmental Science and Pollution Research*, 30(10), 25836–25850. <https://doi.org/10.1007/s11356-022-23903-y>

Hossain, M. R., Rao, A., Sharma, G. D., Dev, D., & Kharbanda, A. (2024). Empowering energy transition: Green innovation, digital finance, and the path to sustainable prosperity through green finance initiatives. *Energy Economics*, 136, 107736. <https://doi.org/10.1016/j.eneco.2024.107736>

Huang, C., Deng, Y., Yang, X., Cao, J., & Yang, X. (2021). A network perspective of comovement and structural change: Evidence from the Chinese stock market. *International Review of Financial Analysis*, 76, 101782. <https://doi.org/10.1016/j.irfa.2021.101782>

Huang, G., Chen, L., & Luo, B. (2024). International trade sanctions imposed due to the Russia-Ukraine war may cause unequal distribution of environmental and health impacts. *Communications Earth & Environment*, 5(1). <https://doi.org/10.1038/s43247-024-01741-9>

Huang, S., & Guo, M. (2012). An optimal multi-step quadratic risk-adjusted hedging strategy. *Journal of the Korean Statistical Society*, 42(1), 37–49. <https://doi.org/10.1016/j.jkss.2012.04.008>

Huang, Y. (2025). Fintech as a catalyst for sustainable development: a bibliographic review of drivers, technologies, econometrics and regional insights. *Journal of Accounting Literature*. <https://doi.org/10.1108/jal-02-2025-0094>

Hung, N. T. (2024). Price Spillovers from Decentralized Finance to CEE Stock Markets. *Politická Ekonomie*, 72(3), 565–596. <https://doi.org/10.18267/j.polek.1416>

Husain, S., Sohag, K., & Wu, Y. (2022). The response of green energy and technology investment to climate policy uncertainty: An application of twin transitions strategy. *Technology in Society*, 71, 102132. <https://doi.org/10.1016/j.techsoc.2022.102132>

Idrees, A. S., & Sarwar, S. (2022). Spatial convergence clubs and innovation persistence: a country-group comparison of international spatial spillover of innovation capabilities. *Quality & Quantity*, 57(5), 4121–4152. <https://doi.org/10.1007/s11135-022-01545-z>

IEA. (2023). World Energy Investment 2023. In IEA. Retrieved July 2, 2025, from <https://www.iea.org/reports/world-energy-investment-2023>

IEA. (2024a). China's evolving footprint in global energy development finance. In International Energy Agency (Licence: CC BY 4.0). IEA, Paris. <https://www.iea.org/commentaries/china-s-evolving-footprint-in-global-energy-development-finance>

IEA. (2024b). World Energy Investment 2024. In IEA. Retrieved July 2, 2025, from <https://www.iea.org/reports/world-energy-investment-2023>

Ikein, A. A. (2017). Nigeria Oil & External exposure: The crude gains and crude pains of

crude export dependence economy. In *The Business and Management Review* (Vol. 8, Issue 4, pp. 396–397) [Journal-article].

https://cberuk.com/cdn/conference_proceedings/conference_63415.pdf

Ikevuje, N. a. H., Kwakye, N. J. M., Ekechukwu, N. D. E., Ogundipe, N. O. B., & Esiri, N. a. E. (2024). Negative crude oil prices: Supply chain disruptions and strategic lessons. *Open Access Research Journal of Multidisciplinary Studies*, 8(1), 085–093. <https://doi.org/10.53022/oarjms.2024.8.1.0050>

Iman, N. (2020). The rise and rise of financial technology: The good, the bad, and the verdict. *Cogent Business & Management*, 7(1), 1725309.

<https://doi.org/10.1080/23311975.2020.1725309>

Institutional Shareholder Services. (2025). African Development Bank Sustainable Bond newsletter. In Institutional Shareholder Services (pp. 2–9).

<https://www.isscorporatesolutions.com>

International Monetary Fund. (2025). Policy uncertainty tests global resilience.

IPCC. (2019, August 9). Global warming of 1.5 oC —. Global Warming of 1.5 oC. Retrieved July 2, 2025, from <https://www.ipcc.ch/sr15/>

IRENA. (2018). Global Energy Transformation: A roadmap to 2050. In International Renewable Energy Agency (No. 978-92-9260-059-4). International Renewable Energy Agency.

Ishido, H. (2023). APEC’s Response to the COVID-19 Crisis and Social Justice. In *Social Fairness in a Post-Pandemic World: Interdisciplinary Perspectives* (pp. 191–205). Springer Nature. https://doi.org/10.1007/978-981-19-9654-2_10

ITU Publications, International Telecommunication Union, & Zavazava, C. (2023). Measuring Digital Development Facts and Figures 2023. In International Telecommunication Union (No. 978-92-61-38371-8). Retrieved July 1, 2025, from <https://www.itu.int/en/ITU-D/Statistics/Documents/facts/FactsFigures2023.pdf>

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy Policy*, 28(9), 625–640. [https://doi.org/10.1016/s0301-4215\(00\)00041-0](https://doi.org/10.1016/s0301-4215(00)00041-0)

Jagtap, S., Trollman, H., Trollman, F., Garcia-Garcia, G., Parra-López, C., Duong, L., Martindale, W., Munekata, P. E. S., Lorenzo, J. M., Hdaifeh, A., Hassoun, A., Salonitis, K., & Afy-Shararah, M. (2022). The Russia-Ukraine Conflict: Its implications for the global food supply chains. *Foods*, 11(14), 2098. <https://doi.org/10.3390/foods11142098>

Javaid, M., Haleem, A., Singh, R. P., Suman, R., & Khan, S. (2022). A review of Blockchain Technology applications for financial services. *BenchCouncil Transactions on Benchmarks Standards and Evaluations*, 2(3), 100073. <https://doi.org/10.1016/j.tbench.2022.100073>

Jebabli, I., Arouri, M., & Teulon, F. (2014). On the effects of world stock market and oil price shocks on food prices: An empirical investigation based on TVP-VAR models with stochastic volatility. *Energy Economics*, 45, 66–

98. <https://doi.org/10.1016/j.eneco.2014.06.008>

Jebabli, I., Kouaissah, N., & Aroui, M. (2022). Volatility Spillovers between Stock and Energy Markets during Crises: A Comparative Assessment between the 2008 Global Financial Crisis and the COVID-19 Pandemic Crisis. *Finance Research Letters*, 46, 102363. <https://doi.org/10.1016/j.frl.2021.102363>

Jensen, M. C. (1968). THE PERFORMANCE OF MUTUAL FUNDS IN THE PERIOD 1945-1964. *The Journal of Finance*, 23(2), 389–416. <https://doi.org/10.1111/j.1540-6261.1968.tb00815.x>

Jerrett, D., & Cuddington, J. T. (2008). Broadening the statistical search for metal price super cycles to steel and related metals. *Resources Policy*, 33(4), 188–195. <https://doi.org/10.1016/j.resourpol.2008.08.001>

Ji, C., Tan, Z., Chen, B., Zhou, D., & Qian, W. (2024). The impact of environmental policies on renewable energy investment decisions in the power supply chain. *Energy Policy*, 186, 113987. <https://doi.org/10.1016/j.enpol.2024.113987>

Ji, Q., Zhang, H., & Zhang, D. (2018). The impact of OPEC on East Asian oil import security: A multidimensional analysis. *Energy Policy*, 126, 99–107. <https://doi.org/10.1016/j.enpol.2018.11.019>

Jiang, J., & Marsh, T. L. (2020). Volatility spillover effects in the oil and financial market: Cross-Hedging in the US oil market and the energy pipeline sector. In *WORLD SCIENTIFIC eBooks* (pp. 267–299). https://doi.org/10.1142/9789813278387_0012

Jiménez-Rodríguez, R. (2019). What happens to the relationship between EU allowances prices and stock market indices in Europe? *Energy Economics*, 81, 13–24. <https://doi.org/10.1016/j.eneco.2019.03.002>

Jin, Y., & Jorion, P. (2006). Firm Value and Hedging: Evidence from U.S. Oil and Gas Producers. *The Journal of Finance*, 61(2), 893–919. <https://doi.org/10.1111/j.1540-6261.2006.00858.x>

Jones, E. (2023). Digital disruption: artificial intelligence and international trade policy. *Oxford Review of Economic Policy*, 39(1), 70–84. <https://doi.org/10.1093/oxrep/grac049>

Jones, E., & Knaack, P. (2019). Global Financial Regulation: shortcomings and reform options. *Global Policy*, 10(2), 193–206. <https://doi.org/10.1111/1758-5899.12656>

Jones, T. H., & Willms, N. B. (2018). A critique of Hubbert's model for peak oil. *FACETS*, 3(1), 260–274. <https://doi.org/10.1139/facets-2017-0097>

Joshi, P. (2011). Return and volatility spillovers among Asian stock markets. *SAGE Open*, 1(1), 215824401141347. <https://doi.org/10.1177/2158244011413474>

Kakran, S., Kumari, V., Bajaj, P. K., & Sidhu, A. (2023). Exploring crisis-driven return spillovers in APEC stock markets: A frequency dynamics analysis. *The Journal of Economic Asymmetries*, 29, e00342. <https://doi.org/10.1016/j.jeca.2023.e00342>

- Kakran, S., Sidhu, A., Bajaj, P. K., & Dagar, V. (2023). Novel evidence from APEC countries on stock market integration and volatility spillover: A Diebold and Yilmaz approach. *Cogent Economics & Finance*, 11(2). <https://doi.org/10.1080/23322039.2023.2254560>
- Kakran, S., Sidhu, A., Bajaj, P. K., & Dagar, V. (2023b). Novel evidence from APEC countries on stock market integration and volatility spillover: A Diebold and Yilmaz approach. *Cogent Economics & Finance*, 11(2). <https://doi.org/10.1080/23322039.2023.2254560>
- Kamal, E., & Bouri, E. (2025). Green bond, stock, cryptocurrency, and commodity markets: a multiscale analysis and portfolio implications. *Financial Innovation*, 11(1). <https://doi.org/10.1186/s40854-024-00749-6>
- Kang, S. H., & Lee, J. W. (2019). The network connectedness of volatility spillovers across global futures markets. *Physica a Statistical Mechanics and Its Applications*, 526, 120756. <https://doi.org/10.1016/j.physa.2019.03.121>
- Kang, S., & Hur, W. (2011). Investigating the Antecedents of Green Brand Equity: A Sustainable Development Perspective. *Corporate Social Responsibility and Environmental Management*, 19(5), 306–316. <https://doi.org/10.1002/csr.281>
- Kang, W., & Ratti, R. A. (2015). Oil shocks, policy uncertainty and stock returns in China. *Economics of Transition*, 23(4), 657–676. <https://doi.org/10.1111/ecot.12062>
- Karanfil, F., & Omgba, L. D. (2022). The energy transition and export diversification in oil-dependent countries: The role of structural factors. *Ecological Economics*, 204, 107681. <https://doi.org/10.1016/j.ecolecon.2022.107681>
- Karkowska, R., & Urjasz, S. (2023). How does the Russian-Ukrainian war change connectedness and hedging opportunities? Comparison between dirty and clean energy markets versus global stock indices. *Journal of International Financial Markets Institutions and Money*, 85, 101768. <https://doi.org/10.1016/j.intfin.2023.101768>
- Kenn, R. (2020). IAIAEEA BULLA BULLEETITINN. In N. Jawerth & M. Gaspar (Eds.), International Atomic Energy Agency Vienna International Centre. Retrieved July 1, 2025, from <https://www.iaea.org/bulletin>
- KH Digital. (2015, January 7). Drop in oil prices an opportunity for S. Korean economy: finance minister - The Korea Herald. The Korea Herald. <https://www.koreaherald.com/article/331771>
- Khalfaoui, R., Boutahar, M., & Boubaker, H. (2015). Analyzing volatility spillovers and hedging between oil and stock markets: Evidence from wavelet analysis. *Energy Economics*, 49, 540–549. <https://doi.org/10.1016/j.eneco.2015.03.023>
- Khalfaoui, R., Jabeur, S. B., & Dogan, B. (2022). The spillover effects and connectedness among green commodities, Bitcoins, and US stock markets: Evidence from the quantile VAR network. *Journal of Environmental Management*, 306,

114493. <https://doi.org/10.1016/j.jenvman.2022.114493>

Khalfaoui, R., Mefteh-Wali, S., Viviani, J., Jabeur, S. B., Abedin, M. Z., & Lucey, B. M. (2022). How do climate risk and clean energy spillovers, and uncertainty affect U.S. stock markets? *Technological Forecasting and Social Change*, 185, 122083. <https://doi.org/10.1016/j.techfore.2022.122083>

Khalfaoui, R., Sarwar, S., & Tiwari, A. K. (2019). Analysing volatility spillover between the oil market and the stock market in oil-importing and oil-exporting countries: Implications on portfolio management. *Resources Policy*, 62, 22–32. <https://doi.org/10.1016/j.resourpol.2019.03.004>

Khan, A., Khan, M. Y., & Khan, A. Q. (2020). How Do Oil and Natural Gas Prices affect U.S. industrial production? Utilizing wavelet nonlinear denoised based quantile analysis. *Energy Strategy Reviews*, 32, 100550. <https://doi.org/10.1016/j.esr.2020.100550>

Khan, M. I. (2016). Falling oil prices: Causes, consequences and policy implications. *Journal of Petroleum Science and Engineering*, 149, 409–427. <https://doi.org/10.1016/j.petrol.2016.10.048>

Khan, M. I., Yasmeen, T., Khan, M., Hadi, N. U., Asif, M., Farooq, M., & Al-Ghamdi, S. G. (2024). Integrating industry 4.0 for enhanced sustainability: Pathways and prospects. *Sustainable Production and Consumption*. <https://doi.org/10.1016/j.spc.2024.12.012>

Khanna, S. (2025, May 30). Gold ETF investment jumps 170% as jewellery demand slumps: Motilal Oswal Private Wealth. *The Economic Times*. <https://economictimes.indiatimes.com/mf/mf-news/gold-etf-investment-jumps-170-as-jewellery-demand-slumps-motilal-oswal-private-wealth/articleshow/121513057.cms?from=mdr>

Khoury, R. E., Alshater, M. M., & Li, Y. (2023). Multidimensional connectedness among the fourth industrial revolution assets. *Borsa Istanbul Review*, 23(4), 953–979. <https://doi.org/10.1016/j.bir.2023.04.002>

Kim, A., Ryu, D., & Webb, R. I. (2024). Evolving roles of energy futures markets: A Survey. *Borsa Istanbul Review*, 24, 1–14. <https://doi.org/10.1016/j.bir.2024.05.004>

Kocaarslan, B., & Soytaş, U. (2019). Dynamic correlations between oil prices and the stock prices of clean energy and technology firms: The role of reserve currency (US dollar). *Energy Economics*, 84, 104502. <https://doi.org/10.1016/j.eneco.2019.104502>

Kocaarslan, B., & Soytaş, U. (2021). Reserve currency and the volatility of clean energy stocks: The role of uncertainty. *Energy Economics*, 104, 105645. <https://doi.org/10.1016/j.eneco.2021.105645>

Kogan, S., Moskowitz, T. J., & Niessner, M. (2022a). Fake News: Evidence from Financial Markets. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.3237763>

Kogan, S., Moskowitz, T. J., & Niessner, M. (2022b). Social media and financial news manipulation. *Review of Finance*, 27(4), 1229–1268. <https://doi.org/10.1093/rof/rfac058>

- Koljonen, T., & Lehtilä, A. (2012). The impact of residential, commercial, and transport energy demand uncertainties in Asia on climate change mitigation. *Energy Economics*, 34, S410–S420. <https://doi.org/10.1016/j.eneco.2012.05.003>
- Kolodziej, M., Kaufmann, R. K., Kulatilaka, N., Bicchetti, D., & Maystre, N. (2014). Crude oil: Commodity or financial asset? *Energy Economics*, 46, 216–223. <https://doi.org/10.1016/j.eneco.2014.09.006>
- Kolte, A., Roy, J. K., & Vasa, L. (2022). The impact of unpredictable resource prices and equity volatility in advanced and emerging economies: An econometric and machine learning approach. *Resources Policy*, 80, 103216. <https://doi.org/10.1016/j.resourpol.2022.103216>
- Koutmos, G., & Booth, G. (1995). Asymmetric volatility transmission in international stock markets. *Journal of International Money and Finance*, 14(6), 747–762. [https://doi.org/10.1016/0261-5606\(95\)00031-3](https://doi.org/10.1016/0261-5606(95)00031-3)
- Kozul-Wright, A. (2025, June 16). What would an Israel-Iran war mean for the global economy? Al Jazeera. <https://www.aljazeera.com/economy/2025/6/16/what-would-an-israel-iran-war-mean-for-the-global-economy>
- Krivelevich, M. (2019). Export-Oriented Financial Center in the Russian Far East: abstraction or reality? *Spatial Economics*, 15(2), 75–91. <https://doi.org/10.14530/se.2019.2.075-091>
- Kroner, K. F., & Sultan, J. (1993). *Time-Varying Distributions and Dynamic Hedging with Foreign Currency Futures*. https://econpapers.repec.org/RePEc:cup:jfinqa:v:28:y:1993:i:04:p:535-551_00
- Kuang, W. (2021). Are clean energy assets a safe haven for international equity markets? *Journal of Cleaner Production*, 302, 127006. <https://doi.org/10.1016/j.jclepro.2021.127006>
- Kuang, W. (2025). Greening crypto portfolios: the diversification and safe haven potential of clean cryptocurrencies. *Humanities and Social Sciences Communications*, 12(1). <https://doi.org/10.1057/s41599-025-04910-z>
- Kumar, D., & Maheswaran, S. (2013). Correlation transmission between crude oil and Indian markets. *South Asian Journal of Global Business Research*, 2(2), 211–229. <https://doi.org/10.1108/sajgbr-08-2012-0104>
- Kumar, N. (2024, October 31). Climate change to put APAC GDP on thin ice with 41% melt by 2100. Business Standard. https://www.business-standard.com/economy/news/climate-change-may-cut-asia-pacific-gdp-by-up-to-41-by-2100-adb-124103100985_1.html
- Kumar, R., & S, S. K. (2024). Impact of sentimental factors on stock portfolio returns –an empirical analysis. *Heliyon*, 10(9), e30217. <https://doi.org/10.1016/j.heliyon.2024.e30217>
- Kumari, V., Hassan, M., & Pandey, D. K. (2024). Are high-income and innovative nations resilient to the Russia-Ukraine war? *International Review of Economics & Finance*, 93, 1268–1287. <https://doi.org/10.1016/j.iref.2024.04.006>

- Kurihara, Y. (2003). APEC: International trade and output. *Pacific Economic Review*, 8(3), 207–217. <https://doi.org/10.1111/j.1468-0106.2003.00222.x>
- Kuroda, H., & Kawai, M. (2004). *Strengthening regional financial cooperation in East Asia*. <https://doi.org/10.4324/9780203356418-16>
- Kuzemko, C., Blondeel, M., Bradshaw, M., Bridge, G., Faigen, E., & Fletcher, L. (2024). Rethinking Energy Geopolitics: Towards a Geopolitical Economy of Global Energy Transformation. *Geopolitics*, 1–35. <https://doi.org/10.1080/14650045.2024.2351075>
- Lam, C. K. C., He, Q., Cheng, K., Fan, P. Y., Chun, K. P., Choi, B., Mah, D. N., Cheung, D. M., Lo, K., & Yetemen, O. (2022). Impact of climate change and socioeconomic factors on domestic energy consumption: The case of Hong Kong and Singapore. *Energy Reports*, 8, 12886–12904. <https://doi.org/10.1016/j.egyr.2022.09.059>
- Landi, G. C., Turriziani, L., Muto, V., & Ricciardi, I. (2024). Exploring the Nexus between ESG Risk Variations and Investment Preferences: Insights from Sustainable ETFs during the COVID-19 Era. *Socio-Economic Planning Sciences*, 95, 102039. <https://doi.org/10.1016/j.seps.2024.102039>
- Le, L., Yarovaya, L., & Nasir, M. A. (2021). Did COVID-19 change spillover patterns between Fintech and other asset classes? *Research in International Business and Finance*, 58, 101441. <https://doi.org/10.1016/j.ribaf.2021.101441>
- Le, T., Abakah, E. J. A., & Tiwari, A. K. (2020). Time and frequency domain connectedness and spill-over among fintech, green bonds and cryptocurrencies in the age of the fourth industrial revolution. *Technological Forecasting and Social Change*, 162, 120382. <https://doi.org/10.1016/j.techfore.2020.120382>
- Le, T., Abakah, E. J. A., & Tiwari, A. K. (2021). Time and frequency domain connectedness and spill-over among fintech, green bonds and cryptocurrencies in the age of the fourth Industrial Revolution. *Technological Forecasting and Social Change*, 162, 120382. <https://doi.org/10.1016/j.techfore.2020.120382>
- Lee, B. T. F., Sims, J. P., & Lee, Y. (2025). BRICS expansion: threat or opportunity for ASEAN? *India Quarterly a Journal of International Affairs*. <https://doi.org/10.1177/09749284251328226>
- Lee, H., Huh, H., & Kim, W. J. (2012). Cross-border portfolio investment in the APEC region. *Japan and the World Economy*, 24(1), 44–56. <https://doi.org/10.1016/j.japwor.2011.11.002>
- Lee, J. (2025). APEC highlights “fundamental challenges” in global trade as tariffs overshadow meeting. Reuters. <https://www.reuters.com/world/china/us-tariffs-take-centre-stage-apec-trade-gathering-joint-statement-doubt-2025-05-15/>
- Lee, K., & Ni, S. (2002). On the dynamic effects of oil price shocks: a study using industry level data. *Journal of Monetary Economics*, 49(4), 823–852. [https://doi.org/10.1016/s0304-3932\(02\)00114-9](https://doi.org/10.1016/s0304-3932(02)00114-9)

- Lele, A. A. (2020). Puerto Rico Post-Hurricane Maria: Reconstruction and the Pathway to Self-Determination. *William & Mary Journal of Race, Gender, and Social Justice*, 26–26(3), 715–715. <https://scholarship.law.wm.edu/wmjowl/vol26/iss3/8>
- Lescaroux, F. (2009). On the excess co-movement of commodity prices—A note about the role of fundamental factors in short-run dynamics. *Energy Policy*, 37(10), 3906–3913. <https://doi.org/10.1016/j.enpol.2009.05.013>
- Li, A., & Zhong, B. (2025). Asymmetric spillover connectedness between clean energy markets and industrial stock markets: How uncertainties affect it. *PLoS ONE*, 20(3), e0316171. <https://doi.org/10.1371/journal.pone.0316171>
- Li, J., Umar, M., & Huo, J. (2023). The spillover effect between Chinese crude oil futures market and Chinese green energy stock market. *Energy Economics*, 119, 106568. <https://doi.org/10.1016/j.eneco.2023.106568>
- Li, X., & Rose, L. C. (2006). THE IMPACT OF EVOLVING MARKET INTEGRATION ON APEC EMERGING STOCK MARKETS' WORLD BETAS. *Annals of Financial Economics*, 02(01), 0650001. <https://doi.org/10.1142/s2010495206500011>
- Li, Y., Chen, B., Chen, G., & Wu, X. (2021). The global oil supply chain: The essential role of non-oil product as revealed by a comparison between physical and virtual oil trade patterns. *Resources Conservation and Recycling*, 175, 105836. <https://doi.org/10.1016/j.resconrec.2021.105836>
- Lim, G., Nguyen, V., Robinson, T., Tsiaplias, S., & Wang, J. (2021). The Australian economy in 2020–21: the COVID-19 pandemic and prospects for economic recovery. *Australian Economic Review*, 54(1), 5–18. <https://doi.org/10.1111/1467-8462.12405>
- Lin, B., & Chen, Y. (2019). Dynamic linkages and spillover effects between CET market, coal market and stock market of new energy companies: A case of Beijing CET market in China. *Energy*, 172, 1198–1210. <https://doi.org/10.1016/j.energy.2019.02.029>
- Lin, B., Wesseh, P. K., & Appiah, M. O. (2014). Oil price fluctuation, volatility spillover and the Ghanaian equity market: Implication for portfolio management and hedging effectiveness. *Energy Economics*, 42, 172–182. <https://doi.org/10.1016/j.eneco.2013.12.017>
- Lin, C. L., & Rajan, R. S. (1999). Regional responses to the Southeast Asian financial crisis: a case of Self-Help or no help? *Australian Journal of International Affairs*, 53(3), 261–281. <https://doi.org/10.1080/00049919993854>
- Lin, K., Shyu, J., & Ding, K. (2017). A Cross-Strait Comparison of Innovation Policy under Industry 4.0 and Sustainability Development Transition. *Sustainability*, 9(5), 786. <https://doi.org/10.3390/su9050786>
- Lin, L., & Hong, Y. (2022). Developing a Green Bonds Market: Lessons from China. *European Business Organization Law Review*, 23(1), 143–185. <https://doi.org/10.1007/s40804-021-00231-1>
- Lin, S. X., & Tamvakis, M. N. (2001). Spillover effects in energy futures markets. *Energy*

Economics, 23(1), 43–56. [https://doi.org/10.1016/s0140-9883\(00\)00051-7](https://doi.org/10.1016/s0140-9883(00)00051-7)

Liu, C., Tian, M., & Huang, B. (2025). Volatility spillover dynamics between fintech and traditional financial industries and their rich determinants: New evidence from Chinese listed institutions. *International Review of Financial Analysis*, 104034. <https://doi.org/10.1016/j.irfa.2025.104034>

Liu, L. (2020). China: Green finance to green transition. In Deutsche Bank. Retrieved from https://www.dbresearch.com/PROD/RPS_EN-PROD/PROD0000000000513737/China%3A_Green_finance_to_green_transition.pdf?&realload=sFBX9UyJ2TulwoSyvOl3N5STA~CpUcQl~MZGcZGFyQ3fKzgx1VizQFAI9MacjsUn

Liu, M. (2022). The driving forces of green bond market volatility and the response of the market to the COVID-19 pandemic. *Economic Analysis and Policy*, 75, 288–309. <https://doi.org/10.1016/j.eap.2022.05.012>

Liu, N., Liu, C., Da, B., Zhang, T., & Guan, F. (2020). Dependence and risk spillovers between green bonds and clean energy markets. *Journal of Cleaner Production*, 279, 123595. <https://doi.org/10.1016/j.jclepro.2020.123595>

Liu, X. L., Nassios, J., & Giesecke, J. (2023). To tax or to spend? Modelling tax policy responses to oil price shocks. *Energy Policy*, 185, 113929. <https://doi.org/10.1016/j.enpol.2023.113929>

Liu, Y., Wei, Y., Wang, Q., & Liu, Y. (2022). International stock market risk contagion during the COVID-19 pandemic. *Finance Research Letters*, 45. <https://doi.org/10.1016/j.frl.2021.102145>

Liu, Z., Shi, X., Zhai, P., Wu, S., Ding, Z., & Zhou, Y. (2021). Tail risk connectedness in the oil-stock nexus: Evidence from a novel quantile spillover approach. *Resources Policy*, 74, 102381. <https://doi.org/10.1016/j.resourpol.2021.102381>

Liu, Z., Tseng, H., Wu, J. S., & Ding, Z. (2020). Implied volatility relationships between crude oil and the U.S. stock markets: Dynamic correlation and spillover effects. *Resources Policy*, 66, 101637. <https://doi.org/10.1016/j.resourpol.2020.101637>

Liza, F. F., Wei, L., Hassan, S. T., Khan, I., & Ahmad, F. (2024). Driving low-carbon mechanisms through smart investments in renewable resources and green finance initiatives among G20 nations. *Journal of Environmental Management*, 370, 122439. <https://doi.org/10.1016/j.jenvman.2024.122439>

Longin, F., & Solnik, B. (1995). Is the correlation in international equity returns constant: 1960–1990? *Journal of International Money and Finance*, 14(1), 3–26. [https://doi.org/10.1016/0261-5606\(94\)00001-h](https://doi.org/10.1016/0261-5606(94)00001-h)

Lu, Y., Reinert, G., & Cucuringu, M. (2023). Co-Trading networks for modeling dynamic interdependency structures and estimating High-Dimensional Covariances in US equity markets. *SSRN Electronic Journal*. <https://doi.org/10.2139/ssrn.4363048>

Lucey, B. M., & Li, S. (2014). What precious metals act as safe havens, and when? Some US

evidence. *Applied Economics Letters*, 22(1), 35–45.

<https://doi.org/10.1080/13504851.2014.920471>

Luk, G., Pliatsikas, C., & Rossi, E. (2020). Brain changes associated with language development and learning: A primer on methodology and applications. *System*, 89, 102209. <https://doi.org/10.1016/j.system.2020.102209>

Luk, P., Cheng, M., Ng, P., & Wong, K. (2018). Economic policy uncertainty spillovers in small open economies: The case of Hong Kong. *Pacific Economic Review*, 25(1), 21–46. <https://doi.org/10.1111/1468-0106.12283>

Lund, S., Lacombe, J. P., Abad, J., Albert, Q., Bazan, A. R., Dussoubs, E., Elbaz, J., Hintzy, V., Jaulin, T., Law, E., Monteix, V., Slimane, M. B., Bailey, N. C., Hysa, S., Ozyurt, S. G., Stallings, J., Fu, P., Hainski, K., Pesme, J., . . . Sarchenko, I. (2023). Emerging market green bonds. In IFC-Amundi Joint Report. <https://www.ifc.org/content/dam/ifc/doc/2023/ifc-amundi-emerging-market-green-bonds-july2023.pdf>

Lundgren, A. I., Milicevic, A., Uddin, G. S., & Kang, S. H. (2018). Connectedness network and dependence structure mechanism in green investments. *Energy Economics*, 72, 145–153. <https://doi.org/10.1016/j.eneco.2018.04.015>

Lv, Y. (2023). Transitioning to sustainable energy: opportunities, challenges, and the potential of blockchain technology. *Frontiers in Energy Research*, 11. <https://doi.org/10.3389/fenrg.2023.1258044>

Ma, X., Pan, Y., Zhang, M., Ma, J., & Yang, W. (2023). Impact of carbon emission trading and renewable energy development policy on the sustainability of electricity market: A stackelberg game analysis. *Energy Economics*, 129, 107199. <https://doi.org/10.1016/j.eneco.2023.107199>

Ma, Y., Zhang, D., Ji, Q., & Pan, J. (2019). Spillovers between oil and stock returns in the US energy sector: Does idiosyncratic information matter? *Energy Economics*, 81, 536–544. <https://doi.org/10.1016/j.eneco.2019.05.003>

Mac Kinnon, M. A., Brouwer, J., & Samuelsen, S. (2017). The role of natural gas and its infrastructure in mitigating greenhouse gas emissions, improving regional air quality, and renewable resource integration. *Progress in Energy and Combustion Science*, 64, 62–92. <https://doi.org/10.1016/j.pecs.2017.10.002>

Madani, M. A., & Ftiti, Z. (2021). Is gold a hedge or safe haven against oil and currency market movements? A revisit using multifractal approach. *Annals of Operations Research*, 313(1), 367–400. <https://doi.org/10.1007/s10479-021-04288-6>

Magazzino, C., Mele, M., & Morelli, G. (2021). The Relationship between Renewable Energy and Economic Growth in a Time of Covid-19: A Machine Learning Experiment on the Brazilian Economy. *Sustainability*, 13(3), 1285. <https://doi.org/10.3390/su13031285>

Maghyereh, A. I., Awartani, B., & Bouri, E. (2016). The directional volatility connectedness between crude oil and equity markets: New evidence from implied volatility indexes. *Energy Economics*, 57, 78–93. <https://doi.org/10.1016/j.eneco.2016.04.010>

- Maghyereh, A. I., Awartani, B., & Tziogkidis, P. (2017). Volatility spillovers and cross-hedging between gold, oil and equities: Evidence from the Gulf Cooperation Council countries. *Energy Economics*, 68, 440–453. <https://doi.org/10.1016/j.eneco.2017.10.025>
- Maji, I. K., Sulaiman, C., & Abdul-Rahim, A. (2019). Renewable energy consumption and economic growth nexus: A fresh evidence from West Africa. *Energy Reports*, 5, 384–392. <https://doi.org/10.1016/j.egy.2019.03.005>
- Makkar, M. K., Ghayas, A., & Gupta, N. (2023). Performance of Conventional and Sustainable Index in pre and during the COVID-19 Pandemic : A comparative analysis. *Indian Journal of Finance*, 17(5), 39. <https://doi.org/10.17010/ijf/2023/v17i5/172736>
- Malik, I. H., Ahmed, R., Ford, J. D., & Hamidi, A. R. (2025). Arctic Warming: cascading climate impacts and global consequences. *Climate*, 13(5), 85. <https://doi.org/10.3390/cli13050085>
- Malkiel, B. G., Princeton University, De Long, J. B., Taylor, T., & Waldman, M. (2003). The efficient Market hypothesis and its critics. In *CEPS Working Paper* (Working-Paper No. 91). <https://www.princeton.edu/~ceps/workingpapers/91malkiel.pdf>
- Maltais, A., & Nykvist, B. (2020). Understanding the role of green bonds in advancing sustainability. *Journal of Sustainable Finance & Investment*, 1–20. <https://doi.org/10.1080/20430795.2020.1724864>
- Mamgain, R. P. (2021). Understanding labour market disruptions and job losses amidst COVID-19. *Journal of Social and Economic Development*, 23(S2), 301–319. <https://doi.org/10.1007/s40847-020-00125-x>
- Manahov, V., & Li, M. (2023). The implications of virtual money on travel and tourism. *Annals of Tourism Research*, 105, 103686. <https://doi.org/10.1016/j.annals.2023.103686>
- Mandacı, P. E., Cagli, E. Ç., & Taşkın, D. (2020). Dynamic connectedness and portfolio strategies: Energy and metal markets. *Resources Policy*, 68, 101778. <https://doi.org/10.1016/j.resourpol.2020.101778>
- Maraqa, B., & Bein, M. (2020). Dynamic Interrelationship and Volatility Spillover among Sustainability Stock Markets, Major European Conventional Indices, and International Crude Oil. *Sustainability*, 12(9), 3908. <https://doi.org/10.3390/su12093908>
- Martiny, A., Taglialatela, J., Testa, F., & Iraldo, F. (2024). Determinants of environmental social and governance (ESG) performance: A systematic literature review. *Journal of Cleaner Production*, 456, 142213. <https://doi.org/10.1016/j.jclepro.2024.142213>
- McCauley, D., & Pettigrew, K. (2023). Building a just transition in Asia-pacific: Four strategies for reducing fossil fuel dependence and investing in clean energy. *Energy Policy*, 183, 113808. <https://doi.org/10.1016/j.enpol.2023.113808>
- McCollum, D. L., Zhou, W., Bertram, C., De Boer, H.-S., Valentina Bosetti, Busch, S.,

Després, J., Drouet, L., Emmerling, J., Fay, M., Fricko, O., Fujimori, S., Gidden, M., Harmsen, M., Huppmann, D., Iyer, G., Krey, V., Kriegler, E., Nicolas, C., . . . Colorado School of Mines. (2018). Energy investment needs for fulfilling the Paris Agreement and achieving the Sustainable Development Goals. *Nature Energy*.

McKibbin, W., & Fernando, R. (2023). The global economic impacts of the COVID-19 pandemic. *Economic Modelling*, 129, 106551. <https://doi.org/10.1016/j.econmod.2023.106551>

Mehmood, S., Zaman, K., Khan, S., Ali, Z., & Khan, H. U. R. (2023). The role of green industrial transformation in mitigating carbon emissions: Exploring the channels of technological innovation and environmental regulation. *Energy and Built Environment*, 5(3), 464–479. <https://doi.org/10.1016/j.enbenv.2023.03.001>

Mensi, W., Al-Yahyaee, K. H., & Kang, S. H. (2017). Time-varying volatility spillovers between stock and precious metal markets with portfolio implications. *Resources Policy*, 53, 88–102. <https://doi.org/10.1016/j.resourpol.2017.06.001>

Mensi, W., Beljid, M., Boubaker, A., & Managi, S. (2013). Correlations and volatility spillovers across commodity and stock markets: Linking energies, food, and gold. *Economic Modelling*, 32, 15–22. <https://doi.org/10.1016/j.econmod.2013.01.023>

Mensi, W., Brahim, M., Hammoudeh, S., Tiwari, A. K., & Kang, S. H. (2024). Time-varying causality and correlations between spot and futures prices of natural gas, crude oil, heating oil, and gasoline. *Resources Policy*, 93, 105077. <https://doi.org/10.1016/j.resourpol.2024.105077>

Mensi, W., Gubareva, M., & Teplova, T. (2025). Risk transmission between oil price shocks and major equity indices across bull and bear markets over various time horizons. *The North American Journal of Economics and Finance*, 102459. <https://doi.org/10.1016/j.najef.2025.102459>

Mensi, W., Hammoudeh, S., & Kang, S. H. (2015). Precious metals, cereal, oil and stock market linkages and portfolio risk management: Evidence from Saudi Arabia. *Economic Modelling*, 51, 340–358. <https://doi.org/10.1016/j.econmod.2015.08.005>

Mensi, W., Hammoudeh, S., Al-Jarrah, I. M. W., Sensoy, A., & Kang, S. H. (2017). Dynamic risk spillovers between gold, oil prices and conventional, sustainability and Islamic equity aggregates and sectors with portfolio implications. *Energy Economics*, 67, 454–475. <https://doi.org/10.1016/j.eneco.2017.08.031>

Mensi, W., Hammoudeh, S., Nguyen, D. K., & Kang, S. H. (2015). Global financial crisis and spillover effects among the U.S. and BRICS stock markets. *International Review of Economics & Finance*, 42, 257–276. <https://doi.org/10.1016/j.iref.2015.11.005>

Mensi, W., Rehman, M. U., Al-Yahyaee, K. H., & Vo, X. V. (2022). Frequency dependence between oil futures and international stock markets and the role of gold, bonds, and uncertainty indices: Evidence from partial and multivariate wavelet approaches. *Resources Policy*, 80, 103161. <https://doi.org/10.1016/j.resourpol.2022.103161>

- Mensi, W., Rehman, M. U., Maitra, D., Al-Yahyaee, K. H., & Vo, X. V. (2021). Oil, natural gas and BRICS stock markets: Evidence of systemic risks and co-movements in the time-frequency domain. *Resources Policy*, 72, 102062. <https://doi.org/10.1016/j.resourpol.2021.102062>
- Mensi, W., Shafiullah, M., Vo, X. V., & Kang, S. H. (2021). Volatility spillovers between strategic commodity futures and stock markets and portfolio implications: Evidence from developed and emerging economies. *Resources Policy*, 71, 102002. <https://doi.org/10.1016/j.resourpol.2021.102002>
- Mensi, W., Shafiullah, M., Vo, X. V., & Kang, S. H. (2022). Spillovers and connectedness between green bond and stock markets in bearish and bullish market scenarios. *Finance Research Letters*, 49, 103120. <https://doi.org/10.1016/j.frl.2022.103120>
- Merton, R. C. (1987). A Simple Model of Capital Market Equilibrium with Incomplete Information. *The Journal of Finance*, 42(3), 483–510. <https://doi.org/10.1111/j.1540-6261.1987.tb04565.x>
- Mezghani, T., Hamadou, F. B., & Boujelbène-Abbes, M. (2023). Network connectedness and portfolio hedging of green bonds, stock markets and commodities. *International Journal of Emerging Markets*. <https://doi.org/10.1108/ijoem-02-2023-0160>
- Mezghani, T., Hamadou, F. B., Boujelbène, M., & Boutouria, S. (2024). Do green bonds affect extreme spillover and hedging effects across stocks and commodities? *International Journal of the Economics of Business*, 31(2), 103–130. <https://doi.org/10.1080/13571516.2024.2336648>
- Missaoui, A., Ozturk, C., & O’Sullivan, B. (2025). Energy-Aware Blocking Hybrid Flow Shop Scheduling Problem with Sequence-depend Setup Times and Machine Speed Levels. *Procedia Computer Science*, 253, 1134–1143. <https://doi.org/10.1016/j.procs.2025.01.175>
- Missaoui, I., Shah, W. U., & Ben Rejeb, A. (2025). Impact of FinTech and technological innovation on African stock returns: fresh insights from crisis. *Journal of Financial Reporting and Accounting*. <https://doi.org/10.1108/JFRA-10-2024-0716>
- Mnif, E., Daoud, Y., Zied, A., & Jarboui, A. (2024). Islamic cryptocurrency integration for enhanced sustainable finance: evidence from time-frequency volatility transmission investigation. *Journal of Chinese Economic and Business Studies*, 22(4), 435–453. <https://doi.org/10.1080/14765284.2024.2388492>
- Mooney, C. (2024, February 6). Hurricane Harvey was year’s costliest U.S. disaster at \$125 billion in damages. *The Texas Tribune*. Retrieved July 2, 2025, from <https://www.texastribune.org/2018/01/08/hurricane-harvey-was-years-costliest-us-disaster-125-billion-damages/>
- Moosavi, J., Fathollahi-Fard, A. M., & Dulebenets, M. A. (2022). Supply chain disruption during the COVID-19 pandemic: Recognizing potential disruption management strategies. *International Journal of Disaster Risk Reduction*, 75, 102983. <https://doi.org/10.1016/j.ijdr.2022.102983>

- Mrabet, Z., Alsamara, M., Mimouni, K., & Awwad, A. (2024). Do Supply Chain Pressures Affect Consumer Prices in Major Economies? New Evidence from Time-Varying Causality Analysis. *Economic Modelling*, 106914. <https://doi.org/10.1016/j.econmod.2024.106914>
- Muhammad, S., & Huang, X. (2025). Dynamic Dependence and Network Analysis between Renewable Energy Tokens, Sustainability-Driven Investments and Equity Markets: Portfolio Implications. *Renewable Energy*, 123256. <https://doi.org/10.1016/j.renene.2025.123256>
- Muhammad, S., & Huang, X. (2025). Tail Risk Spillovers between FinTech, Sustainability-Driven Investments and SME's Stock Markets: Portfolio Implications. *The Singapore Economic Review*. <https://doi.org/10.1142/s0217590825490128>
- Muharam, H., Mawardi, W., Arfinto, E. D., & Najmudin, N. (2019). Volatility spillovers under difference in the degree of market integration: Evidence from the selected Asian and Eastern European stock markets. *JOURNAL OF INTERNATIONAL STUDIES*, 12(1), 134–150. <https://doi.org/10.14254/2071-8330.2019/12-1/9>
- Naeem, M. A., & Karim, S. (2021). Tail dependence between bitcoin and green financial assets. *Economics Letters*, 208, 110068. <https://doi.org/10.1016/j.econlet.2021.110068>
- Naeem, M. A., Conlon, T., & Cotter, J. (2021). Green bonds and other assets: Evidence from extreme risk transmission. *Journal of Environmental Management*, 305, 114358. <https://doi.org/10.1016/j.jenvman.2021.114358>
- Nafiu, N. A., Balogun, N. S. O., Oko-Odion, N. C., & Odumuwaun, N. O. O. (2025). Risk management strategies: Navigating volatility in complex financial market environments. *World Journal of Advanced Research and Reviews*, 25(1), 236–250. <https://doi.org/10.30574/wjarr.2025.25.1.0057>
- Narayan, P. K., Phan, D. H. B., & Liu, G. (2020). COVID-19 lockdowns, stimulus packages, travel bans, and stock returns. *Finance Research Letters*, 38, 101732. <https://doi.org/10.1016/j.frl.2020.101732>
- NASA Earth Observatory. (2017). 2017 was the second hottest year on record. NASA. Retrieved July 2, 2025, from <https://www.earthobservatory.nasa.gov/Figs/91604/2017-was-the-second-hottest-year-on-record>
- Naseer, S., Khalid, S., Parveen, S., Abbass, K., Song, H., & Achim, M. V. (2023). COVID-19 outbreak: Impact on global economy. *Frontiers in Public Health*, 10. <https://doi.org/10.3389/fpubh.2022.1009393>
- Natanelov, V., Alam, M. J., McKenzie, A. M., & Van Huylenbroeck, G. (2011). Is there co-movement of agricultural commodities futures prices and crude oil? *Energy Policy*, 39(9), 4971–4984. <https://doi.org/10.1016/j.enpol.2011.06.016>
- Naughten, K. A., Holland, P. R., & De Rydt, J. (2023). Unavoidable future increase in West Antarctic ice-shelf melting over the twenty-first century. *Nature Climate Change*, 13(11), 1222–1228. <https://doi.org/10.1038/s41558-023-01818-x>

Neagu, A., Godin, F., & Kosseim, L. (2025, April 7). *Deep reinforcement learning Algorithms for option hedging*. arXiv.org. <https://arxiv.org/abs/2504.05521v2>

Network for Greening the Financial System, & Elderson, F. (2019). Network for Greening the Financial System First comprehensive report A call for action Climate change as a source of financial risk.

https://www.ngfs.net/sites/default/files/medias/documents/ngfs_first_comprehensive_report_-_17042019_0.pdf

Nguyen, C. T., Costa, G., Girardi, L., Volpato, G., Bressan, A., Chen, Y., Marigo, P., Fu, X., & Goudfrooij, P. (2022). PARSEC V2.0: Stellar tracks and isochrones of low- and intermediate-mass stars with rotation. *Astronomy and Astrophysics*, 665, A126. <https://doi.org/10.1051/0004-6361/202244166>

Nguyen, H. H., Van Nguyen, P., & Ngo, V. M. (2024). Energy security and the shift to renewable resources: The case of Russia-Ukraine war. *The Extractive Industries and Society*, 17, 101442. <https://doi.org/10.1016/j.exis.2024.101442>

Nguyen, Q. N., Bedoui, R., Majdoub, N., Guesmi, K., & Chevallier, J. (2020). Hedging and safe-haven characteristics of Gold against currencies: An investigation based on multivariate dynamic copula theory. *Resources Policy*, 68, 101766. <https://doi.org/10.1016/j.resourpol.2020.101766>

Noor, M. (2012, April 17). Economic integration in the Asia-Pacific Region and the role of APEC | APEC. APEC. Retrieved July 1, 2025, from https://www.apec.org/press/blogs/2012/0417_economic

Nunes, L. J. R. (2023). The rising threat of Atmospheric CO₂: A review on the causes, impacts, and mitigation strategies. *Environments*, 10(4), 66. <https://doi.org/10.3390/environments10040066>

O'Neill, T., Penm, J., & Terrell, R. (2009). The role of higher oil prices: A case of major developed countries. In *Research in finance* (pp. 287–299). [https://doi.org/10.1016/s0196-3821\(07\)00211-0](https://doi.org/10.1016/s0196-3821(07)00211-0)

OECD. (2021a). OECD economic outlook [Print]. In OECD Economic Outlook (No. 109; Vols. 2021–Issue 1). OECD Publishing. <https://doi.org/10.1787/edfbca02-en>

OECD. (2021b). Strengthening Economic resilience Following the COVID-19 Crisis: A firm and industry perspective. OECD Publishing, Paris. <https://doi.org/10.1787/2a7081d8-en>

OECD. (2025). OECD Environmental Performance Reviews: Japan 2025. OECD Publishing. https://www.oecd.org/content/dam/oecd/en/publications/reports/2025/03/oecd-environmental-performance-reviews-japan-2025_947dc3da/583cab4c-en.pdf

OECD/BCG/INSEAD. (2025). The adoption of artificial intelligence in firms. OECD Publishing, Paris. <https://doi.org/10.1787/f9ef33c3-en>

OECD/UNDP. (2025). Investing in climate for growth and development. OECD Publishing, Paris., <https://doi.org/10.1787/16b7cbc7-en>

OECD/UNDP. (2025). Investing in climate for growth and development. OECD Publishing, Paris. <https://doi.org/10.1787/16b7cbc7-en>

Olson, E., Vivian, A. J., & Wohar, M. E. (2014). The relationship between energy and equity markets: Evidence from volatility impulse response functions. *Energy Economics*, 43, 297–305. <https://doi.org/10.1016/j.eneco.2014.01.009>

Overland, I., Sagbakken, H. F., Chan, H., Merdekawati, M., Suryadi, B., Utama, N. A., & Vakulchuk, R. (2020). The ASEAN climate and energy paradox. *Energy and Climate Change*, 2, 100019. <https://doi.org/10.1016/j.egycc.2020.100019>

Owusu, P., Junior, Tetteh, J. E., Nkrumah-Boadu, B., & Adjei, A. N. K. (2024). Comovement of african stock markets: Any influence from the COVID-19 pandemic? *Heliyon*, 10(9), e29409. <https://doi.org/10.1016/j.heliyon.2024.e29409>

Özdemir, M., & Taş, O. (2024). Investor attention and its impact on portfolio volatility and sectoral risk spillovers in Borsa Istanbul. *Borsa Istanbul Review*. <https://doi.org/10.1016/j.bir.2024.12.014>

Pandey, D. K. (2024). Effects of Israel-Iran conflict: insights on global stock indices and currencies. *Journal of Economic Studies*. <https://doi.org/10.1108/jes-04-2024-0286>

Pašiušienė, I., Podvieszko, A., Malakaitė, D., Žarskienė, L., Liučvaitienė, A., & Martišienė, R. (2023). Exploring Generation Z's Investment Patterns and Attitudes towards Greenness. *Sustainability*, 16(1), 352. <https://doi.org/10.3390/su16010352>

Pástor, L., & Veronesi, P. (2009). Technological revolutions and stock prices. *American Economic Review*, 99(4), 1451–1483. <https://doi.org/10.1257/aer.99.4.1451>

Pea-Assounga, J. B. B., Bambi, P. D. R., Jafarzadeh, E., & Ngapey, J. D. N. (2025). Investigating the impact of crude oil prices, CO2 emissions, renewable energy, population growth, trade openness, and FDI on sustainable economic growth. *Renewable Energy*, 122353. <https://doi.org/10.1016/j.renene.2025.122353>

Peng, M. (2020). Outbreak of COVID-19: An emerging global pandemic threat. *Biomedicine & Pharmacotherapy*, 129, 110499. <https://doi.org/10.1016/j.biopha.2020.110499>

Perga, I. (2025). The international implications of the Russo-Ukrainian War. In *SpringerBriefs in international relations* (pp. 27–42). https://doi.org/10.1007/978-981-96-2295-5_3

Pesaran, H., & Shin, Y. (1998). Generalized impulse response analysis in linear multivariate models. *Economics Letters*, 58(1), 17–29. [https://doi.org/10.1016/s0165-1765\(97\)00214-0](https://doi.org/10.1016/s0165-1765(97)00214-0)
Pham, L. (2016). Is it risky to go green? A volatility analysis of the green bond market. *Journal of Sustainable Finance & Investment*, 6(4), 263–291. <https://doi.org/10.1080/20430795.2016.1237244>

Pham, L. (2019). Do all clean energy stocks respond homogeneously to oil price? *Energy Economics*, 81, 355–379. <https://doi.org/10.1016/j.eneco.2019.04.010>

- Pham, L. (2021). Frequency connectedness and cross-quantile dependence between green bond and green equity markets. *Energy Economics*, 98, 105257. <https://doi.org/10.1016/j.eneco.2021.105257>
- Pham, L., & Nguyen, C. P. (2021). Asymmetric tail dependence between green bonds and other asset classes. *Global Finance Journal*, 50, 100669. <https://doi.org/10.1016/j.gfj.2021.100669>
- Philip, L., & Williams, F. (2018). Remote rural home based businesses and digital inequalities: Understanding needs and expectations in a digitally underserved community. *Journal of Rural Studies*, 68, 306–318. <https://doi.org/10.1016/j.jrurstud.2018.09.011>
- Pillai, D., Doifode, A., Parashar, N., Bhosale, T., Ghosh, A., Surapalli, S., & Sharma, R. (2024). Diverse linkages between green bonds and equity indices of developed and developing economies. *International Journal of Management and Sustainability*, 13(2), 221–231. <https://doi.org/10.18488/11.v13i2.3643>
- Potts, T. B., & Yerger, D. B. (2024). The macroeconomic impact of energy price shocks: Threshold effects and the fracking boom. *Resources Policy*, 90, 104772. <https://doi.org/10.1016/j.resourpol.2024.104772>
- Pouresmaieli, M., Ataei, M., Qarahasanlou, A. N., & Barabadi, A. (2023). Integration of renewable energy and sustainable development with strategic planning in the mining industry. *Results in Engineering*, 20, 101412. <https://doi.org/10.1016/j.rineng.2023.101412>
- Press Information Bureau & Ministry of Commerce and Industry. (2025). India's exports reach historic heights [Press-release]. <https://static.pib.gov.in/WriteReadData/specificdocs/documents/2025/feb/doc202521494001.pdf>
- Prest, B. C. (2018). Explanations for the 2014 oil price decline: Supply or demand? *Energy Economics*, 74, 63–75. <https://doi.org/10.1016/j.eneco.2018.05.029>
- PTI. (2024, January 20). Climate change may cut labour productivity in India to 40% by 2100: Study. *The Economic Times*. <https://economictimes.indiatimes.com/news/economy/indicators/climate-change-may-cut-labour-productivity-in-india-to-40-by-2100-study/articleshow/107010818.cms?from=mdr>
- Qadir, S. A., Al-Motairi, H., Tahir, F., & Al-Fagih, L. (2021). Incentives and strategies for financing the renewable energy transition: A review. *Energy Reports*, 7, 3590–3606. <https://doi.org/10.1016/j.egyr.2021.06.041>
- Qiao, G., & Jiang, G. (2023). VIX futures pricing based on high-frequency VIX: A hybrid approach combining SVR with parametric models. *Journal of Futures Markets*, 43(9), 1238–1260. <https://doi.org/10.1002/fut.22439>
- Quito, B., De La Cruz Del Río-Rama, M., García, J. Á., & Bekun, F. V. (2023). Spatiotemporal influencing factors of energy efficiency in 43 european countries: A spatial econometric analysis. *Renewable and Sustainable Energy Reviews*, 182, 113340. <https://doi.org/10.1016/j.rser.2023.113340>

- Rafiuddin, A., Gaytan, J. C. T., Mohnot, R., Sisodia, G. S., & Ahmed, G. (2023). Growth evaluation of fintech connectedness with innovative thematic indices – An evidence through wavelet analysis. *Journal of Open Innovation: Technology, Market, and Complexity*, 9(2). <https://doi.org/10.1016/j.joitmc.2023.100023>
- Rahman, A., Dargusch, P., & Wadley, D. (2021). The political economy of oil supply in Indonesia and the implications for renewable energy development. *Renewable and Sustainable Energy Reviews*, 144, 111027. <https://doi.org/10.1016/j.rser.2021.111027>
- Rahman, M. S., Alam, M. A., Salekin, S., Belal, M. a. H., & Rahman, M. S. (2021). The COVID-19 pandemic: A threat to forest and wildlife conservation in Bangladesh? *Trees Forests and People*, 5, 100119. <https://doi.org/10.1016/j.tfp.2021.100119>
- Raihan, A., Ibrahim, S., Ridwan, M., Rahman, M. S., Bari, A. M., & Atasoy, F. G. (2024). Role of renewable energy and foreign direct investment toward economic growth in Egypt. *Innovation and Green Development*, 4(1), 100185. <https://doi.org/10.1016/j.igd.2024.100185>
- Rajesh, R., & Nandini, A. S. (2023). Hedging Efficiency of Energy Commodities between Indian and American Commodity Exchanges: Constant and Time-Varying Approaches. *International Journal of Energy Economics and Policy*, 13(6), 537–546. <https://doi.org/10.32479/ijeep.15062>
- Rashid, A. B., & Kausik, M. a. K. (2024). AI Revolutionizing Industries Worldwide: A comprehensive overview of its diverse applications. *Hybrid Advances*, 7, 100277. <https://doi.org/10.1016/j.hybadv.2024.100277>
- Ravindra, K., Bhardwaj, S., Ram, C., Goyal, A., Singh, V., Venkataraman, C., Bhan, S. C., Sokhi, R. S., & Mor, S. (2024). Temperature projections and heatwave attribution scenarios over India: A systematic review. *Heliyon*, 10(4), e26431. <https://doi.org/10.1016/j.heliyon.2024.e26431>
- Raza, T., Shehzad, M., Abbas, M., Eash, N. S., Jatav, H. S., Sillanpaa, M., & Flynn, T. (2022). Impact assessment of COVID-19 global pandemic on water, environment, and humans. *Environmental Advances*, 11, 100328. <https://doi.org/10.1016/j.envadv.2022.100328>
- Reboredo, J. C. (2013). Is gold a hedge or safe haven against oil price movements? *Resources Policy*, 38(2), 130–137. <https://doi.org/10.1016/j.resourpol.2013.02.003>
- Reboredo, J. C. (2014). Is there dependence and systemic risk between oil and renewable energy stock prices? *Energy Economics*, 48, 32–45. <https://doi.org/10.1016/j.eneco.2014.12.009>
- Reboredo, J. C. (2015). Is there dependence and systemic risk between oil and renewable energy stock prices? *Energy Economics*, 48, 32–45. <https://doi.org/10.1016/j.eneco.2014.12.009>
- Reboredo, J. C. (2018). Green bond and financial markets: Co-movement, diversification and price spillover effects. *Energy Economics*, 74, 38–50. <https://doi.org/10.1016/j.eneco.2018.05.030>

- Reboredo, J. C., & Ugolini, A. (2015). Quantile dependence of oil price movements and stock returns. *Energy Economics*, 54, 33–49. <https://doi.org/10.1016/j.eneco.2015.11.015>
- Reboredo, J. C., & Ugolini, A. (2018). The impact of Twitter sentiment on renewable energy stocks. *Energy Economics*, 76, 153–169. <https://doi.org/10.1016/j.eneco.2018.10.014>
- Reboredo, J. C., & Ugolini, A. (2019). Price connectedness between green bond and financial markets. *Economic Modelling*, 88, 25–38. <https://doi.org/10.1016/j.econmod.2019.09.004>
- Reboredo, J. C., & Ugolini, A. (2020). Price connectedness between green bond and financial markets. *Economic Modelling*, 88, 25–38. <https://doi.org/10.1016/j.econmod.2019.09.004>
- Reboredo, J. C., Quintela, M., & Otero, L. A. (2017). Do investors pay a premium for going green? Evidence from alternative energy mutual funds. *Renewable and Sustainable Energy Reviews*, 73, 512–520. <https://doi.org/10.1016/j.rser.2017.01.158>
- Reboredo, J. C., Rivera-Castro, M. A., & Ugolini, A. (2016). Wavelet-based test of co-movement and causality between oil and renewable energy stock prices. *Energy Economics*, 61, 241–252. <https://doi.org/10.1016/j.eneco.2016.10.015>
- Reboredo, J. C., Ugolini, A., & Aiube, F. a. L. (2020). Network connectedness of green bonds and asset classes. *Energy Economics*, 86, 104629. <https://doi.org/10.1016/j.eneco.2019.104629>
- Rehman, M. U., & Vo, X. V. (2020). Energy commodities, precious metals and industrial metal markets: A nexus across different investment horizons and market conditions. *Resources Policy*, 70, 101843. <https://doi.org/10.1016/j.resourpol.2020.101843>
- Rehman, M. U., Nautiyal, N., & Vo, X. V. (2025). Is it just green? Asymmetry behavior of returns in green investments. *International Review of Economics & Finance*, 104088. <https://doi.org/10.1016/j.iref.2025.104088>
- Rehman, M. U., Nautiyal, N., Zeitun, R., Vo, X. V., & Ghardallou, W. (2025). The resilience of green bonds to oil shocks during extreme events. *Journal of Environmental Management*, 378, 124685. <https://doi.org/10.1016/j.jenvman.2025.124685>
- Rehman, M. U., Vo, X. V., Ko, H., Ahmad, N., & Kang, S. H. (2022). Quantile connectedness between Chinese stock and commodity futures markets. *Research in International Business and Finance*, 64, 101810. <https://doi.org/10.1016/j.ribaf.2022.101810>
- Ren, B., & Lucey, B. (2022). A clean, green haven?—Examining the relationship between clean energy, clean and dirty cryptocurrencies. *Energy Economics*, 109, 105951. <https://doi.org/10.1016/j.eneco.2022.105951>
- Ren, B., Lucey, B., & Luo, Q. (2023). An examination of green bonds as a hedge and safe haven for international equity markets. *Global Finance Journal*, 58, 100894. <https://doi.org/10.1016/j.gfj.2023.100894>
- Reuters. (2024, May 24). What is OPEC+ and how does it affect oil prices? Reuters. <https://www.reuters.com/markets/commodities/what-is-opec-how-does-it-affect-oil-prices->

[2024-05-24/](#)

Rivera, L., Gauthier-Umaña, V., & Chauhan, C. (2024). Blockchain: An opportunity to improve supply chains in the wake of digitalization. *International Journal of Information Management Data Insights*, 4(2), 100290. <https://doi.org/10.1016/j.jjime.2024.100290>

Rohini Krishnamurthy, & Rohini Krishnamurthy. (2025, June 5). China leads global energy investments in 2025, developing countries still face barriers: IEA. Down to Earth. Retrieved July 2, 2025, from <https://www.downtoearth.org.in/energy/>

Rua, A., & Nunes, L. C. (2009). International comovement of stock market returns: A wavelet analysis. *ideas.repec.org*. <https://ideas.repec.org/a/eee/empfin/v16y2009i4p632-639.html>

Rubio-Varas, M., & Muñoz-Delgado, B. (2019). Long-term diversification paths and energy transitions in Europe. *Ecological Economics*, 163, 158–168. <https://doi.org/10.1016/j.ecolecon.2019.04.025>

Ruiz-Campillo, X. (2024). Post-Paris agreement negotiations: A commitment to multilateralism despite the lack of funding. *Environmental Science & Policy*, 156, 103754. <https://doi.org/10.1016/j.envsci.2024.103754>

Saari, M. Y., Dietzenbacher, E., & Los, B. (2016). The impacts of petroleum price fluctuations on income distribution across ethnic groups in Malaysia. *Ecological Economics*, 130, 25–36. <https://doi.org/10.1016/j.ecolecon.2016.05.021>

Sadorsky, P. (2001). Risk factors in stock returns of Canadian oil and gas companies. *Energy Economics*, 23(1), 17–28. [https://doi.org/10.1016/s0140-9883\(00\)00072-4](https://doi.org/10.1016/s0140-9883(00)00072-4)

Sadorsky, P. (2002). Time-varying risk premiums in petroleum futures prices. *Energy Economics*, 24(6), 539–556. [https://doi.org/10.1016/s0140-9883\(02\)00062-2](https://doi.org/10.1016/s0140-9883(02)00062-2)

Sadorsky, P. (2011). Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics*, 34(1), 248–255. <https://doi.org/10.1016/j.eneco.2011.03.006>

Sadorsky, P. (2012). Correlations and volatility spillovers between oil prices and the stock prices of clean energy and technology companies. *Energy Economics*, 34(1), 248–255. <https://doi.org/10.1016/j.eneco.2011.03.006>

Saeed, T., Bouri, E., & Alsulami, H. (2020). Extreme return connectedness and its determinants between clean/green and dirty energy investments. *Energy Economics*, 96, 105017. <https://doi.org/10.1016/j.eneco.2020.105017>

Sahoo, S., & Kumar, S. (2023). Volatility Spillover Among the Sustainable Indices of Emerging Markets: Evidence from Pre-COVID and COVID Periods. *Vision the Journal of Business Perspective*. <https://doi.org/10.1177/09722629231212107>

Sakemoto, R. (2017). Do precious and industrial metals act as hedges and safe havens for currency portfolios? *Finance Research Letters*, 24, 256–

262. <https://doi.org/10.1016/j.frl.2017.09.011>

Salisu, A. A., & Oloko, T. F. (2015). Modeling oil price–US stock nexus: A VARMA–BEKK–AGARCH approach. *Energy Economics*, 50, 1–12. <https://doi.org/10.1016/j.eneco.2015.03.031>

Sam-Abugu, C., Luo, X., & Wong, B. (2025). The combined role of FinTech innovation and financial literacy in sustainable financial inclusion in Nigeria. *International Review of Economics*, 72(2). <https://doi.org/10.1007/s12232-025-00490-1>

San Andres, E., Shin, A., Vasquez, G. N. A., & Chen, T. (2024). Enhancing MSME data interoperability in the APEC region. In Asia-Pacific Economic Cooperation Policy Support Unit. Asia-Pacific Economic Cooperation Policy.

Sandaka, B. P., & Kumar, J. (2023). Alternative vehicular fuels for environmental decarbonization: A critical review of challenges in using electricity, hydrogen, and biofuels as a sustainable vehicular fuel. *Chemical Engineering Journal Advances*, 14, 100442. <https://doi.org/10.1016/j.ceja.2022.100442>

Sanderson, O. (2018). How to trust green bonds. In Elsevier eBooks (pp. 273–288). <https://doi.org/10.1016/b978-0-12-814447-3.00020-3>

Sarwar, S., Tiwari, A. K., & Tingqiu, C. (2020). Analyzing volatility spillovers between oil market and Asian stock markets. *Resources Policy*, 66, 101608. <https://doi.org/10.1016/j.resourpol.2020.101608>

Seba, E. (2025, June 18). Oil prices rise more than 4% as Iran-Israel conflict escalates. REUTERS. <https://www.reuters.com/business/energy/oil-prices-rise-iran-israel-conflict-fans-supply-worries-2025-06-17/>

Seneviratne, S. I., Zhang, X., Adnan, M., Badi, W., Dereczynski, C., Di Luca, A., Ghosh, S., Iskandar, I., Kossin, J., Lewis, S., Otto, F., Pinto, I., Satoh, M., Vicente-Serrano, S. M., Wehner, M., & Zhou, B. (2021). Weather and climate Extreme events in a changing climate. In *Climate Change 2021: The Physical Science Basis* (pp. 1513–1766) [Book]. Cambridge University Press. <https://doi.org/10.1017/9781009157896.013>

Sergio, I., & Wedemeier, J. (2025). Global surge: exploring cryptocurrency adoption with evidence from spatial models. *Financial Innovation*, 11(1). <https://doi.org/10.1186/s40854-025-00765-0>

Seth, N., & Singh, D. (2025). Modelling connectedness and diversification among socially responsible investments in Asia. *International Journal of Sustainable Economy*, 17(2), 123–146. <https://doi.org/10.1504/ijse.2025.145276>

Shah, W. U., Younis, I., Missaoui, I., & Liu, X. (2025). Environmental transitions effect of renewable energy and fintech markets on Europe’s real estate stock market. *Renewable Energy*, 122603. <https://doi.org/10.1016/j.renene.2025.122603>

Shahzad, S. J. H., Bouri, E., Roubaud, D., Kristoufek, L., & Lucey, B. (2019). Is Bitcoin a better safe-haven investment than gold and commodities? *International Review of Financial*

Analysis, 63, 322–330. <https://doi.org/10.1016/j.irfa.2019.01.002>

Shahzad, U., Asl, M. G., & Tedeschi, M. (2023). Is there any market state-dependent contribution from Blockchain-enabled solutions to ESG investments? Evidence from conventional and Islamic ESG stocks. *International Review of Economics & Finance*, 86, 139–154. <https://doi.org/10.1016/j.iref.2023.03.001>

Shaik, M., Varghese, G., & Madhavan, V. (2023). The dynamic volatility connectedness of global financial assets during the Ebola & MERS epidemic and the COVID-19 pandemic. *Applied Economics*, 56(8), 880–900. <https://doi.org/10.1080/00036846.2023.2174499>

Shakya, S., Li, B., & Etienne, X. (2022). Shale revolution, oil and gas prices, and drilling activities in the United States. *Energy Economics*, 108, 105877. <https://doi.org/10.1016/j.eneco.2022.105877>

Shan, W. (2025, March 17). Accelerating the clean energy transition across Asia-Pacific | APEC. APEC. Retrieved July 2, 2025, from <https://www.apec.org/press/blogs/2025/accelerating-the-clean-energy-transition-across-asia-pacific>

Sher, A., Haizhong, A., Khan, M. K., & Sági, J. (2024). Chinese stock market integration with developed world: A portfolio diversification analysis. *Heliyon*, 10(9), e29413. <https://doi.org/10.1016/j.heliyon.2024.e29413>

Shiller, R. J. (1999). Chapter 20 Human behavior and the efficiency of the financial system. In *Handbook of macroeconomics* (pp. 1305–1340). [https://doi.org/10.1016/s1574-0048\(99\)10033-8](https://doi.org/10.1016/s1574-0048(99)10033-8)

Shirley, C., & Swanson, W. (2025). The effects of climate change on GDP in the 21st century. In Working Paper Series (Working Paper No. 2025–02). Congressional Budget Office. <https://www.cbo.gov/system/files/2025-02/61186-Climate-GDP.pdf>

Shirley, C., Congressional Budget Office, Swanson, W., Elizabeth Kopits, Ishan Nath, Brian Prest, Valerie Ramey, James Stock, Christopher Adams, Nicholas Chase, Michael Falkenheim, Evan Hernstadt, Joseph Kile, Jeffrey Kling, Junghoon Lee, Hark Yoo, & Christine Browne. (2025). The effects of climate change on GDP in the 21st century. In Working Paper Series (Working Paper No. 2025–02). Congressional Budget Office. <https://www.cbo.gov/system/files/2025-02/61186-Climate-GDP.pdf>

Shohoji, T., Yamashita, Y., & Tarumi, T. (1981). Generalization of Fisher's z-transformation. *Journal of Statistical Planning and Inference*, 5(4), 347–354. [https://doi.org/10.1016/0378-3758\(81\)90035-5](https://doi.org/10.1016/0378-3758(81)90035-5)

Silvennoinen, A., & Thorp, S. (2012). Financialization, crisis and commodity correlation dynamics. *Journal of International Financial Markets Institutions and Money*, 24, 42–65. <https://doi.org/10.1016/j.intfin.2012.11.007>

Singh, N. P., & Joshi, N. (2018). Investigating gold investment as an inflationary hedge. *Business Perspectives and Research*, 7(1), 30–41.

<https://doi.org/10.1177/2278533718800178>

Singh, N., Singh, H., Arora, C., & Chaturvedi, V. (2024). Role of financial players in the Indian carbon market. CEEW the Council, Issue Brief.

Singhal, S., & Ghosh, S. (2016). Returns and volatility linkages between international crude oil price, metal and other stock indices in India: Evidence from VAR-DCC-GARCH models. *Resources Policy*, 50, 276–288. <https://doi.org/10.1016/j.resourpol.2016.10.001>

Smales, L. (2021). Geopolitical risk and volatility spillovers in oil and stock markets. *The Quarterly Review of Economics and Finance*, 80, 358–366. <https://doi.org/10.1016/j.qref.2021.03.008>

Smith, K. (2022). Climate change and macro social work. Encyclopedia of Social Work. <https://doi.org/10.1093/acrefore/9780199975839.013.1417>

Solnik, B. H. (1974). An equilibrium model of the international capital market. *Journal of Economic Theory*, 8(4), 500–524. [https://doi.org/10.1016/0022-0531\(74\)90024-6](https://doi.org/10.1016/0022-0531(74)90024-6)

Somasekhar, A. (2024, October 15). Oil falls 2% as OPEC cuts oil demand growth view, China concerns. Reuters. <https://www.reuters.com/business/energy/oil-prices-fall-by-more-than-1-chinese-economic-data-2024-10-13/>

Song, Y., Ji, Q., Du, Y., & Geng, J. (2019). The dynamic dependence of fossil energy, investor sentiment and renewable energy stock markets. *Energy Economics*, 84, 104564. <https://doi.org/10.1016/j.eneco.2019.104564>

Soori, M., Dastres, R., & Arezoo, B. (2023). AI-powered blockchain technology in industry 4.0, a review. *Journal of Economy and Technology*, 1, 222–241. <https://doi.org/10.1016/j.ject.2024.01.001>

Soussi, A., Zero, E., Sacile, R., Trincherro, D., & Fossa, M. (2024). Smart Sensors and Smart Data for Precision Agriculture: A review. *Sensors*, 24(8), 2647. <https://doi.org/10.3390/s24082647>

Sovacool, B. K. (2017). Reviewing, reforming, and Rethinking Global Energy Subsidies: Towards a Political Economy Research Agenda. *Ecological Economics*, 135, 150–163. <https://doi.org/10.1016/j.ecolecon.2016.12.009>

Sreelakshmi, S., Gowlikar, V. K., & Suryanarayana Murthy, Y. (2025). A study on Impact of investor psychology on green bond in Sustainable development. In *International Journal of Creative Research Thoughts (IJCRT) & Vardhaman College of Engineering, International Journal of Creative Research Thoughts (IJCRT) (Vol. 13, Issue 4, pp. 285–287) [Journal-article]*. <https://www.ijcrt.org>

Stern, N., & Valero, A. (2021). Innovation, growth and the transition to net-zero emissions. *Research Policy*, 50(9), 104293. <https://doi.org/10.1016/j.respol.2021.104293>

Steurer, E., Fahling, E. J., & Du, J. (2022). Empirical Analysis of Potential Put-Call Parity Arbitrage Opportunities with Particular Focus on the Shanghai Stock Exchange 50 Index.

Journal of Financial Risk Management, 11(01), 66–78.

<https://doi.org/10.4236/jfrm.2022.111003>

Sumant, O. (2023). Green bonds market hit \$ 1555.1 billion by 2033. Allied Market Research. Retrieved July 2, 2025, from <https://www.alliedmarketresearch.com/press-release/green-bonds-market.html>

Sun, G., Yao, X., Li, J., & Lu, T. (2022). Risk linkages between China's stock market and APEC stock markets under China's market liberalization. *Finance Research Letters*, 52, 103586. <https://doi.org/10.1016/j.frl.2022.103586>

Sun, M., Cao, X., Liu, X., Cao, T., & Zhu, Q. (2024). The Russia-Ukraine conflict, soaring international energy prices, and implications for global economic policies. *Heliyon*, 10(16), e34712. <https://doi.org/10.1016/j.heliyon.2024.e34712>

Sun, M., Cao, X., Liu, X., Cao, T., & Zhu, Q. (2024). The Russia-Ukraine conflict, soaring international energy prices, and implications for global economic policies. *Heliyon*, 10(16), e34712. <https://doi.org/10.1016/j.heliyon.2024.e34712>

Sunge, R., Mudzingiri, C., & Mkhize, N. (2024). The COVID-19 pandemic and economic recovery: The mediating role of governance, a global perspective. *Heliyon*, 10(22), e39869. <https://doi.org/10.1016/j.heliyon.2024.e39869>

Surana, S. (2021). Informational efficiency in the context of securities litigation. *Illinois Law Review*. <https://illinoislawreview.org/online/informational-efficiency-in-the-context-of-securities-litigation/>

Sutiene, K., Schwendner, P., Sipos, C., Lorenzo, L., Mirchev, M., Lameski, P., Kabasinskas, A., Tidjani, C., Ozturkkal, B., & Cerneviciene, J. (2024). Enhancing portfolio management using artificial intelligence: literature review. *Frontiers in Artificial Intelligence*, 7. <https://doi.org/10.3389/frai.2024.1371502>

Sweidan, O. D. (2025). Economic challenges of economic diversification and sustainability in the GCC countries. *Review of Political Economy*, 1–23. <https://doi.org/10.1080/09538259.2025.2493269>

Tabash, M. I., Farooq, U., Al-Faryan, M. a. S., & Wong, W. (2024). Effect of Geopolitical Risk on Energy Consumption Policy: New Empirical Evidence from BRICS. *Heliyon*, 10(19), e38049. <https://doi.org/10.1016/j.heliyon.2024.e38049>

Tang, C., & Aruga, K. (2021). Relationships among the Fossil Fuel and Financial Markets during the COVID-19 Pandemic: Evidence from Bayesian DCC-MGARCH Models. *Sustainability*, 14(1), 51. <https://doi.org/10.3390/su14010051>

Tang, C., Aruga, K., & Hu, Y. (2023). The Dynamic Correlation and Volatility Spillover among Green Bonds, Clean Energy Stock, and Fossil Fuel Market. *Sustainability*, 15(8), 6586. <https://doi.org/10.3390/su15086586>

Tchoukouang, R. D., Onyeaka, H., & Nkoutchou, H. (2024). Assessing the vulnerability of food supply chains to climate change-induced disruptions. *The Science of the Total*

Environment, 920, 171047. <https://doi.org/10.1016/j.scitotenv.2024.171047>

The Economic Times. (2024, April 11). World Goods trade growth in value terms May dip 1.2 PC in 2024: GTRI. The Economic Times.

<https://economictimes.indiatimes.com/news/economy/foreign-trade/world-goods-trade-growth-in-volume-terms-may-dip-1-2-in-2024-gtri/articleshow/109218163.cms?from=mdr>

Theodossiou, P., & Lee, U. (1993). MEAN AND VOLATILITY SPILLOVERS ACROSS MAJOR NATIONAL STOCK MARKETS: FURTHER EMPIRICAL EVIDENCE. *The Journal of Financial Research*, 16(4), 337–350. <https://doi.org/10.1111/j.1475-6803.1993.tb00152.x>

Thorbecke, W. (2025). How Oil Prices Impact the Japanese and South Korean Economies: Evidence from the Stock Market and Implications for Energy Security. *Sustainability*, 17(11), 4794. <https://doi.org/10.3390/su17114794>

Tian, J., Yu, L., Xue, R., Zhuang, S., & Shan, Y. (2021). Global low-carbon energy transition in the post-COVID-19 era. *Applied Energy*, 307, 118205. <https://doi.org/10.1016/j.apenergy.2021.118205>

Tian, M., Khoury, R. E., Nasrallah, N., & Alshater, M. M. (2023). Assessing systemic risk spillovers from FinTech to China's financial system. *European Journal of Finance*, 30(8), 803–826. <https://doi.org/10.1080/1351847x.2023.2244008>

Tiwari, A. K., Abakah, E. J. A., Dwumfour, R. A., & Mefteh-Wali, S. (2021). Connectedness and directional spillovers in energy sectors: international evidence. *Applied Economics*, 54(22), 2554–2569. <https://doi.org/10.1080/00036846.2021.1998326>

Tiwari, A. K., Trabelsi, N., Abakah, E. J. A., Nasreen, S., & Lee, C. (2023). An empirical analysis of the dynamic relationship between clean and dirty energy markets. *Energy Economics*, 124, 106766. <https://doi.org/10.1016/j.eneco.2023.106766>

Today, O. (2025, January 23). JSE formally launches its Green Bond Market - Our Today. Our Today. <https://our.today/jse-formally-launches-its-green-bond-market/>

TRADING ECONOMICS. (2025, July). India - Fixed broadband internet subscribers (per 100 people) - 2025 data 2026 forecast 1998-2022 historical. Retrieved July 1, 2025, from <https://tradingeconomics.com/india/fixed-broadband-internet-subscribers-per-100-people-wb-data.html>

Truong, L. D., Friday, H. S., & Pham, T. D. (2024). The Effects of Geopolitical Risk on Foreign Direct Investment in a Transition Economy: Evidence from Vietnam. *Journal of Risk and Financial Management*, 17(3), 101. <https://doi.org/10.3390/jrfm17030101>

Tse, A. S. L., & Zheng, H. (2023). Portfolio selection, periodic evaluations and risk taking. *Operations Research*, 71(6), 2078–2091. <https://doi.org/10.1287/opre.2021.0780>

Tully, E., & Lucey, B. M. (2006). A power GARCH examination of the gold market. *Research in International Business and Finance*, 21(2), 316–325. <https://doi.org/10.1016/j.ribaf.2006.07.001>

U.S. Bureau of Labor Statistics. (2025, June). THE EMPLOYMENT SITUATION — MAY 2025 [Press-release]. THE EMPLOYMENT SITUATION. <https://www.bls.gov/news.release/pdf/empsit.pdf>

Umar, M., Farid, S., & Naeem, M. A. (2021). Time-frequency connectedness among clean-energy stocks and fossil fuel markets: Comparison between financial, oil and pandemic crisis. *Energy*, 240, 122702. <https://doi.org/10.1016/j.energy.2021.122702>

Umar, Z., Aziz, S., & Tawil, D. (2021). The impact of COVID-19 induced panic on the return and volatility of precious metals. *Journal of Behavioral and Experimental Finance*, 31, 100525. <https://doi.org/10.1016/j.jbef.2021.100525>

United Nations Economic and Social Commission for Asia and the Pacific, & Akhtar, S. (2016). The economics of climate change in the Asia-Pacific region. United Nations Economic and Social Commission for Asia and the Pacific. <https://www.unescap.org/sites/default/files/The%20Economics%20of%20Climate%20Change%20in%20the%20Asia-Pacific%20region.pdf>

Vacha, L., & Barunik, J. (2012). Co-movement of energy commodities revisited: Evidence from wavelet coherence analysis. *Energy Economics*, 34(1), 241–247. <https://doi.org/10.1016/j.eneco.2011.10.007>

Valdes, R., Von Cramon-Taubadel, S., & Engler, A. (2016). What drives stock market integration? An analysis using agribusiness stocks. *Agricultural Economics*, 47(5), 571–580. <https://doi.org/10.1111/agec.12256>

Van Aert, R. C. M. (2023). Meta-analyzing partial correlation coefficients using Fisher's z transformation. *Research Synthesis Methods*, 14(5), 768–773. <https://doi.org/10.1002/jrsm.1654>

Vilas, P., Andreu, L., & Sarto, J. L. (2021). The Convergence between Sustainability and Conventional Stock Indices. Are We on the Right Track? *Sustainability*, 13(14), 7613. <https://doi.org/10.3390/su13147613>

Vu, T. N., Lehkonen, H., Junttila, J., & Lucey, B. (2024). ESG investment performance and global attention to sustainability. *The North American Journal of Economics and Finance*, 75, 102287. <https://doi.org/10.1016/j.najef.2024.102287>

Walia, A. (2025, June 21). India to be world's 4th largest electric car maker by 2030; must cut costs to compete with China: Rhodium. *The Indian Express*. <https://indianexpress.com/article/business/economy/india-4th-largest-electric-car-maker-2030-china-rhodium-group-10077852/>

Wang, C., Wang, L., Xue, Y., & Li, R. (2022). Revealing Spatial Spillover Effect in High-Tech Industry Agglomeration from a High-Skilled Labor Flow Network Perspective. *Journal of Systems Science and Complexity*, 35(3), 839–859. <https://doi.org/10.1007/s11424-022-1056-1>

Wang, F., Harindintwali, J. D., Yuan, Z., Wang, M., Wang, F., Li, S., Yin, Z., Huang, L., Fu,

Y., Li, L., Chang, S. X., Zhang, L., Rinklebe, J., Yuan, Z., Zhu, Q., Xiang, L., Tsang, D. C., Xu, L., Jiang, X., . . . Chen, J. M. (2021). Technologies and perspectives for achieving carbon neutrality. *The Innovation*, 2(4), 100180. <https://doi.org/10.1016/j.xinn.2021.100180>

Wang, G., Sbai, E., Wen, L., & Sheng, S. (2024). The Impact of Renewable Energy on Extreme Volatility in Wholesale Electricity Prices: Evidence from Organisation for Economic Co-operation and Development Countries. *Journal of Cleaner Production*, 144343. <https://doi.org/10.1016/j.jclepro.2024.144343>

Wang, H. (1993). CHINA'S IMPACT ON THE WORLD CRUDE-OIL MARKET. *The Journal of Energy and Development*, 19(1), 81–96. <https://www.jstor.org/stable/24808017>

Wang, M., Chen, M., Mirzaliev, S., & Hao, W. (2025). The Economics of Circular Supply Chains: Transformative implications for businesses and Stakeholders. *Journal of Cleaner Production*, 145638. <https://doi.org/10.1016/j.jclepro.2025.145638>

Wang, R. (2023). The impact of geopolitical stability on foreign investment and transnational corporations: A case study of the Russia-Ukraine conflict. *Advances in Economics Management and Political Sciences*, 63(1), 141–147. <https://doi.org/10.54254/2754-1169/63/20231395>

Wang, X., & Wang, Y. (2019). Volatility spillovers between crude oil and Chinese sectoral equity markets: Evidence from a frequency dynamics perspective. *Energy Economics*, 80, 995–1009. <https://doi.org/10.1016/j.eneco.2019.02.019>

Wang, X., Chen, M., & Chen, N. (2024). How artificial intelligence affects the labour force employment structure from the perspective of industrial structure optimisation. *Heliyon*, 10(5), e26686. <https://doi.org/10.1016/j.heliyon.2024.e26686>

Wang, Y., Ali, S., & Ayaz, M. (2023). Equity markets and ESG dynamics: Assessing spillovers and portfolio strategies through time-varying parameters. *Energy Economics*, 134, 107548. <https://doi.org/10.1016/j.eneco.2024.107548>

Wang, Z., Esangbedo, M. O., & Bai, S. (2023). Project portfolio selection based on multi-project synergy. *Journal of Industrial and Management Optimization*, 19(1), 117. <https://doi.org/10.3934/jimo.2021177>

Wen, B., He, Y., Jing, X., & Haroon, M. (2025). Advancing renewable energy and green finance for economic growth and ecological resilience. *Energy Strategy Reviews*, 59, 101747. <https://doi.org/10.1016/j.esr.2025.101747>

Wiegand, J., Scott, A., Srinivasan, K., Helbling, T., Hlatshwayo, S., Kim, J., Xu, Y., Giri, R., Baba, C., & Oeking, A. (2024). Regional economic outlook. Asia and Pacific: resilient growth but higher risks.

WIPO. (2024). 2 Global patenting and research in GEnAI. World Intellectual Property Organization. <https://doi.org/10.34667/tind.49740>

Wishnick, E. (2023, January 30). Ukraine's ripple effect on Russia's Indo-Pacific horizon. CNA. <https://www.cna.org/our-media/indepth/2023/01/ukraines-ripple-effect-on-russias->

Wu, F. (2019). Stock market integration in East and Southeast Asia: The role of global factors. *International Review of Financial Analysis*, 67, 101416. <https://doi.org/10.1016/j.irfa.2019.101416>

Wu, G., Liu, X., & Cai, Y. (2023). The impact of green finance on carbon emission efficiency. *Heliyon*, 10(1), e23803. <https://doi.org/10.1016/j.heliyon.2023.e23803>

Wu, J., Zhang, C., & Chen, Y. (2022). Analysis of risk correlations among stock markets during the COVID-19 pandemic. *International Review of Financial Analysis*, 83, 102220. <https://doi.org/10.1016/j.irfa.2022.102220>

Xiao, B., Yu, H., Fang, L., & Ding, S. (2019). Estimating the connectedness of commodity futures using a network approach. *Journal of Futures Markets*, 40(4), 598–616. <https://doi.org/10.1002/fut.22086>

Ximei, K., Javaid, M. Q., Shams, T., & Sibt-e-Ali, M. (2024). Information and communication technology, economic globalization, and environmental sustainability in APEC nations: Insights from LCC and EKC hypotheses testing. *Sustainable Development*. <https://doi.org/10.1002/sd.3163>

Xu, N. H., & Trong, N. N., DO. (2023). Exporting to the members of Asia-Pacific Economic Cooperation (APEC) - a direction for Vietnam's agricultural products. *International Journal of Scientific Research in Science and Technology*, 01–11. <https://doi.org/10.32628/ijrst2310175>

Xu, R., Yu, P., Liu, Y., Chen, G., Yang, Z., Zhang, Y., Wu, Y., Beggs, P. J., Zhang, Y., Boocock, J., Ji, F., Hanigan, I., Jay, O., Bi, P., Vargas, N., Leder, K., Green, D., Quail, K., Huxley, R., . . . Guo, Y. (2023). Climate change, environmental extremes, and human health in Australia: challenges, adaptation strategies, and policy gaps. *The Lancet Regional Health - Western Pacific*, 40, 100936. <https://doi.org/10.1016/j.lanwpc.2023.100936>

Yadav, M., Mishra, N., & Ashok, S. (2022). Dynamic connectedness of green bond with financial markets of European countries under OECD economies. *Economic Change and Restructuring*, 56(1), 609–631. <https://doi.org/10.1007/s10644-022-09430-3>

Yamazawa, I. (1992). *On Pacific economic integration*. <https://econpapers.repec.org/RePEc:ecj:econjl:v:102:y:1992:i:415:p:1519-29>

Yang, F., & Gu, S. (2021). Industry 4.0, a revolution that requires technology and national strategies. *Complex & Intelligent Systems*, 7(3), 1311–1325. <https://doi.org/10.1007/s40747-020-00267-9>

Yang, J., & Bessler, D. A. (2003). The international price transmission in stock index futures markets. *Economic Inquiry*, 42(3), 370–386. <https://doi.org/10.1093/ei/cbh067>

Yang, K., Wei, Y., Li, S., & He, J. (2020). Geopolitical risk and renewable energy stock markets: An insight from multiscale dynamic risk spillover. *Journal of Cleaner Production*, 279, 123429. <https://doi.org/10.1016/j.jclepro.2020.123429>

- Yang, Z., Wang, Y., Li, X., Li, J., Fu, L., & Qiao, L. (2024). Time-frequency spillovers and connectedness between Chinese climate risk perception and energy markets. *Weather Climate and Society*. <https://doi.org/10.1175/wcas-d-24-0005.1>
- Yao, C., & Kuang, P. (2019). A study of lead–lag structure between international crude oil price and several financial markets. *Physica a Statistical Mechanics and Its Applications*, 531, 121755. <https://doi.org/10.1016/j.physa.2019.121755>
- Yarovaya, L., Brzeszczyński, J., Goodell, J. W., Lucey, B., & Lau, C. K. M. (2022). Rethinking financial contagion: Information transmission mechanism during the COVID-19 pandemic. *Journal of International Financial Markets Institutions and Money*, 79, 101589. <https://doi.org/10.1016/j.intfin.2022.101589>
- Yeung, H. W., & Lin, G. C. S. (2000). Theorizing economic geographies of Asia. *Economic Geography*, 79(2), 107–128. <https://doi.org/10.1111/j.1944-8287.2003.tb00204.x>
- Yoo, I., & Yi, C. (2022). Economic innovation caused by digital transformation and impact on social systems. *Sustainability*, 14(5), 2600. <https://doi.org/10.3390/su14052600>
- Yousaf, I., Ijaz, M. S., Umar, M., & Li, Y. (2024). Exploring volatility interconnections between AI tokens, AI stocks, and fossil fuel markets: evidence from time and frequency-based connectedness analysis. *Energy Economics*, 133, 107490. <https://doi.org/10.1016/j.eneco.2024.107490>
- Yousaf, I., Youssef, M., & Goodell, J. W. (2023). Tail connectedness between artificial intelligence tokens, artificial intelligence ETFs, and traditional asset classes. *Journal of International Financial Markets Institutions and Money*, 91, 101929. <https://doi.org/10.1016/j.intfin.2023.101929>
- Yue, P., Fan, Y., Batten, J. A., & Zhou, W. (2020). Information Transfer between Stock Market Sectors: A Comparison between the USA and China. *Entropy*, 22(2), 194. <https://doi.org/10.3390/e22020194>
- Zahraee, S. M., Shiwakoti, N., & Stasinopoulos, P. (2022). Agricultural biomass supply chain resilience: COVID-19 outbreak vs. sustainability compliance, technological change, uncertainties, and policies. *Cleaner Logistics and Supply Chain*, 4, 100049. <https://doi.org/10.1016/j.clscn.2022.100049>
- Zaman, M., Saeed, S., Bajwa, R. I., Rahman, M. S. U., Rahman, S., Jamshaid, M., Rasool, M., Majeed, A., Imran, I., Alqahtani, F., Alshehri, S., AlAsmari, A., Ali, N., & Alasmari, M. (2024). Correction: Zaman et al. Synthesis and Evaluation of Thiol-Conjugated Poloxamer and Its Pharmaceutical Applications. *Pharmaceutics* 2021, 13, 693. *Pharmaceutics*, 16(5), 690. <https://doi.org/10.3390/pharmaceutics16050690>
- Zaman, T., Syed, M., Feng, Z., & Burt, G. (2024). A realigned instantaneous frequency approach for SSCI oscillation localization in power networks. *IEEE Transactions on Power Systems*, 1–13. <https://doi.org/10.1109/tpwrs.2024.3474177>

Zhang, B., Yang, F., & Li, Y. (2023). Recent progress in Large-Area organic solar cells. *Small Science*, 3(7). <https://doi.org/10.1002/smssc.202300004>

Zhang, D., & Broadstock, D. C. (2018). Global financial crisis and rising connectedness in the international commodity markets. *International Review of Financial Analysis*, 68, 101239. <https://doi.org/10.1016/j.irfa.2018.08.003>

Zhang, H., Chen, J., & Shao, L. (2021). Dynamic spillovers between energy and stock markets and their implications in the context of COVID-19. *International Review of Financial Analysis*, 77, 101828. <https://doi.org/10.1016/j.irfa.2021.101828>

Zhang, J., & Khan, I. (2024). Energy use, energy access, and oil price fluctuations as new determinants of environmental quality in APEC countries. *Gondwana Research*, 132, 309–322. <https://doi.org/10.1016/j.gr.2024.04.015>

Zhang, M., Tang, Y., Liu, L., & Zhou, D. (2022). Optimal investment portfolio strategies for power enterprises under multi-policy scenarios of renewable energy. *Renewable and Sustainable Energy Reviews*, 154, 111879. <https://doi.org/10.1016/j.rser.2021.111879>

Zhang, Q., Hu, Y., Jiao, J., & Wang, S. (2024). Assessing the extent and persistence of major crisis events in the crude oil market and economy: evidence from the past 30 years. *Humanities and Social Sciences Communications*, 11(1). <https://doi.org/10.1057/s41599-024-03364-z>

Zhang, Q., Yang, K., Hu, Y., Jiao, J., & Wang, S. (2023). Unveiling the impact of geopolitical conflict on oil prices: A case study of the Russia-Ukraine War and its channels. *Energy Economics*, 126, 106956. <https://doi.org/10.1016/j.eneco.2023.106956>

Zhang, W., He, X., & Hamori, S. (2022). Volatility spillover and investment strategies among sustainability-related financial indexes: Evidence from the DCC-GARCH-based dynamic connectedness and DCC-GARCH t-copula approach. *International Review of Financial Analysis*, 83, 102223. <https://doi.org/10.1016/j.irfa.2022.102223>

Zhang, W., Zhuang, X., Wang, J., & Lu, Y. (2020). Connectedness and systemic risk spillovers analysis of Chinese sectors based on tail risk network. *The North American Journal of Economics and Finance*, 54, 101248. <https://doi.org/10.1016/j.najef.2020.101248>

Zhang, X., & Huang, C. (2024). Investor characteristics, intention toward socially responsible investment (SRI), and SRI behavior in Chinese stock market: The moderating role of risk propensity. *Heliyon*, 10(14), e34230. <https://doi.org/10.1016/j.heliyon.2024.e34230>

Zhang, Y. (2024). Role of green finance, green bonds, public private partnership, and technology innovation in carbon neutrality and sustainable development. *Heliyon*, e37189. <https://doi.org/10.1016/j.heliyon.2024.e37189>

Zhang, Y., & Umair, M. (2023). Examining the interconnectedness of green finance: an analysis of dynamic spillover effects among green bonds, renewable energy, and carbon markets. *Environmental Science and Pollution Research*, 30(31), 77605–77621. <https://doi.org/10.1007/s11356-023-27870-w>

- Zhang, Y., & Wei, Y. (2010). The crude oil market and the gold market: Evidence for cointegration, causality and price discovery. *Resources Policy*, 35(3), 168–177. <https://doi.org/10.1016/j.resourpol.2010.05.003>
- Zhang, Y., Chevallier, J., & Guesmi, K. (2017). “De-financialization” of commodities? Evidence from stock, crude oil and natural gas markets. *Energy Economics*, 68, 228–239. <https://doi.org/10.1016/j.eneco.2017.09.024>
- Zhang, Y., Hajiyeve, N., & Smirnov, V. (2021). Tariff and non-tariff instruments of OPEC+ trade wars. *Energy Strategy Reviews*, 38, 100771. <https://doi.org/10.1016/j.esr.2021.100771>
- Zhang, Z., Wang, Y., Xiao, J., & Zhang, Y. (2022). Not all geopolitical shocks are alike: Identifying price dynamics in the crude oil market under tensions. *Resources Policy*, 80, 103238. <https://doi.org/10.1016/j.resourpol.2022.103238>
- Zheng, H., Lau Chor Tak Institute of Global Economics and Finance, & The Chinese University of Hong Kong. (2021). Climate policy and corporate green bonds. In *Working Paper* (No. 88). https://www.igef.cuhk.edu.hk/igef_media/working-paper/IGEF/IGEF%20Working%20Paper%20No.%2088%20English%20version.pdf
- Zheng, J., Jiang, Y., Cui, Y., & Shen, Y. (2023). Green bond issuance and corporate ESG performance: Steps toward green and low-carbon development. *Research in International Business and Finance*, 66, 102007. <https://doi.org/10.1016/j.ribaf.2023.102007>
- Zheng, T., Zhang, H., & Ye, S. (2024). Monetary policies on green financial markets: Evidence from a multi-moment connectedness network. *Energy Economics*, 136, 107739. <https://doi.org/10.1016/j.eneco.2024.107739>
- Zhong, Y., & Liu, J. (2021). Correlations and volatility spillovers between China and Southeast Asian stock markets. *The Quarterly Review of Economics and Finance*, 81, 57–69. <https://doi.org/10.1016/j.qref.2021.04.001>
- Zhong, Y., & Liu, J. (2021). Correlations and volatility spillovers between China and Southeast Asian stock markets. *The Quarterly Review of Economics and Finance*, 81, 57–69. <https://doi.org/10.1016/j.qref.2021.04.001>
- Zhou, D., & Kythreotis, A. (2024). Why issue green bonds? Examining their dual impact on environmental protection and economic benefits. *Humanities and Social Sciences Communications*, 11(1). <https://doi.org/10.1057/s41599-024-04318-1>
- Zhou, F., Pan, Y., Wu, J., Xu, C., & Li, X. (2024). The impact of green finance on renewable energy development efficiency in the context of energy security: Evidence from China. *Economic Analysis and Policy*, 82, 803–816. <https://doi.org/10.1016/j.eap.2024.04.012>
- Ziadat, S. A., Mensi, W., Al-Kharusi, S., Vo, X. V., & Kang, S. H. (2024). Are clean energy markets hedges for stock markets? A tail quantile connectedness regression. *Energy Economics*, 136, 107757. <https://doi.org/10.1016/j.eneco.2024.107757>
- Zohuri, B., Mossavar-Rahmani, F., & Behgounia, F. (2022). Nonrenewable energy. In Elsevier eBooks (pp. 465–512). <https://doi.org/10.1016/b978-0-323-95112-8.00015-5>

