MUHAMMAD MARI

CURRENT ISSUES IN FINANCIAL SUSTAINABILITY AND ENVIRONMENTAL CHANGE

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NEAR EAST UNIVERSITY

INSTITUTE OF GRADUATE STUDIES

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Ph.D. THESIS

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Nicosia

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Onay

Özel Hukuk Doktora programı öğrencisi 20157810 numaralı Berke Ada tarafından hazırlanan **"KKTC'de Gazetecilerin İş Güvencesi Basın İş Sözleşmesinin Feshi ve Hukuki Sonuçları"** başlıklı tez, kapsam ve nitelik açısından kalite standartlarına uygunluğu ile ilgili Özel Hukuk Anabilim Dalında Doktora Tezi olarak 03.07.2023 tarihinde kabul edilmiştir.

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Declaration

I hereby declare that all information, documents, analysis and results in this thesis have been collected and presented according to the academic rules and ethical guidelines of Institute of Graduate Studies, Near East University. I also declare that as required by these rules and conduct, I have fully cited and referenced information and data that are not original to this study.

MUHAMMAD MARI
…../…../2023

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MUHAMMAD MARI

Abstract

Current Issues in Financial Sustainability and Environmental Change

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Recently, the notions of financial sustainability and environmental changes have become increasingly interconnected, which requires the incorporation of environmental considerations into developmental endeavors at both governmental and corporate levels. This study delves into various financial issues concerning environmental changes at different levels. The novelty and originality of this study reside in its investigation of financial sustainability across two levels: the governmental level and the institutional and financial markets level. Furthermore, the research examines the interaction of green financial assets, which adhere to financial sustainability standards, with other financial assets. It also analyzes their sensitivity to uncertainty and financial stress in comparison to other financial assets, and finally, the study investigates the potential effect of renewable energy on economic growth. To address these issues, the study was partitioned into seven chapters. Each chapter, from the second to the sixth, addresses a distinct financial sustainability perspective.

The study sample consists of the Group of Twenty countries, considered the main carbon dioxide-producing countries. The research covers intermittent periods from 1990 to 2022. The study employs different econometric techniques to examine the relationships and dynamics between financial issues and environmental changes, including Panel Autoregressive Distributed Lag, Quantile on Quantile, Regular Vine Copula, and Wavelet Analysis. At the macro level, the study found that the fiscal policy followed in the G20 countries negatively affects the environment by contributing to the rise in CO_2 emissions. At the micro level, the study found that the development of financial institutions and financial markets in carbon dioxide-producing countries sends shocks that contribute to reducing CO_2 emissions. Regarding the effect of financial stress and uncertainty on conventional and green financial bonds, the study found that green assets are less responsive to negative shocks.

The main recommendations of the study are to reexamine the applicable fiscal policy and redirect it to support clean energy projects. Incentives should be offered for initiatives that combat environmental deterioration by adopting environmentally friendly financial policies, with the support of green projects by G20. Additionally, the study suggests incorporating environmental factors into regulatory frameworks and providing financial incentives for carbon reduction activities. Furthermore, the study recommends that cooperation between enforcement agencies and financial institutions is essential. Creating channels for information sharing and reporting suspicious activities can greatly assist in detecting and preventing illicit behaviors. Finally, the study recommends that investors, especially those who are risk-averse, include green bonds in their portfolios.

Keywords: Financial Sustainability, Financial Development, Green Investment, G20, Quantile on Quantile.

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List of Abbreviations

ADF:	Augmented Dickey–Fuller
ARDL:	Autoregressive Distributed Lag
BRICS:	Brazil, Russia, India, China and South Africa
BRT:	Brent Price
CCE:	Common Correlated Effects
CIPS:	Cross-Sectionally Augmented IPS Unit Root Test
CO_2:	Carbon Dioxide Emissions
COP27:	The United Nations Climate Change Conference
CRY:	Cryptocurrency
CS-ARDL:	Cross-Sectional Augmented Distributed Lag
ECT:	Error Correction Model
EF:	Economic Freedom
EGS:	Environmental, Social, And Governance Index
EKC:	Environmental Kuznets Curve
EU:	European Union Countries
FDI:	Foreign Direct Investment
FDV:	Financial Development
FI:	Financial Institutions
FM:	Financial Markets
FMOLS:	Fully Modified Ordinary Least Squares
FNI:	Financial Inclusion
FSP:	Fiscal Policy
G20:	Group Of Twenty
G-7:	Canada, France, Germany, Italy, Japan, The United Kingdom, and The United States, as well as the European Union.
GDC:	GDP Per Capita
GDP:	Gross Domestic Product
GDPS:	GDP Square
GLB:	Global Market Capitalization
GMM:	The Generalized Method of Moments
IMF:	International Monetary Fund
ISM:	Islamic Investment

MG:	Panel Autoregressive Distributed Lag of Mean Group
MW:	Mann-Whitney Unit Root Test
N-11:	Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey, And Vietnam
NARDL:	Nonlinear Autoregressive Distributed Lag
OECD:	Organization For Economic Cooperation and Development
OLS:	Ordinary Least Squares
PCA:	Principle Component Analysis
PMG:	Panel Autoregressive Distributed Lag of Pooled Mean Group
PQR:	Panel Quantile Regression
PVAR:	Panel Vector Autoregressive
QARDL:	Quantile Autoregressive Distributed Lag Model
QQ:	Quantile-On-Quantile
REN:	Renewable Energy Consumption Per Capita
RENS:	Squared of Renewable Energy Consumption Per Capita
SEM:	Structural Equation Modeling
TEC:	Technology
TVP-VAR:	Time-Varying Parameter Vector Autoregression
USA:	United State of America
VECM:	Vector Error Correction Model
WDI:	World Development Indicators

Introduction

Years ago, following Hurricane Katrina, the extent of the destruction was alarming. The U.S. government faced accusations of exacerbating the crisis due to its failure to implement necessary measures in advance to mitigate potential impacts. The American Society of Engineers had previously warned about deficiencies in the region's preparations and defenses against major storms well before Katrina's impact on the Gulf Coast of the united state of America (USA). Unfortunately, these warnings were disregarded, resulting in a significant financial burden of over $110 billion for the nation. Similarly, in subsequent years, the same community's warnings in 2009 regarding the vulnerable state of New York were met with indifference. They recommended preparing and installing protective measures to mitigate the potential negative effects of hurricanes and storms. However, their recommendations were sidelined, and Hurricane Sandy struck the Northeastern seaboard two years later, leading to initial damage assessments significantly surpassing $100 billion (Fatemi & Fooladi, 2013).

The recurrent characteristic of such governmental actions, or rather inaction, seems to be an apparent failure of policymakers to consider sustainability in their decisions. The preceding example demonstrated how the United States government's reluctance to bear sustainable costs has resulted in compounding consequences. Opting for short-term measures and dismissing sustainable solutions to relieve financial burdens has had adverse implications for society's long-term requirements. Such practices, involving prioritizing short-term gains at the expense of long-term benefits, are prevalent. They are not limited to governments but extend to companies and even academic circles. In this context, the notion of financial sustainability has historically been associated with financial considerations, specifically the maximization of shareholder wealth. However, this perspective has been challenged by researchers who advocate for integrating financial sustainability with a company's environmental and social contexts, contending that the traditional approach of maximizing shareholder wealth is no longer efficient for generating real financial sustainability (Fooladi & Hebb, 2023). The financial system plays a paramount role in achieving sustainable development goals. Efficient financial markets facilitate capital transfer, risk reduction, and stable financing for the real economy. However, the conventional finance paradigm tends to prioritize profit over sustainability considerations. In contrast, sustainable finance incorporates social and environmental dimensions, particularly carbon dioxide (CO_2) emissions and environmental changes, aligning it effectively with the principles of sustainable development (Ziolo et al. 2019). CO_2 emissions and environmental changes are among the most pressing global challenges, posing significant dangers to human well-being. To combat climate change, widespread efforts are underway to lower carbon emissions and achieve carbon neutrality. Governments worldwide are transitioning to renewable energy options to meet energy-saving and carbon-reduction obligations established by international treaties. Unfortunately, the high costs associated with renewable energy infrastructure hinder the growth of clean energy, particularly in impoverished nations. Addressing this issue necessitates innovation in financial tools, involving the modernization of existing ones and the creation of new instruments. These financial mechanisms should support and activate renewable energy projects, considering environmental factors to effectively reduce CO_2 emissions. The integration of financing and environmental considerations is vital to achieving financial sustainability while promoting a sustainable future (Tao et al., 2022). Recently, the role of the financial system in achieving environmental, social, and economic sustainability has garnered global attention, marking it as an emerging field of research. Of particular interest is the sector's contribution to combatting climate change and reducing CO_2 emissions. Despite the progress made in this area, certain aspects of financial sustainability still lack sufficient research and understanding. Addressing such issues contributes to making further progress in this field, especially by examining the various ways in which the financial sector interacts with other sectors. This study presents five distinct topics, each delving into a different financial aspect alongside other economic and environmental concerns. Through investigation, the study examines the existence and interactions of financial sustainability with other variables, as well as the mechanisms through which it engages with contemporary environmental issues.

Fiscal policy serves as a crucial tool for policymakers in guiding the economy, and its effects extend to various aspects of our lives, including its impact on CO_2 emissions. Therefore, it is essential to investigate the role of the current fiscal policy in the country concerning its contribution to combating environmental change and reducing CO_2 emissions. In this regard, Chapter One, titled "The Role of Fiscal Policy in the G20 Countries in the Context of the Environmental Kuznets Curve Hypothesis," examines how fiscal policy, along with gross domestic product, technology (TEC), and FDV, can help mitigate CO_2 emissions within the framework of the Environmental Kuznets Curve (EKC) theory. The study utilizes panel autoregressive distributed lag (ARDL) approaches to analyze data spanning from 1995 to 2019, covering the G20 group.

In the same context, Chapter Two delves into the crucial role of financial development (FDV) in addressing the challenge of increasing CO_2 emissions. More precisely, the chapter investigates the impacts and causal links between financial market and institution development and CO_2 emissions in five major polluting countries: China, the USA, Russia, Japan, and India. The study employs quantile-quantile (QQ) and nonparametric causality-in-quantile methodologies, covering the period from 1990 to 2019. The focus on these major polluting countries is particularly relevant, given their significant contributions to global emissions and their potential for implementing impactful policies. The chapter is titled "Investigating the Causality Between FDV and Carbon Emissions: A Quantile-Based Analysis" and contributes to a more comprehensive understanding of how financial institutions and financial market development can effectively mitigate CO_2 emissions.

In the third chapter, a significant step was taken by studying the dependency between financial markets and the lead-lag relationship. The study's importance lies in its analysis of the multivariate relationships and interactions between different financial assets, including Environmental, Social, and Governance (EGS) indicators. EGS is an indicator that reflects the performance of companies that prioritize Environmental, Social, and Governance best practices. This chapter is particularly relevant for investors seeking to invest in sustainable assets and hedge against volatility in the financial markets. It sheds light on the relationship between EGS and other markets, namely oil (BRT), global equity (GLB), cryptocurrency (CRY), and Islamic markets (ISM), in both bearish and bullish conditions. The chapter, titled "The Tail Dependence and Lead-Lag Relationship in Financial Markets," covers the period from January 2014 to December 2022, employing copula and wavelet techniques to obtain results.

At a time when sustainable financial instruments have emerged, taking into account clean energy and supporting environmentally friendly projects, a question arises: Are these sustainable investments affected by financial stress and uncertainty in a manner similar to other equities and bonds, or do they behave differently? This question has been answered in the fourth chapter. The chapter, entitled "The Impact of Financial Stress and Uncertainty on Green and Conventional Bonds and Stocks: A Nonlinear and Nonparametric Quantile Analysis," investigates the impact of financial stress and uncertainty on the returns of green and conventional bonds and stocks in the United States from 2010 to 2022. It uses nonlinear and nonparametric analysis, more precisely QQ and nonparametric causality-in-quantiles. The importance of this chapter lies in enabling investors to understand the diverse sensitivity arising from such stress and uncertainties in the economy on both green and conventional investments. This understanding allows them to assess the potential benefits of diversifying their portfolios and managing portfolio risks while accounting for such circumstances.

The fifth chapter explores the impact of renewable energy on GDP per capita, including the role of financial inclusion (FNI) as a mediator in this relationship. The chapter is entitled "The Impact of Renewable Energy, Economic Freedom, and Financial Inclusion on GDP Per Capita: An Empirical Analysis." Covering the years 1995 to 2019, the chapter employs ARDL and Structural Equation Modeling (SEM) techniques to analyze the relationships and assess the mediating role of FNI in the Group of Twenty (G20) countries. The chapter is motivated by the need to identify and comprehend the mechanisms through which renewable energy influences GDP per capita, particularly via FNI. As a result, it assesses the impact of different policies related to renewable energy on GDP per capita and explores the role that FNI plays in shaping this relationship.

This study holds substantial significance due to its multifaceted exploration of various interconnected aspects within the realm of financial sustainability. Firstly, by analyzing the effects of Gross Domestic Product on CO_2 emissions through the scope of the EKC, the research offers a valuable opportunity to glean insights into the intricate equilibrium between economic progress and environmental sustainability. Additionally, the assessment of fiscal policy's influence on environmentally-conscious governance contributes to the understanding of how policy mechanisms can shape environmentally-friendly practices. Furthermore, the study delves into the pivotal role that financial institutions and markets play in mitigating CO_2 emissions, thereby uncovering a critical facet of sustainable financial practices. The investigation's scope extends to exploring the tail dependency between green assets and other diverse financial assets, an exploration that provides both investors and policymakers with indispensable information to evaluate risks comprehensively and devise effective diversification strategies. An equally pivotal dimension of the research lies in the scrutiny of the repercussions of financial stress and uncertainty, which holds immense relevance in deciphering the response patterns of both environmentally-friendly and conventional financial assets during challenging times. This understanding substantially bolsters risk management approaches and facilitates well-informed decision-making within the realm of investments. Lastly, the investigation's inquiry into the ramifications of adopting renewable energy sources on Gross Domestic Product (GDP) per capita underscores its pivotal role in enhancing our comprehension of the developmental impact of renewable energy. Collectively, these dimensions of the study contribute to an enriched and comprehensive comprehension of financial sustainability development, spanning from economic and policy dimensions to financial and environmental-related realms.

CHAPTER 1

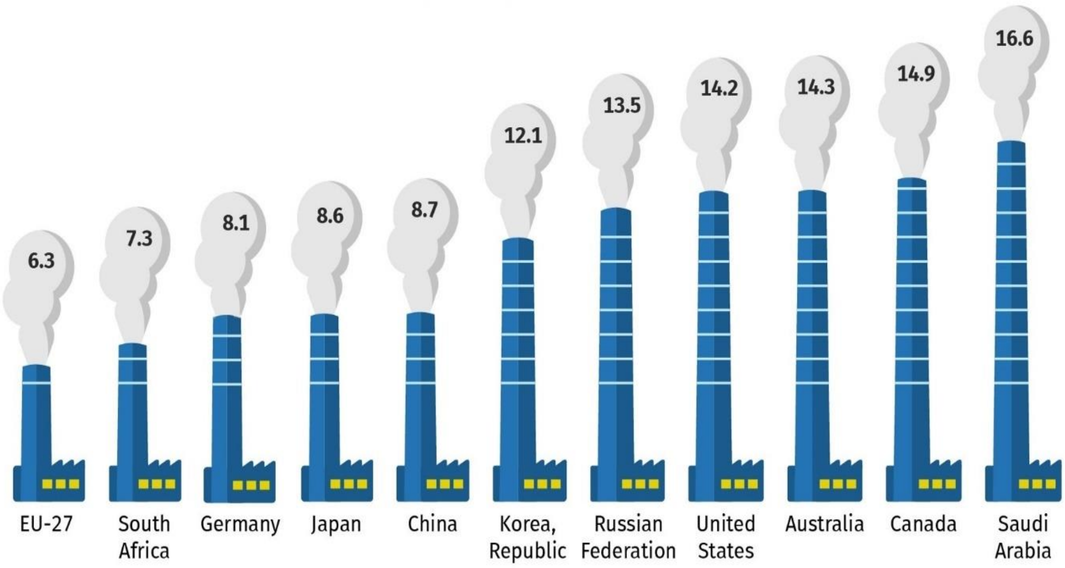
The role of fiscal policy in the G20 countries in the context of the Environmental Kuznets Curve hypothesis

1.1. Introduction

Due to human activity and energy use, notably in the last century, the world has faced serious climatic concerns, particularly regarding CO_2 emissions (Cheng et al., 2021). Governments have been compelled to raise public awareness of the environmental problems brought on by the rapid exploitation of natural resources and the resulting rise in CO_2 emissions that have coincided with global economic growth and advancements in human well-being (Y. Chen & Lee, 2020). The mitigation of global warming and CO_2 emissions is a crucial goal of worldwide efforts to prevent the negative impacts of environmental change globally. Since 2011, many governments worldwide have developed plans for dealing with global warming and its environmental impact at the national level, addressing it, and mitigating its adverse effects under the UN Framework Convention on Climate Change (UNFCCC, 2012). However, because these plans were prepared at a local level, they were not unified and did not show coordination between countries, which may question their effectiveness in combating global warming and CO_2 emissions (Rogelj et al., 2016). To enhance cooperation to combat global warming and CO_2 emissions, as well as raise awareness about the world's environmental risks, the Paris Agreement was signed on April 2016. All parties to the Paris Agreement committed to strengthening the global response to climate change by increasing the ability of all to adapt, build resilience, and reduce vulnerability (Atkinson et al. 2019). Reducing CO_2 emissions is contingent on the willingness of the leading CO_2-producing countries to achieve global emissions reduction (Tamazian et al., 2009). In general, the commitment of big polluters, especially the Group of Twenty countries, which are considered the most significantly responsible for global warming (Bicer, 2021), and the effectiveness of energy use are crucial for the success of efforts to reduce global CO_2 emissions (Paramati et al., 2017).

There is broad scientific consensus that human activities, economic activity, technological advancements, and the development of political and financial institutions are to be blamed for the exponential increase in CO_2 emissions around the world (Barrera-Santana et al., 2022; Marrero et al., 2021; Yao et al., 2015). The G20 countries represent the greatest economies worldwide and have a significant effect on the global greenhouse effect by being responsible for about 80% of the world's CO_2 emissions (Bicer, 2021). Figure 1.1 shows the leading CO_2-producing countries and their contributions to global emissions.

Figure 1.1: *The Main Producers of CO_2 in Metric Tons*



Source: Destatis (2022)

The G20 is the largest economic grouping around the world, representing 85% of the global gross domestic product (GDP) and contributing to 75% of international trade. It is also the most prominent economic group that emits CO_2. Nevertheless, because of their extensive impact on the entire world through TEC, business, industry, and development funding, G20 nations are well positioned to lead global efforts to mitigate and decrease the negative impact on the environment through implementing comprehensive fiscal and structural reforms while taking effective climate action (Atkinson et al., 2019).

This paper studies the relationship between CO_2 emissions and four main variables: GDP, innovation, FDV, and fiscal policy. This paper aims to (1) verify the validity of the Environmental Kuznets Curve hypothesis in the G20 countries during 1995–2019 (hence, the GDP square was introduced to infer the existence of the inverted U-shape) and (2) investigate the impact of the fiscal policy on CO_2 emissions in the G20. Therefore, two models were used: fiscal policy was introduced in the second model. This study was motivated by the literature and previous studies' shortage regarding the impact of fiscal policy on CO_2 emissions, especially in the G20 countries. The importance of the study arises from shedding light on the validity of the Environmental Kuznets Curve hypothesis in the G20 countries and the investigation of the critical role that fiscal policy plays in influencing CO_2 emissions.

The study applied the Westerlund (2007) test to examine the long-run relationship between the variables, using the panel autoregressive distributed lag with two estimators: Pooled mean group (PMG) and mean group (MG). The Hausman (1978) test was applied to choose the appropriate estimator. The interest in the long-term relationship between study variables and CO_2 emissions arises from the fact that government strategies and policies to combat climate change cannot reduce CO_2 in short periods (Shahnazi & Shabani, 2021).

1.2. Literature Review

The relationship between financial and economic variables and CO_2 emissions has attracted many scholars, organizations, and governments worldwide. Researchers sought to study the various effects of these variables to clarify the nature and direction of the relationship and try to provide solutions that may contribute to mitigating CO_2 emissions (Ziaei, 2015). Regarding the G20, Yao et al. (2015) aimed to identify the main factors influencing CO_2 emissions. The research findings indicated substantial variations in the driving forces of CO_2 emissions between advanced and emerging economies within the G20 group. Overall, economic expansion emerged as the primary driver of CO_2 emissions across the G20 nations. Particularly, the impact of emerging economies on the increase in CO_2 emissions was most significant. However, in most industrialized countries and certain emerging economies, the rise in emissions attributed to population growth was partially mitigated by enhanced energy efficiency and reduced carbon intensity. In contrast, other G20 nations, such as France, Brazil, Mexico, South Africa, and Saudi Arabia, observed a growing energy intensity, which contributed to an escalation in CO_2 emissions. Next, the study briefly explores the relationship between the study's variables and CO_2 according to the study hypothesis.

1.2.1. The relationship between Economic development and carbon dioxide.

Environmental degradation and the high rate of CO_2 emissions are a matter of concern globally. Therefore, many countries try to develop policies to reduce the rate of CO_2 emissions (UNFCCC, 2012). The relationship between economic growth and CO_2 emissions is complicated. Many factors contribute to the high rate of CO_2, the most important of which is the high rate of production and consumption of individuals and factories, especially in developed countries. This leads to an increase in energy demand and hence is considered one of the main factors of pollution, in addition to the obsolescence of TEC and the lack of development-friendly TEC, especially in developing countries (Blanco et al., 2014). However, the most popular tool that justifies the relationship between economic growth and CO_2 emissions is the EKC hypothesis, which shows that this relationship takes the inverse U-shape (Sarkodie & Strezov, 2019). Based on the EKC, in the early stages of economic growth, the consumption of energy and natural resources increases and thus leads to environmental degradation until this economic boom reaches its peak. At this point, the economy will be able to work more efficiently and make greater use of the available resources. From here begins the second stage, which is based on economic growth with less consumption of resources and, thus, a decrease in environmental degradation (Bae et al., 2017). However, there is no consensus among experts regarding the precise axis of the relationship between economic development and CO_2 emissions. Even though the EKC hypothesis, which holds that the relationship between economic expansion and pollution follows the shape of an inverted U-shape (Kivyiro & Arminen, 2014; Mehmood et al., 2021). Bae et al. (2017) found a positive relationship between economic growth and CO_2. Others found a bidirectional relationship (Shahbaz et al., 2013; Ziaei 2015). Among the important studies that dealt with the relationship between economic development and CO2 emissions in the context of the EKC is a study by Halkos (2003) that aimed to rigorously assess the validity of the EKC hypothesis concerning sulfur emissions and economic development. Specifically, the study investigates the existence of an inverted U-shaped relationship between sulfur emissions and GDP. The research employs panel data from a sample of 73 countries, comprising both OECD and non-OECD nations, spanning the period from 1960 to 1990. The study's findings, based on the implementation of the Generalized Method of Moments (GMM) econometric approach, support the EKC hypothesis, as it is not refuted in this analysis. However, when employing a random coefficients model, no evidence is found to support the existence of an EKC. Regarding the turning points in the sulfur emissions-GDP relationship, they are found to range between \$2805 and \$6230 per capita.

A recent study by An et al. (2021) that examined the implications of climate change and pollution on countries within the Belt and Road Initiative. To investigate these aspects, the study adopted the EKC and pollution haven hypotheses as theoretical frameworks. The research encompasses data from Belt and Road host countries spanning the period from 2003 to 2018. The study findings reveal that the relationship between economic growth and CO_2 emissions is contingent upon the emission levels, demonstrating variability at different emission thresholds. Specifically, an inverted U-shaped relationship between economic development and CO_2 emissions, as posited by the EKC theory, is observed solely in nations with lower to medium emission levels. Furthermore, the research provides evidence supporting the pollution haven theory, as it indicates that Chinese outbound foreign direct investment (FDI) flows contribute to an increase in carbon emissions in countries characterized by medium to high emission levels. Furthermore, Suki et al. (2020) explored the existence of the Environmental Kuznets Curve in Malaysia by examining the impact of globalization on the country's ecological footprint. Their analysis revealed evidence of a significant long-run association between globalization and environmental degradation. The study highlighted the importance of focusing on social and political globalization for sustainable environmental outcomes in Malaysia.

In regard to economic development and CO_2 emissions, Halkos (2013) examines the relationship between economic progress and environmental degradation using panel data spanning 97 countries from the years 1950 to 2003. The first sample comprises panel data specifically from European union member states (EU), while the second sample includes panel data from both EU and non-EU countries. The study uncovers notable cross-country heterogeneity in the estimated slopes for the entire sample of EU and non-EU nations. This variability in the results indicates highly diverse characteristics that make aggregation impractical. However, contrasting findings emerge when focusing solely on the sample of EU nations. In this context, the association between economic development and environmental degradation appears to be more consistent and less subject to significant variations. Recently, Adebayo and Acheampong (2022) conducted a study to better understand the variables influencing carbon emissions within the context of sustainable development strategies targeted at reaching net-zero emissions in Australia. They used QQ technique to investigate the effects of economic globalization on carbon emissions in Australia from 1970 to 2018. Using the QQ technique, the results revealed a significant positive association between economic globalization and carbon emissions at all quantiles. Additionally, the majority of quantiles demonstrated a positive relationship between economic growth and carbon emissions. Furthermore, the analysis highlighted a positive correlation between carbon emissions and coal consumption at all quantiles, indicating a clear influence of coal consumption on carbon emissions.

1.2.2. The relationship between Fiscal policy and CO_2 emissions.

The fiscal policy is considered one of the main components of the macroeconomy. It plays a significant role in all economic aspects since government spending and taxes are the primary tools of fiscal policy and therefore play a significant role in consumption and production. This applies to not only energy but also all economic activities, which makes the fiscal policy a key player in influencing CO_2 emissions and environmental degradation (Katircioglu & Katircioglu, 2018). Governments can achieve economic expansion by controlling the tools of the fiscal policy, especially spending, which can be directed to environmentally friendly economic activities and businesses (Halkos & Paizanos, 2016; Shakeel, 2021a, 2021b). The government might also control environmental degradation through taxes, and it might impose environmental taxes to increase the share of environmentally friendly products in the market (Shahnazi & Shabani, 2021; Wu et al. 2022). To combat climate change, based on what was adopted in the Paris Agreement, there was an urgent need to take government policies that would reduce CO_2 emissions. One suggestion is to issue new tax policies towards economic activities to control environmental degradation and pollution. The new government policies are not limited to the imposition of environmental taxes but may also include tax exemptions for environmental products in a way that encourages institutions and individuals to rely on renewable energy (Dumrul & Kılıçarslan, 2017; Shahbaz et al., 2019).

Despite the few studies that dealt with the relationship between fiscal policy and CO_2 emissions, they all agreed that fiscal policy negatively affects CO_2 emissions, and therefore its tools, whether taxes or government spending, can be used to reduce environmental degradation and climate change (Frenkel et al., 1996; Ike et al., 2020; Katircioglu & Katircioglu, 2018; Yilanci & Pata, 2022). In this regard Halkos & Paizanos (2016) conducted a comprehensive examination of the influence of fiscal policy on CO_2 emissions in the United States. The study's primary objective is to gain insights into the short- and medium-term interrelations between fiscal policy and emissions under various scenarios. To investigate the impact of fiscal policy on CO_2 emissions, the researchers employ Vector Autoregressions analysis on quarterly data spanning from 1973 to 2013 in the United States. The research findings reveal that the implementation of expansionary fiscal expenditure leads to a reduction in CO_2 emissions from both production and consumption sources. On the other hand, when deficit-financed tax cuts are implemented, they are associated with an increase in CO_2 emissions stemming from consumption.

1.2.3. The relationship between TEC and CO_2 emissions.

Technological innovation can be evident in the development of new technologies. It usually takes one of two forms: the development of new TEC or the creative application of existing TEC. It is regarded as a vital solution to environmental difficulties and long-term growth, particularly if oriented to address environmental degradation concerns. According to the endogenous theory of economic growth, advancement in technical innovation may improve economic production and resource use efficiency, reducing waste resources and CO_2 emissions (Y. Chen & Lee, 2020). However, some researchers still question the feasibility of innovation and technological progress in improving the quality of the environment. They believe that TEC has a negative impact on the environment, claiming that TEC can increase the effectiveness of resource usage, but their marginal impact is waning, and a fast-expanding economic scale may nevertheless necessitate increased investment in natural resources rather than TEC (Newell, 2009). The debate about the effects of TEC encourages scholars worldwide to examine the role of technological progress in reducing CO_2 emissions. The majority of scholars found a negative relationship, where TEC mitigates CO_2 emissions and contributes significantly to environmental sustainability and combating climate change (Hashmi & Alam, 2019; Yii & Geetha, 2017). Also, they found that a higher level of TEC in high-income countries can reduce CO_2 in local and neighboring countries (Y. Chen & Lee, 2020) and offset the positive impact of economic growth regarding CO_2 that arises from the large energy consumption and resources in the economic expansion (Cheng et al., 2021). However, some still argue that the impact of technological progress and innovation on environmental quality, particularly CO_2 emissions, is still not clear and needs further investigation (Cheng et al., 2019). There are many studies that have looked at the relationship between TEC and carbon emissions. For example, Hashmi and Alam (2019) conducted an empirical study to explore the impact of environmental legislation and TEC on carbon emission reductions in OECD nations during the period from 1999 to 2014. The research findings reveal that a 1% rise in environmentally favorable patents is associated with a reduction of 0.017% in carbon emissions in the OECD countries. Moreover, the study indicates that a 1% increase in environmental tax income per capita leads to a notable decrease of 0.03% in carbon emissions in the OECD nations. Adebayo et al. (2023) conducted a comprehensive investigation to examine the intricate relationship between TEC, renewable energy consumption, natural resources, and CO_2 emissions in the BRICS countries. The study's primary objective was to assess the extent to which these factors contribute to achieving the goals set out in the Paris Climate Conference regarding CO_2 emission reduction and the promotion of environmental sustainability. The research findings provide compelling evidence that TEC, renewable energy utilization, and the sustainable management of natural resources positively impact environmental sustainability by effectively reducing CO_2 emissions in both the short and long term. Specifically, the study found negative coefficients, ranging from -0.05 to -0.14, indicating that TEC -related activities play a significant role in mitigating CO_2 emissions. Moreover, the interplay between TEC, natural resource rent, and the adoption of renewable energy sources is found to contribute significantly to further reductions in CO_2 emissions and an overall improvement in environmental well-being.

Ali et al. (2023) conducted an investigation into the interplay between industrialization, FDI, TEC, and CO_2 using data from the Kingdom of Saudi Arabia. The study covers the time span from 1991 to 2020. The findings reveal that the impact of urbanization and energy consumption on CO_2 exhibits a growing trend across all quantiles of the data distribution. Conversely, the influence of industrialization, FDI, and technical innovation on CO_2 shows a diminishing pattern in most quantiles. It is noteworthy that the strength of these variables' influence on CO_2 varies across different quantiles of the data distribution.

In their study, Xie et al. (2023) conducted an empirical analysis covering the period from 1990 to 2020 to examine the interconnections between Green

Innovations, exports and imports, Environmental policy stringency, and Consumption-based CO_2 emissions. The findings demonstrate that stringent environmental regulations positively influence the adoption and advantages of green technologies, thereby encouraging the adoption of environmentally friendly practices. However, the research also highlights the negative impact of imports on environmental quality.

1.2.4. The relationship between FDV and CO_2 emissions.

The role of FDV in combating CO_2 emissions is not always clear, and the results of the studies can differ according to whether it is a developing or developed country, especially since no specific variable has been agreed upon that represents FDV. Yet the majority of the previous studies showed that FDV reduces CO_2 emissions, as the relationship is negative in the long run; the higher level of FDV is considered the engine that leads to a decrease in CO_2 emissions (Shahnazi & Shabani, 2021; Tamazian et al., 2009; Zhao & Yang, 2020) through the adoption of environmentally friendly financial TEC. Also, the developed financial system contributes to attracting FDI and thus the development of the economic system, which contributes to improving the quality of the environment (Frankel & Romer, 1999). In addition, the development of the financial system may increase the ability of the banking system to support environmental projects locally through environmental activities adopted by the government or private institutions to support and protect the environment (Claessens & Feijen, 2007). Other studies found no significant effect of FDV on CO_2 (Salahuddin et al., 2018; Ziaei 2015). Generally, scholars have paid close attention to the impact of FDV on CO_2 emissions, as well as their mutually inextricable relationship, considering the importance of FDV in sustainability and energy efficiency. The majority see FDV as a driving force behind the advancement of energy-efficient or environmentally friendly TEC. As a result, pollutants in the environment, such as CO_2, will be reduced (B. Zhao & Yang, 2020). Researchers have not reached a consensus on the precise form of the relationship between economic variables and carbon emissions. The outcomes often vary depending on the study sample and the methodology employed. In this context, Table 1.1 provides a comprehensive summary of previous studies and their respective results.

Table 1.1: *Summary of previous studies*

Authors	Region	Period	Method	Result
Economic growth				
Shahbaz et al. (2013)	Indonesia	1975–2011	VECM	Bidirectional causality
Kivyiro and Arminen (2014)	Sub-Saharan countries	1971–2009	PMG	Inverted U-shape
Ziaei (2015)	Worldwide	1989–2011	PVAR	Bidirectional causality
Bae et al. (2017)	Post-Soviet Union	2000–2011	GMM	Positive relationship
Mehmood et al. (2021)	Pakistan, India, and Bangladesh	1996–2016	PMG	Inverted U-shape
Fiscal policy				
Halkos and Paizanos (2016)	USA	1973–2013	VECM	Negative relationship
Katircioglu and Katircioglu (2018)	Turkey	1960–2013	ARDL	Negative relationship
Yuelan et al. (2019)	China	1980–2016	VECM	Negative relationship
Ike et al. (2020)	Thailand	1972–2014	Causality test	Negative relationship
Yilanci and Pata (2022)	G-7	1875–2016	Frequency domain causality test	Negative relationship
Technology				
Yii and Geetha (2017)	Malaysia	1971–2013	VECM	Negative relationship
Cheng et al. (2019)	OECD countries	1996–2015	PQR	No significant effect
Hashmi and Alam (2019)	OECD countries	1999–2014	Static panel model and GMM	Negative relationship
Y. Chen and Lee (2020)	96 countries	1996–2008	Spatial dynamic panel model	Negative relationship

Table 1.1 (Continued).

Cheng et al. (2021)	OECD countries	1996–2015	PQR	Negative relationship
Financial development				
Tamazian et al. (2009)	BRIC countries	1992–2004	Random effect	Negative relationship
Shahbaz et al. (2013)	Indonesia	1975–2011	ARDL, VECM	Negative relationship
Ziaei (2015)	EU and East Asia	1989–2011	PMG	No significant effect
Salahuddin et al. (2018)	Kuwait	1980–2013	ARDL, VECM	No significant effect
Zhao and Yang (2020)	China	2001–2015	Static panel model	Negative relationship

PVAR stand for Panel Vector Autoregressive, PQR stand for panel quantile regression, VECM stands to vector error correction model.

1.2.5. Hypotheses of the study

Based on the literature, the study tests the following hypotheses:

- Hypothesis 1: The relationship between Economic development and CO_2 emissions takes an inverted U-shape.
- Hypothesis 2: Fiscal policy is negatively related to CO_2 emissions.
- Hypothesis 3: Technology is negatively related to CO_2 emissions.
- Hypothesis 4: Financial development is negatively related to CO_2 emissions.

1.3. Data and Methodology

1.3.1. The Data

This study employs annual data for the period from 1995 to 2019 for G20 countries which include Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, the Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, and the United States. The descriptions of the variables and their sources are listed in Table 1.2.

Table 1.2: *Descriptions and source of the variables*

The variables	Definitions	Sources
Dependent variable		
CO_2	Carbon dioxide	WDI
Independent variables		
GDP	The output of a country in a year.	WDI
Technology	Total patent applications	WDI
Financial development	The degree of development of financial institutions and markets; this indicator considers the development of both the financial institution and financial market.	IMF
Government spending	Government expenditure in a given year as a percentage of GDP.	WDI
Tax revenue	compulsory transfers to the central government for public purposes as a percentage of GDP	WDI

WDI and IMF represent world development indicators and international monetary fund respectively.

The natural logarithm was taken for the variables of the study, specifically CO_2, GDP, TEC, and FDV. The fiscal policy (FSP) was constructed from government spending and tax burden by using principal component analysis. The main function of the model can be written as follows:

$$Co2 = f(GDP, TEC, FDV, FSP)$$

The main function of the model in the constant of EKC can be generalized to a simple panel model as follows:

$$CO2_{it} = a_0 + \beta_1 GDP_{it} + \beta_2 GDPS_{it} + \beta_3 TEC_{it} + \beta_4 FDV_{it} + \varepsilon_{it}$$
$$CO2_{it} = a_0 + \beta_1 GDP_{it} + \beta_2 GDPS_{it} + \beta_3 TEC_{it} + \beta_4 FDV_{it} + \beta_5 FSP_{it} + \varepsilon_{it}$$

CO2 refers to the dependent variable, CO_2 emissions, i stands for the cross-sectional unit, t refers to the time, a_0 is a constant, $\beta_1, \beta_2, and\ \beta_3$ represent the linear parameter of GDP, GDPS represents the squared term of GDP, TEC stands for technology, FDV is financial development, and FSP_{it} is a vector representing the fiscal policy, containing the government expenditure and tax burden, and ε represents the error term.

1.3.2. The Methodology

1.3.2.1. Principle Component Analysis (PCA)

PCA is a common dimensionality reduction technique that enables us to reduce variance in a set of variables into a fewer number of factors. The objective of PCA identifies components $Y = [Y_1, Y_2, \dots, Y_p]$; that is, a linear combination $e = [e_1, e_2, \dots, e_p]'$ of the main series $x = [x_1, x_2, \dots, x_p]$. The purpose of this technique is to re-orient the information from a large set of variables to a few numbers of factors or components that catch the majority of information in the original set (F. Wang, 2009). In addition to reducing a large set of data to a small number of factors, PCA has another advantage. It can be used in the case of existing collinearity between the predictor variables that it will account for. It takes the important information from these correlated variables and combines it into fewer numbers of variables (Brooks, 2019).

1.3.2.2. Unit root test

To test the stationary variables, the study used the Maddala and Wu (1999) test, known as the MW test, and the Pesaran (2007) test, known as the CIPS test. Maddala and Wu (1999) discussed the different panel unit root tests, such as LL and IPS tests. They argued that these tests are not efficient and lack power. They suggested a new unit root test based on the principle of Fisher. The suggested test permits the heterogeneity in the panels and can be written as follows:

$$P_{MW} = -2\sum_{i=1}^{N} log\,\pi_i$$

Pesaran (2007) introduced a new panel data unit root test. It can be seen as a modified version of the IPS test. The suggested test is based on Dickey-Fuller regression and permits heterogeneity and allows the existence of an unobserved common factor while considering the serial correlation. It is possible to calculate it as follows:

$$CIPS = \frac{1}{N}\sum_{i=1}^{N} t_i(N,T)$$

1.3.2.3. Panel ARDL model.

Since we are not interested in testing the EKC hypothesis that has been previously tested and proven (Kivyiro & Arminen, 2014; Mehmood et al., 2021), we follow the literature by adopting a linear model for the relationship between economic development and CO_2 (Bae et al., 2017). Selecting a specific model to analyze the data, whether a dynamic or static model, is usually based on the unit root test result. In case the variables are mixed or integrated, we cannot use the static panel model because it will generate spurious regression; instead, the dynamic model will be favorable (Brooks, 2019). It is common in economics and finance that most observations are not integrated at I (0), so in case of the study variables are mixed or integrated, then the panel ARDL is appropriate to analyze the model. The ARDL model was introduced by Pesaran et al. (1999), and Pesaran and Smith (1995). Although the ARDL approach's restriction on only one level-relationship among the variables under examination and does not allow for more long-term relationships, the ARDL method can be used to test the cointegration in a one equation model at different spans, long run and short run, by utilizing two estimators to analyze the data: PMG and MG. The PMG estimator permits heterogeneous dynamic panels, while the MG estimator allows for slope and disturbance terms to differ across countries (Blackburne & Frank, 2007). The model of panel ARDL(p,q,q,…,q) based on (Pesaran et al., 1999; Pesaran & Smith, 1995) can be written as follows:

$$\Delta CO2_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij} \Delta CO2_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il} \Delta GDP_{i,t-1} + \sum_{r=0}^{n-1} \varphi_{il} \Delta GDPS_{i,t-1} + \sum_{v=0}^{p-1} \gamma_{ir} \Delta TEC_{i,t-r} + \sum_{w=0}^{s-1} \theta_{iu} \Delta FDV_{i,t-u} + \sigma_1 CO2_{i,t-1} + \sigma_2 GDP_{i,t-1} + \sigma_3 GDPS_{i,t-1} + \sigma_4 TEC_{i,t-1} + \sigma_5 FDV_{i,t-1} + \varepsilon_{i,t}$$

$$\Delta CO2_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij} \Delta CO2_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il} \Delta GDP_{i,t-1} + \sum_{r=0}^{n-1} \varphi_{il} \Delta GDPS_{i,t-1} + \sum_{v=0}^{p-1} \gamma_{ir} \Delta TEC_{i,t-r} + \sum_{u=0}^{s-1} \theta_{iu} \Delta FDV_{i,t-u} + \sum_{w=0}^{v-1} \delta_{iw} \Delta FSP_{i,t-w} + \sigma_1 CO2_{i,t-1} + \sigma_2 GDP_{i,t-1} + \sigma_3 GDP_{i,t-1} + \sigma_4 TEC_{i,t-1} + \sigma_5 FDV_{i,t-1} + \sigma_6 FSP_{i,t-1} + \varepsilon_{i,t}$$

Where, $\mathrm{CO2}_{\mathrm{it}}$ is the dependent variable at time t for i unit, a is a constant to the units, GDP, GDPS, TEC, FDV, and FSP are the dependent variables, $\beta_{\mathrm{ij}}, \phi_{\mathrm{il}}, \gamma_{\mathrm{ir}}, \theta_{\mathrm{iu}}, \delta_{\mathrm{iw}}$, and ρ_{iz} stand for the short-run parameters, $\varepsilon_{\mathrm{I,t}}$ is the identical disturbance term for the model, and β stands for the error correction model (ETC); it has to be significantly negative and less than one to infer the existing long-run relationship and conclude that the variables are cointegrated. The first model does not contain the financial policy variable, as it was included in the second equation to show the difference in the results of the two models before and after the introduction of the fiscal policy.

1.3.2.4. Cointegration test

Based on the suggested methodology by Menegaki (2019), estimating the panel ARDL model usually needs a robustness test after estimating the panel ARDL. The study uses the error-correction–based cointegration tests for panel data suggested by Westerlund (2007); this cointegration test presents coherent results even in case of presence heterogeneity and cross-sectional dependence. The error correction model can be written as follows:

$$\Delta y_{it} = \delta_i' d_t + \alpha_i \left(y_{i,t-1} - \beta_i' x_{i,t-1} \right) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{i,t-j} + \sum_{j=-q_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + e_{it}$$

Where, it stands for cross-sectional countries and time series, respectively, y refers to the dependent variable, x is the independent variable, j, p are the lagged period, α_i denotes the speed of adjustment, d_t is the deterministic component, and e_{it} is the error term.

1.4. Empirical Result

1.4.1. PCA

The best variable that can express fiscal policy is the combination of fiscal policy tools, government spending, and taxes. To obtain all the vital information embedded in these tools, the study used PCA, which enables the collection of critical information from the fiscal policy variables into a single composite variable, rather than using separate variables for government spending and taxes. The results of PCA are presented in Table 1.3.

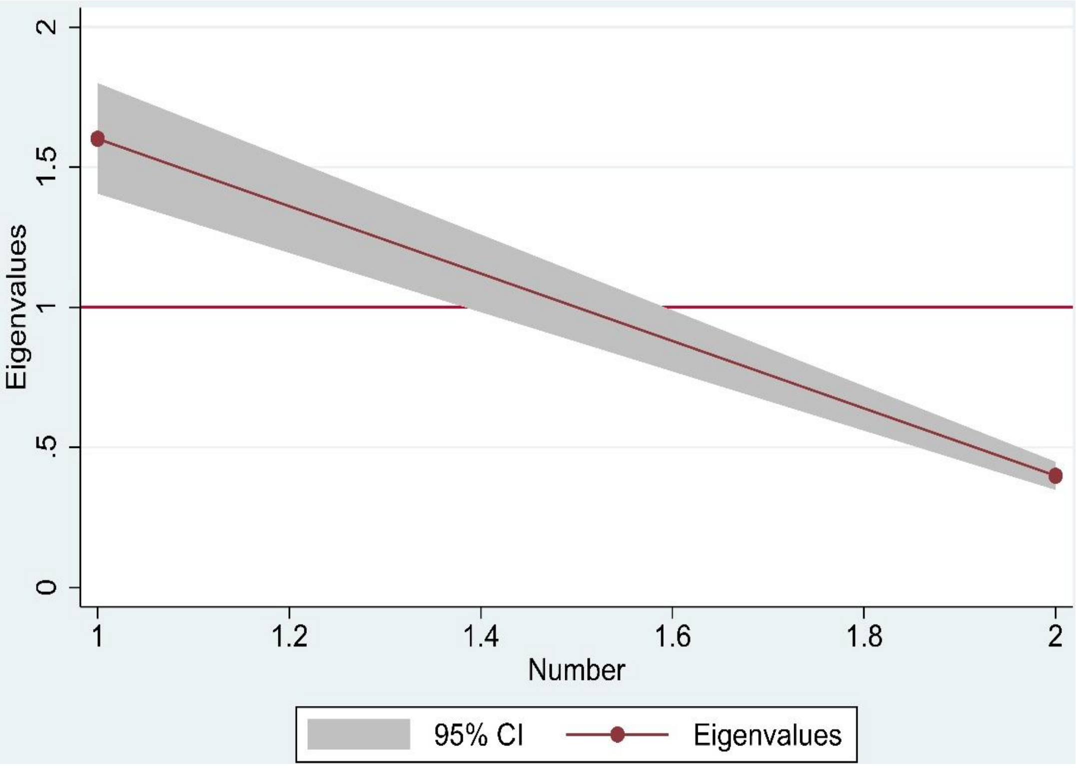
Table 1.3: *Principal component analysis*

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.601	1.202	0.801	0.801
Comp2	0.398	.	0.199	1

Comp1 and Comp2 represent the component factors extracted using PCA.

As evident from Table 1.3, the new factor exhibits a variance of 1.60 and accounts for approximately 80% of the total variance. Referring to the second column of the same table, we can reduce the two variables into one factor, given that the eigenvalue of the first component is greater than 1. The criterion for selecting the number of reduced factors is whether they are above the threshold of one or not. Figure 1.2 provides evidence supporting the selection of one factor in the FSP case.

Figure 1.2: *PCA- loading factor*



The shadow area represents the confidence interval.

1.4.2. Unit Root Test

Table 1.4 presents the result of the unit root test based on the Pesaran (2007) and Maddala and Wu (1999) tests, the null hypothesis for MW and CIPS tests is that the series are integrated at first order I(1). Table 1.4 shows that it cannot reject the null hypothesis for CO_2 based on CIPS and MW tests, meaning that alternative hypothesis is accepted, that CO_2 is integrated in the first order for both tests. At the same time, for GDP, the conflict between the results of the CIPS and MW tests is apparent. Based on the CIPS test, the study rejects the null hypothesis in both cases of the constant and the constant with the trend for TEC. In contrast, the null hypothesis is accepted based on the MW test.

Table 1.4: *The Results of the Unit Root Test*

Variables/Tests	CIPS		MW	
	Constant	Constant with trend	Constant	Constant with trend
CO_2	0.348	0.714	10.436	47.559
	(0.636)	(0.763)	(1.000)	(0.138)
GDP	-3.255	-1.786	23.176	15.186
	(0.001)	(0.037)	(0.972)	(0.999)
TEC	-0.870	-1.406	101.592	86.344
	(0.192)	(0.080)	(0.000)	(0.000)
FDV	-4.194	-3.660	189.988	104.424
	(0.000)	(0.000)	(0.000)	(0.000)
FSP	-2.927	-2.487	80.241	62.437
	(0.003)	(0.006)	(0.000)	(0.007)

The *P*-value is in parentheses.

Regarding FDV and FSP, the null hypothesis is accepted by the CIPS and MW tests at the significance level of 5%. Since the variables are mixed stationary and integrated at level I(0) and first order I(1), the most appropriate method to test the models is the Panel ARDL approach.

1.4.3. Cointegration test

The study adopts the Westerlund (2007) test to examine the long-run relationship between the explained and explanatory variables. The Westerlund (2007) test can produce credible results even in cases of cross-sectional dependency and heterogeneity. The Westerlund test offers four statistical measures: Gt and Ga, used to ascertain the presence of cointegration within individual panels, and Pt and Pa, employed to evaluate cointegration across the entire panel. Based on the results of Westerlund (2007) presented in Table 1.5, the null hypothesis, stating that no cointegration exists for all variables, is not rejected at a significance level of less than 1%. This provides evidence that the variables cointegrate in the long run.

Table 1.5: *Westerlund Cointegration Results*

Cointegration	**Gt**	**Ga**	**Pt**	**Pa**
GDP	-4.408 (0.000)	-20.843 (0.000)	-11.153 (0.000)	-13.353 (0.000)
TEC	-3.868 (0.000)	-20.749 (0.000)	-10.753 (0.000)	-13560 (0.001)
FDV	-3.768 (0.000)	-20.049 (0.000)	-9.435 (0.396)	-13.455 (0.001)
FSP	-4.010 (0.000)	-22.09 (0.000)	-10.16 (0.000)	-16.782 (0.000)

The p-value is indicated in parentheses. Gt and Ga assess the presence of cointegration within each group, while Pt and Pa assess cointegration across the entire panel.

1.4.4. The Panel ARDL model

The study employs two estimators to address the relationship between CO_2 and GDP: Technology, financial development, and fiscal policy. Table 1.6 shows the estimation of the first model and the second model using MG, and MPG. The study utilizes Hausman (1978) to determine the appropriate estimator of panel ARDL.

Results of the First Model. The initial model comprises four explanatory variables, namely GDP, GDP square, Technology, and financial development. As shown in Table 1.6, the error correction model (ECT) is both significant and negative, indicating that the variables in the model are cointegrated in the long run. Hausman (1978) test for the first model failed to reject the null hypotheses that PMG the is a more efficient estimation than MG. Regarding the signs of the variables, GDP exhibits a positive sign, while GDP square has a negative sign. This observation aligns with the EKC hypothesis, which posits that economic expansion leads to increased CO_2 production due to energy-intensive economic and production activities. As a result, the relationship between economic growth and CO_2 production follows an inverted U-shape pattern (Bae et al., 2017). However, the EKC hypothesis, which demonstrates an inverted U-shape relationship, serves as the most widely used framework supporting the link between economic growth and CO_2 emissions (Sarkodie & Strezov, 2019). According to the EKC, during the early stages of economic growth, energy and natural resource consumption increases, leading to environmental degradation until the peak of this economic boom is reached. At this juncture, the economy becomes more efficient, utilizing available resources more effectively. Subsequently, the second stage ensues, characterized by continued economic growth with reduced resource consumption and a consequent decrease in environmental degradation (Bae et al., 2017). The findings of the first model are in line with the EKC hypothesis, which suggests an inverted U-shaped relationship between economic growth and CO_2 emissions during the early stages of economic expansion. However, it should be noted that, in the first model, all model parameters are deemed insignificant, possibly due to the absence of a leading variable. Consequently, in the second model, we introduced fiscal policy as an additional factor to examine whether the model parameters would attain significance and to gain insights into the impact of fiscal policy on CO_2 emissions.

Table 1.6: *Panel ARDL results*

Variable	First model		Second model	
	MG	PMG	MG	PMG
Long run				
GDP	2.871	1.275	9.356	1.212
	(0.339)	(0.13)	(0.245)	(0.021)
GDPS	-0.504	-0.024	-2.866	-0.0241
	(0.328)	(0.111)	(0.243)	(0.016)
TEC	-0.340	-0.024	0.545	-0.016
	(0.147)	(0.019)	(0.232)	(0.000)
FDV	-0.675	-0.606	-2.264	-0.276
	(0.211)	(0.000)	(0.159)	(0.000)
FSP			0.821	0.095
			(0.365)	(0.000)

Table 1.6 (Continued).

Short run				
GDP	-1.284	10.069	-3.332	11.989
	(0.765)	(0.120)	(0.573)	(0.122)
GDPS	0.027	-0.174	0.055	-0.206
	(0.709)	(0.102)	(0.757)	(0.120)
TEC	-0.271	0.027	0.016	0.032
	(0.428)	(0.098)	(0.787)	(0.086)
FDV	0.377	0.1130	-0.137	0.115
	(0.339)	(0.207)	(0.460)	(0.124)
FSP			0.014	0.005
			(0.405)	(0.574)
ECT	-0.801	-0.126	-0.463	-0.208
	(0.002)	(0.000)	(0.000)	(0.005)
Constant	-57.306 (0.486)	-2.161	-15.485	-3.306
		(0.000)	(0.841)	(0.005)
Hausman		0.242		0.369
Turning point		8.086		

The *P* value is in parentheses.

Results of the Second Model. The second model includes an additional variable, fiscal policy, to investigate its impact on CO_2 emissions under the framework of the EKC hypothesis. The Hausman (1978) test did not reject the null hypotheses, indicating that the long-run homogeneity restriction is supported against the alternative hypothesis. Consequently, the PMG estimator is deemed more efficient than MG. Thus, the appropriate estimator for this model is the PMG estimator. The error correction model for the two estimators of the second model is negative, less than one, and statically significant. Hence, there is a long-run cointegration between the explanatory and explained variables. Regarding the PMG estimator in the second model, we notice that the ECT value is about -20.8%, which means that the error in the short run is corrected by 20.8% in the long run. Comparing the results of the first and second models, as shown in Table 1.6, we can note that the variables became statistically significant after introducing the fiscal policy variable into the model. Concerning the impact of GDP and GDP square on CO_2 emissions, we notice that the sign of GDP is positive, and GDP square is negative, and both are statically significant in the long run, which means that the model is consistent with the EKC hypothesis.

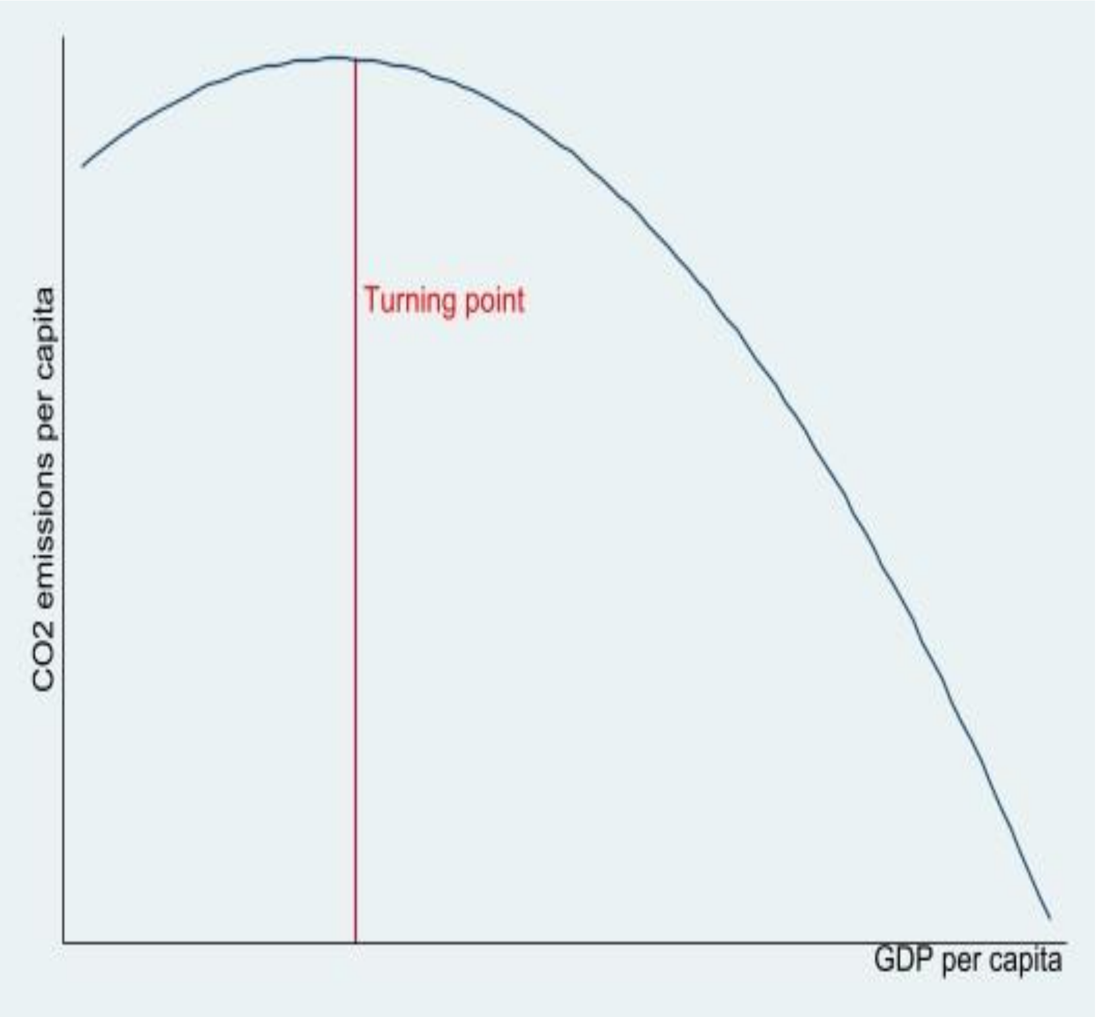
1.4.5. Hypothesis results

Hypothesis 1. The relationship between Economic development and CO_2 emissions follows an inverted U-shape pattern. This observation aligns with previous studies by Kivyiro and Arminen (2014) and Mehmood et al. (2021), both of which reported a similar inverted U-shape relationship between economic development and CO_2 emissions. During economic expansions, the quantities of carbon released increase due to the heightened demand for energy to sustain economic growth. As a result, the effect of GDP on CO_2 emissions is positive. This phase involves significant energy consumption in activities such as raw material extraction, industrial production, and other energy-intensive processes. Subsequently, as economic growth reaches maturity, a negative impact on CO_2 emissions emerges. This occurs as the country invests in and develops environmentally friendly technologies, including renewable energy sources. As a consequence, the effect of GDP square on CO_2 emissions becomes negative (Bae et al., 2017).

Hypothesis 2. Fiscal policy contributes to the reduction of CO_2 emissions. The findings regarding the impact of fiscal policy on CO_2 emissions indicate a statistically significant and positive relationship, suggesting that the implemented fiscal policy in the study sample contributes to the increase in CO_2 emissions. However, examining the existing literature on the relationship between fiscal policy and CO_2 emissions reveals that fiscal policy often plays a role in reducing CO_2 emissions. Several studies (Ike et al., 2020; Katircioglu & Katircioglu, 2018; Yilanci & Pata, 2022; Yuelan et al., 2019) have reported a negative correlation between fiscal policy and carbon emissions. The role of fiscal policy in economic growth can justify the positive relationship between fiscal policy and CO_2 emissions. On the one hand, many scholars contend that fiscal policy significantly boosts economic growth by providing public financing for infrastructure and productive activity (Mitchell, 2005). Considering different energy sources are required for these economic activities (Blanco et al., 2014), which came based on an expansionary fiscal policy, CO_2 increases due to excessive energy use to boost economic growth. On the other hand, reducing taxes may drive up CO_2 emissions associated with consumption (Halkos & Paizanos, 2016).

Hypothesis 3. Technology combats CO_2 emissions. Regarding technology, the result indicates that technology negatively affects CO_2; hence, technological progress leads to decreased CO_2 emissions in the long run. Technology can improve the effectiveness of the raw materials used in production during economic growth (Newell, 2009). This result is consistent with the literature, especially Cheng et al. (2019) in Malaysia and Cheng et al. (2021), and Hashmi & Alam, (2019) in OCED countries. Technology can reduce the positive impact of economic growth on CO_2 emissions derived from large energy consumption and resources (Cheng et al., 2021). Figure 1.3 displays an inverted U-shape, indicating the point at which the impact of economic growth on CO_2 emissions starts to reverse, in accordance with the EKC hypothesis.

Figure 1.3: *The Environmental Kuznets Curve Turning Point*



The red line represents the turning point at which the positive effects of economic development on CO_2 start to shift towards the negative.

Hypothesis 4. FDV is inversely proportional to CO_2 emissions. Finally, the findings of FDV reveal that it has a negative and statistically significant impact on carbon emissions in the long run, which suggests that it helps reduce CO_2. This result is consistent with (Shahnazi & Shabani, 2021; Tamazian et al., 2009; Zhao & Yang, 2020) who consider that FDV is the engine for reducing CO_2 emissions as it contributes to the adoption and financing of environmentally friendly projects. A summary of hypotheses results is presented in Table 1.7.

Table 1.7: *Summary of hypotheses results.*

Hypothesis	Result
The relationship between Economic development and CO_2 takes an inverted U-shape.	✓
Fiscal policy is negatively related to CO_2 *emissions.*	X
Technology is negatively related to CO_2 *emissions.*	✓
Financial development is negatively related to CO_2 *emissions.*	✓

1.5. Conclusion

This paper investigated the impact of fiscal policy economic growth, technology, and financial development on CO_2 emissions in the context of the EKC hypothesis. The study sample consisted of the G20 countries covering the period 1995–2019. The study used two models to investigate the effect of the explanatory variables on the explained one. The fiscal policy was introduced in the second model to examine whether it is consistent with the EKC theory and whether it affects significantly CO_2. The two models were analyzed using the panel ARDL approach using three estimators, MG, PMG, and DEF. The (Hausman, 1978) test was applied to choose the appropriate estimator. The empirical results indicated the presence of cointegration between the variables in the long run following the inclusion of fiscal policy in the second model. Furthermore, the explanatory variables were found to be statistically significant in the second model. The highly significant error correction term in the second model confirms the existence of a stable long-run relationship among the variables.

The findings revealed that the relationship between economic growth and CO_2 emissions follows an inverted U-shape pattern. This observation aligns with the results reported by Kivyiro and Arminen (2014) and Mehmood et al. (2021). During periods of economic expansion, the demand for energy to sustain economic growth leads to a positive relationship between economic growth and CO_2 emissions.

However, as economic growth reaches maturity, a negative impact on CO_2 emissions emerges, attributed to the country's ability to develop and implement environmentally friendly economic activities. In line with previous studies (Ike et al., 2020; Katircioglu & Katircioglu, 2018; Yilanci & Pata, 2022; Yuelan et al., 2019), fiscal policy was found to have a positive effect on CO_2 emissions, which can be justified in the context of its role in economic development. Sound fiscal policies boost economic activity during periods of recession, leading to an increased demand for energy sources to sustain this expansion, potentially resulting in higher CO_2 emissions. Additionally, fiscal policy has been shown to play a crucial role in promoting economic growth during times of prosperity, leading to an increased reliance on the supply of resources, particularly energy sources and raw materials, which are associated with higher CO_2 emissions. The results also demonstrated a negative association between both technology and FDV with CO_2 emissions in the long run, indicating that increases in technology and FDV lead to a decrease in CO_2 emissions. The finding regarding technology aligns with the literature, particularly the studies by Cheng et al. (2021) and Hashmi & Alam (2019), where improved raw material efficiency during economic expansion was attributed to advancements in technology. Likewise, the results related to FDV align with the findings of Shahnazi & Shabani (2021), Tamazian et al. (2009), and Zhao & Yang (2020). This suggests that FDV fosters the adoption and financing of environmentally friendly projects, serving as a catalyst for lowering CO_2 emissions.

1.5.1. Policy implications

- Policymakers should have a clear understanding of the type of relationship between economic development and CO_2 that take an inverted U-shape, which should be included in policy agendas.
- The fiscal policies of the G20 countries should be reviewed and redirected in order to reduce CO_2 emissions.
- Technology and financial development play a significant role in the G20 countries' efforts to cut CO_2 emissions, and the government should promote policies that support environmentally friendly technological innovations.

1.5.2. Policy recommendation

The study findings lead to the following recommendations:

- Closer attention should be paid to technology, especially those that support and adopt eco-friendly sectors that rely on environmentally friendly energy and promote technology that improve resource efficiency.
- Financial growth should be encouraged so that it can offer the required assistance and funding for environmentally friendly initiatives and technology that reduces carbon dioxide.
- The applicable fiscal policy should be reexamined and redirected to assist clean energy projects, and incentives should be offered for initiatives that fight environmental deterioration.

Finally, this study emphasizes the significance of fiscal policy in the G20 countries in the context of the Environmental Kuznets Curve hypothesis. This sets the stage for future research to examine taxes and government spending independently from one another to better understand how each tool's impact may vary. Also, it paves the way to investigate how different sources of CO_2 emissions, including gas and electricity consumption, are affected by fiscal policy so that the effects of financial policies on these sources of CO_2 emissions can be understood and clarified.

CHAPTER 2

Investigating the Causality Between Financial Development and Carbon Emissions: A Quantile-Based Analysis

2.1. Introduction

Policymakers universally acknowledge the inherent importance of financial development (FDV), and substantial efforts are currently underway to promote its advancement in both developed and developing nations. Nevertheless, it is essential to recognize that the extent and magnitude of FDV vary considerably across countries, thereby rendering a universally applicable approach unsuitable for all contexts of FDV (Beck & Levine, 1999).

Due to its numerous contributions, FDV is widely recognized as a vital component of the economy. It plays a critical role in facilitating optimal resource allocation and enhancing the overall efficiency of economic systems. (Levine, 1997). Furthermore, FDV holds considerable potential in promoting financial stability. By bolstering the resilience of financial institutions, FDV safeguards against systemic risks and vulnerabilities within the financial sector. Additionally, it contributes to the refinement of regulatory and supervisory frameworks, enhancing their effectiveness in ensuring the soundness and stability of financial systems (Honohan, 2008). The relationship between FDV and environmental sustainability has garnered increasing attention, as both issues are of paramount importance and have been extensively discussed. Particularly, there is a growing focus on the role of FDV in addressing the escalating challenge of rising CO_2 emissions. Scholars worldwide are actively working towards achieving sustainable development and enhancing environmental quality through various approaches, such as reducing CO_2 emissions, promoting energy transition, and fostering FDV (Adebayo et al., 2023; Ullah et al., 2023). In line with these efforts, the United Nations climate change conference (COP27) was held in Egypt in November of the previous year. The conference formed part of the ongoing global initiatives to mitigate global climate change and combat rising temperatures. The conference aimed to establish innovative strategies and measures, commonly known as "building blocks," that can effectively support the implementation of the Paris Agreement. These actions are intended to propel the world towards a sustainable future characterized by environmental sustainability (Xie et al.,2023).

Several scholars argue that FDV can play a role in promoting long-term environmental sustainability. This is because advancements in the financial system and technology can lead to the adoption of more environmentally friendly practices, which can attract FDI and enhance the overall economic system, thereby improving environmental quality (Mar’I et al. 2023; Shahnazi & Shabani, 2021). Furthermore, FDV can increase the capacity of financial institutions to support local environmental projects through government policies and regulations or private institutions (Salahuddin et al. 2018; Ziaei 2015). The current study aims to examine the power of effect and causal effect relationships between FI development and FM development, as the main components of FD, and CO_2 emissions in five major polluting countries. These countries, namely China, the USA, Russia, Japan, and India, account for more than 60% of the world's total CO_2 emissions (Fominova, 2022). This study holds considerable significance as it examines the causal relationship between FDV and CO_2 emissions in countries with high pollution levels. By providing empirical analysis on the impact of FI and FM on CO_2 emissions, it contributes to a more comprehensive understanding of how FDV can effectively mitigate them. The study employs two econometric methods to achieve the research objectives: (1) The QQ technique is used to assess the transmission of shocks from the independent variables to the dependent variables. In comparison to OLS or quantile regression, the QQ technique offers a more comprehensive modeling of the relationship between the dependent and independent variables. It surpasses quantile regression by examining the impact of different quantiles of FI and FM development on the conditional quantile of CO_2 emissions. This approach provides detailed information about the relationship between these variables and can reveal intricate behavioral patterns (Sim & Zhou, 2015). (2) The nonparametric causality-in-quantiles test enables the examination of causality in the conditional mean and conditional variance, without making any assumptions about the distribution of the data (Balcilar et al. 2016). The utilization of QQ and nonparametric causality analysis techniques enhances the understanding of complex relationships, heterogeneity, asymmetric effects, and nonlinear dynamics between FI, FM development, and CO_2 emissions. These methods contribute to the broader field of time series analysis in assessing sustainability and environmental concerns more comprehensively and accurately.

2.2. Literature Review

In recent years, considerable attention has been given to investigating the correlation between FDV and environmental sustainability, particularly concerning CO_2 emissions. Researchers have undertaken numerous investigations to examine this association and shed light on its implications for sustainable development objectives and climate change mitigation efforts. One notable study by Sharif et al. (2019) explored the connection between energy use, CO_2 emissions, and FDV using panel data from 74 countries spanning the years 1990 to 2015. Their research revealed that while the use of non-renewable energy exacerbates environmental risks, the utilization of FDV and renewable energy helps to alleviate these concerns. Similarly, another study by S. A. R. Khan et al. (2019) examined the relationship between logistics operations and various economic and environmental aspects in Asian emerging economies. Their findings demonstrated positive correlations between logistics operations and per capita income, manufacturing value added, and trade openness. However, logistics operations were found to be negatively associated with social and environmental issues, including climate change, carbon emissions, and pollution.

In the context of China, Wan et al. (2022) focused on investigating the factors influencing sustainable environmental performance. Their research revealed that effective natural resource management, green investment, and the implementation of environmental taxes contribute to enhancing environmental sustainability. However, economic growth remains a challenge in reducing carbon emissions. Moreover, Jian and Afshan (2023) conducted a study on the role of green financing and innovations in achieving carbon balance. Their panel estimations supported the validity of the EKC and suggested that green financing and technologies promote carbon neutrality in both the long and short run, indicating convergence towards a steady-state equilibrium.

2.2.1. FI Development

The relationship between FDV and CO_2 emissions has been extensively studied, with researchers investigating its role in various economic and social contexts, as well as its potential to address environmental degradation and reduce CO_2 emissions. Most of these studies have found a negative correlation between FDV and CO_2 emissions across countries worldwide. For instance, Tamazian et al.

(2009) found a negative link between FDV and CO_2 emissions in Brexit countries. Shahbaz et al., (2013) also observed the same in Indonesia. Additionally, Ziaei (2015) examined 25 countries, reporting a negative relationship between FDV and CO_2 emissions.

Similarly, Zhao & Yang, (2020) found a similar inverse relationship in China. Mar'I et al. (2023) suggest an inverse relationship between CO_2 and FDV in the Group of Twenty. However, the existing literature on the relationship between FDV and CO_2 emissions has largely overlooked the fundamental components of FDV (Habiba et al. 2021). The financial system consists of FI and FM. In developing countries, FI play a more prominent role in the financial system, while in developed countries, FM is the primary driver (Zeqiraj et al. 2020). Therefore, by differentiating between these two components when examining the effects of FDV on CO_2 emissions, this study can comprehensively understand the distinct aspects and dimensions of this relationship, thus enabling more comprehensive research in this field. Only a limited number of studies have specifically discussed the relationship between FI and CO_2 emissions.

Cochran et al. (2014) emphasized the significance of FI in promoting private investment in low-carbon projects and infrastructure. Their research highlighted that five FI located in OECD countries had invested over 100 billion euros in equity and financing towards sustainable transport, energy efficiency, and renewable energy projects from 2010 to 2012. These FI employed various strategies, both conventional and innovative, to connect low-carbon projects with financing, such as expanding capital accessibility, mitigating and distributing risks, enhancing the competence of FM participants, and shaping FM behavior and environments.

Anbumozhi et al. (2020) examined the requirement for changing private investments and developing new financing models to guide Asian economies towards a low-carbon trajectory. They found that a group of investors is actively seeking environmentally friendly opportunities, but achieving sufficient scale necessitates modifying risk reduction measures and investment facilitators. Collaborative initiatives involving banks, regulators, and stakeholders are crucial for establishing shared criteria and improving the ability to finance low-carbon projects. The study outlined prevailing patterns, limitations, and offered recommendations to banks, banking regulators, and institutional investors in ASEAN and East Asia for enhancing their approaches to low-carbon financing.

González & Núñez, (2021) examined the function of the FI in facilitating the transition towards a low-carbon economy. The authors emphasized the importance of financial institutions in directing funds towards environmentally friendly investments and evaluating the financial risks associated with climate change. Although advancements have been made in the development of green financing instruments, such as green bonds, several challenges remain unresolved.

In their study, Habiba et al. (2021) investigated the influence of FM and FI development, renewable energy consumption, and FDI on carbon emissions. The findings of their research indicate that FM development leads to a decrease in carbon emissions in developed nations, whereas it contributes to an increase in carbon emissions in developing nations. Conversely, FI development is found to elevate carbon emissions in developed countries, while it does not exert a significant influence on the economies of developing nations.

2.2.2. FM Development

In relation to the connection between FM development and CO_2, Paramati et al. (2017) conducted a research study aiming to examine the influence of FM growth on CO_2 emissions. Using panel data analysis, the authors established a significant long-term association between these variables. The study's findings indicated that FM growth contributes to a reduction in emissions within developed economies.

In a related study, Paramati et al. (2018) investigated the impact of FM indicators on global CO_2 emissions. The study revealed that advanced nations exert a significant negative influence on carbon emissions, while developing market economies display positive effects. The study suggests that the effectiveness of FM in reducing CO_2 emissions varies considerably between established and developing market nations. Developed economies employ more effective strategies to decrease emissions among listed corporations.

Zafar et al. (2019) investigated the impact of the FM development index on carbon emissions in various countries. Their findings revealed that the relationship between FM development and carbon emissions differs across nations, with some experiencing an increase while others witnessing a decline.

In a study by Li et al. (2020), the researchers investigated the connection between FM growth and CO_2 emissions in 25 OECD nations from 1971 to 2007. The study's outcomes indicated a relationship between FM growth and CO_2 emissions in high-GDP countries. This suggests that these nations have the potential to reduce their CO_2 emissions by promoting FM growth. However, the study observed a positive relationship between FM development and CO_2 emissions in low-GDP countries. This implies that FM growth does not lead to a reduction in CO_2 emissions in these nations.

Chang et al. (2020) utilized data from 18 nations with advanced FM included in the MSCI Global Index spanning from 1971 to 2017. The study utilized the Granger causality test to examine whether stock returns influence CO_2 emissions or vice versa. The empirical findings of the study indicated a unidirectional relationship between FM returns and CO_2 emissions. The regression analysis revealed that a 1% increase in stock returns resulted in a 9% decrease in CO_2 emissions from burning coal, while CO_2 emissions from burning oil increased by 2%.

Furthermore, Alam et al. (2021) examined the relationship between FM growth and CO_2 emissions using data for thirty selected OECD countries spanning the period from 1996 to 2013. The findings indicated that FM growth had a negative impact on CO_2 emissions, suggesting a detrimental effect. However, it was observed that FM growth had a significantly positive influence on the adoption of clean energy. Consequently, the report suggests that governments should prioritize the support of research and development initiatives and the implementation of environmentally friendly policies among listed companies. These measures aim to facilitate the adoption of clean energy and foster the development of low-carbon economies.

Sharma et al. (2021) investigated the effects of FM growth on CO_2 emissions in four South Asian nations from 1990 to 2016. The finding of the study indicates that the growth of the FM led to an increase in CO_2 emissions. However, the analysis of the interaction between FM development, renewable energy, and technical developments revealed negligible coefficients, suggesting that these factors were ineffective in reducing the CO_2 driven by the FM.

Also, Younis et al. (2021) demonstrated that FM negatively affects CO_2 emissions in India, China, Russia, and South Africa, while it has a positive association in Brazil.

2.2.3. Empirical Approaches

QQ and nonparametric causality analysis techniques are essential tools in investigating the relationship between sustainable development and environmental quality in time series analysis. These approaches offer several advantages compared to traditional linear models by capturing nonlinear associations and evaluating heterogeneity across various quantiles of the data. By incorporating QQ and nonparametric causality-in-Quantiles methods, researchers are able to examine the diverse impacts of sustainable development on CO_2 emissions and other sustainability indicators across different quantiles. Additionally, these techniques enable the detection of potential asymmetric effects and offer robustness and flexibility in analyzing intricate relationships (Balcilar et al. 2016; Sim & Zhou, 2015).

The utilization of QQ and nonparametric causality analysis methods contributes significantly to obtaining a comprehensive understanding of sustainability and environmental issues. For instance, Balcilar et al. (2016) investigated the connections between gold returns and returns of other asset classes during economic downturns and periods characterized by heightened uncertainty. The study employed the QQ method and analyzed data at daily, monthly, and quarterly frequencies. The research findings reveal compelling evidence of causation running from various uncertainty metrics to both gold returns and volatility in the daily and monthly data sets. These results indicate that fluctuations and volatility in the price of gold are notably influenced by policy-related uncertainties and uncertainties in the equity market, especially over shorter time spans. However, the evidence of causation diminishes in significance when examining quarterly data, with only specific uncertainty measures exhibiting a significant association with gold volatility. This finding suggests that the influence of uncertainty on gold price fluctuations and volatility becomes less prominent over longer time periods.

Kartal, et al. (2022a) conducted a study that investigated the asymmetric impact of electricity consumption on CO_2 emissions in the United States using Granger Causality-in-Quantiles and QQ Regression techniques. Moreover, Kartal & Depren (2023) examined the asymmetric relationship between global and national factors and domestic food prices through the application of Granger Causality-in-Quantiles and QQ Regression analysis. These studies illustrate the broad range of applications of time series analysis in assessing the interrelationships between different variables within the realm of sustainability and environmental concerns.

Adebayo (2023) examines the trade-off between economic growth and environmental sustainability in China by analyzing the effects of coal consumption and natural resource exploitation using wavelet coherence analysis.

Kartal, et al., (2022b) investigates the influence of renewable and fossil fuel energy consumption on environmental degradation in the USA through the application of Granger Causality-in-Quantiles and QQ Regression methods.

Alola & Adebayo, (2023a) utilize Fourier function approaches to study greenhouse gas emissions from waste management, industrial activities, and agriculture in Iceland, with a specific focus on the utilization of biomass, fossil fuels, and metallic ores.

2.2.4. Gap in the Literature

The existing literature on the relationship between FDV and CO_2 emissions has primarily focused on the overall impact of FD, without adequately considering the components of FDV (Habiba et al., 2021). While several studies have investigated the relationship between FDV and CO_2 emissions, there remains a notable gap in understanding the specific contributions of FI and FM to this relationship, particularly in the context of the five primary polluting countries: China, the USA, Russia, Japan, and India. Understanding the role of FI and FM in these countries is crucial due to their significant production of carbon emissions and contribution to global warming. Thus, a comprehensive understanding of the relationship between FDV and CO_2 emissions in these countries is essential. Therefore, more research is required to examine the precise relationship between FI and CO_2 emissions, as well as the impacts of FM on CO_2 emissions. Finally, the methodologies used in the analysis differ according to the variables and objectives of the study. Table 2.1 presents a summary of previous studies in this context, along with the methodologies used, the study sample, and the results that have been found.

Table 2.1: *Summary of previous studies*

Authors	Region	Period	Method	Result
Paramati et al. (2017)	G20	1991-2012	VECM	Negative relationship
Paramati et al. (2018)	Worldwide	1990-2011	CCE	Negative relationship
Sharif et al. (2019)	Worldwide	1990-2015	FMOLS	Negative relationship
Zafar et al. (2019)	G-7 and N-11	1990-2016	Bootstrap panel Cointegration	Differs across countries
Chang et al. (2020)	Worldwide	1971-2017	Granger causality test	Negative relationship
Li et al. (2020)	OCED	1971-2007	panel threshold regression	Differs across countries
Alam et al. (2021)	OCED	1996-2013	CCE	Negative relationship
Sharma et al. (2021)	South Asia	1990-2016	CS-ARDL	Neutral
Younis et al. (2021)	BRICS	1993-2018	GMM	Differs across countries
Mar'I et al. (2023)	G20	1995-2019	Panel ARDL	Negative relationship

CCE stands for Common Correlated Effects, CS-ARDL stands for Cross-Sectional Augmented Distributed Lag, and FMOLS stands for Fully Modified Ordinary Least Squares.

2.2.5. Hypotheses of the study

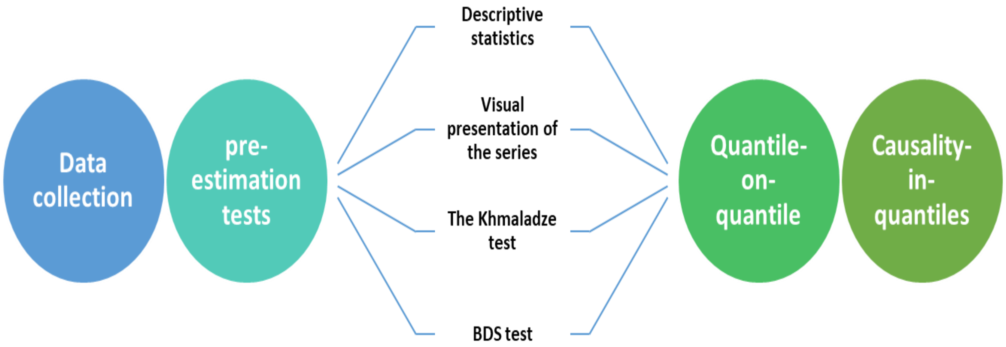
Building on the preceding information, the study examines the following hypotheses:

- Hypothesis 1: The impact of financial institution development on CO_2 emissions is asymmetric.
- Hypothesis 2: The influence of financial market development on CO_2 emissions is asymmetric.

2.3. Data Description and Methodology

Specific steps were followed in analyzing this study, starting from data collection and processing to obtaining results, in order to ensure the acquisition of robust findings. Figure 2.1 provides a visual representation of these steps.

Figure 2.1: *Study Procedures*



2.3.1. *Data Description*

The data used in this research relates to the primary polluting countries in the world, namely, China, the USA, Russia, Japan, and India, and covers the period from 1990 to 2019. In order to achieve the objective of this research, three variables were utilized, namely, CO_2, which was sourced from the WDI, and FI development and FM development, which were obtained from the IMF. The FI and FM variables are each composed of three sub-indicators, including depth, access, and efficiency (Svirydzenka, 2016).

In academic literature, it is recognized that financial and economic data frequently encounter disturbances. To mitigate this concern, the current study follows previous works of Akhayere et al. (2022), Ali et al. (2023), and Ayhan et al. (2023) by converting the data into continuously compounded returns. The computation of continuously compounded returns entails the utilization of the natural logarithm and is presented by the subsequent formula:

$$R_t = 100 * \ln\left(\frac{P_t}{P_t} - 1\right)$$

Where R_t represents the return percentage, P_t denotes the price at time t, and $P_t - 1$ represents the previous price (Brooks, 2019). Figures 2.2 to 2.6 display the series plots. Upon initial examination of the graph, it becomes evident that CO_2 emissions exhibit a downward trend in the study sample, while the development of financial markets and financial institutions demonstrates a reversible pattern, characterized by an upward and sometimes volatile trend. This pattern suggests a potential negative relationship between these variables. Figure 2.2 presents the trend of China's variables. It is evident that CO_2 emissions take a strong downward trend, while the development of financial institutions shows a smooth upward trend. In contrast, the development of financial markets exhibits a strong upward trend with the emergence of shocks, particularly between the years 2000 and 2005. Regarding the United States of America, Figure 2.3 illustrates that CO_2 emissions followed a downward trend but with smoother movement compared to China. Additionally, both the development of financial institutions and the development of financial markets exhibited strong up-trends until the year 2000, after which they exhibited a sideways trend. With regard to Russia, in Figure 2.4, it can be noted that CO_2 emissions took a downward trend until about 2010, after which it appears to start taking a sideways trend. As for the development of financial institutions, an upward trend can be observed with some shocks, especially in 1995. Meanwhile, financial markets experienced stronger shocks during their upward trend until approximately 2010, after which a downward trend begins. Figure 2.5 illustrates that CO_2 emissions exhibit a downward trend. Simultaneously, the development of financial institutions displays an upward trend with some shocks, particularly between 1990 and 1995. Additionally, the development of financial markets demonstrates an upward trend until approximately 2010, followed by an erratic trend that continues until approximately 2010, after which it transitions to a downward trend. For India, as depicted in Figure 2.6, CO_2 emissions are following a strong downward trend. In contrast, the development of financial institutions and financial markets is witnessing an upward trend, although it is also affected by several significant negative shocks. Despite these shocks, the upward trend in financial institutions and financial markets persists.

Figure 2.2: *Plot of CO_2, FI, and FM in China*

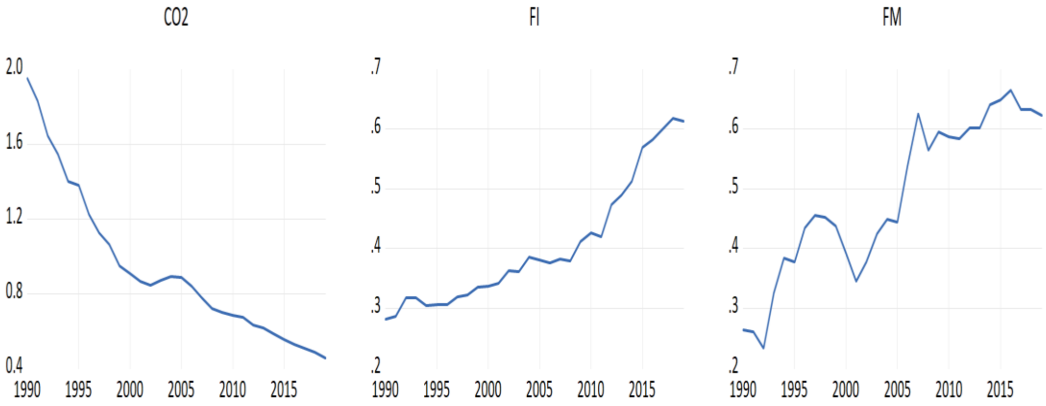


Figure 2.3: *Plot of CO_2, FI, and FM in the USA*

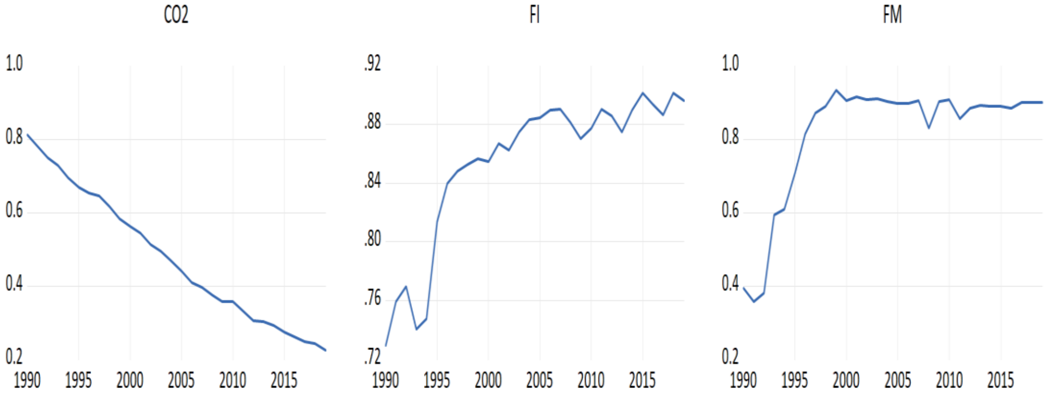


Figure 2.4: *Plot of CO_2, FI, and FM in Russia*

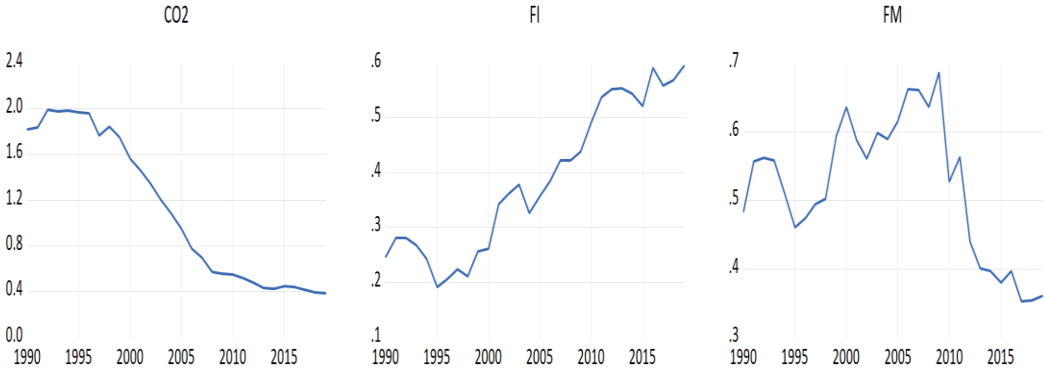


Figure 2.5: *Plot of CO_2, FI, and FM in Japan*

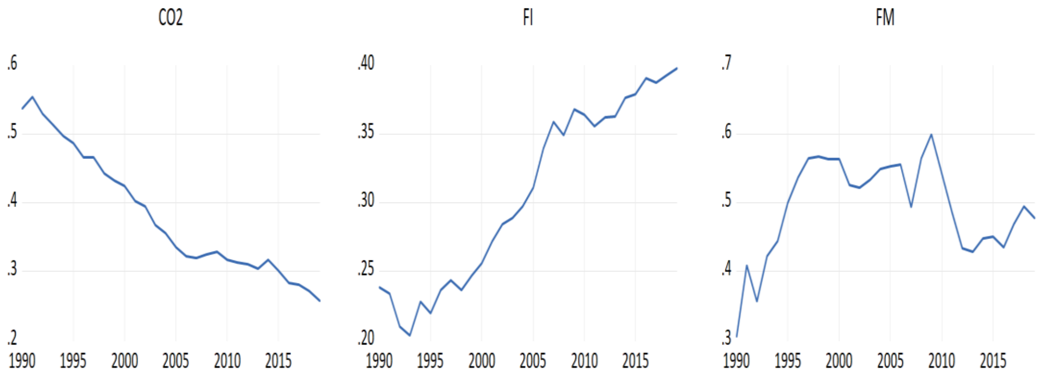
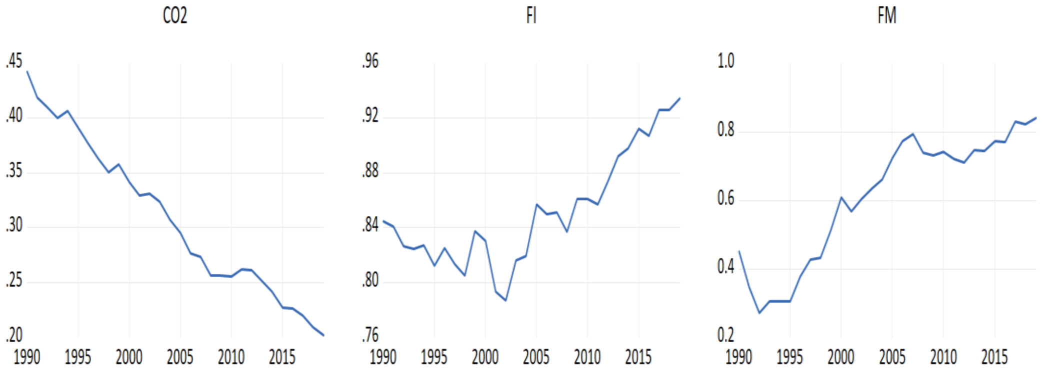


Figure 2.6: *Plot of CO_2, FI, and FM in India*



2.3.2. Methodology

2.3.2.1. QQ

The primary objective of this study is to explore the impact of FI and FM on CO_2 emissions using the QQ method introduced by Sim & Zhou, (2015). The QQ methodology demonstrates significant superiority over conventional regression techniques such as OLS or quantile regression, as it provides a more comprehensive model of economic relationships. While OLS regression can only assess the influence of FDV and intermediation shocks on the average level of CO_2 emissions, quantile regression dissects this effect by analyzing the conditional quantiles. In contrast, the QQ technique further extends the quantile regression method by investigating how the quantiles of FDV and intermediation shocks might impact the conditional quantile of CO_2 emissions. Among the three estimation methods, the QQ approach provides the most detailed information about the relationship between FD, intermediation, and CO_2 emissions. This method allows for a more nuanced understanding of the highly complex relationship between these variables. To estimate the effect that the quantiles of cause variable shocks have on the quantiles of the effect variable a model for the θ-quantile of the effect variable (r_t) based on the cause variable (X_t) shocks, as the follow:

$$r_t = \beta^{\theta}(X_t) + \alpha^{\theta} r_{t-1} + v_t^{\theta},$$

Where the disturbance term v_t^{θ} has a θ-quantile of zero. The link function denoted by $\beta^{\theta}(\cdot)$ does not have pre-existing information about how the cause-and-effect variable shocks are related. The above equation can be linearized by taking a first-order Taylor expansion to get:

$$\min_{b_0, b_1} \sum_{i=1}^{n} \rho_{\theta} \left[r_t - b_0 - b_1\left(\hat{X}_t - X^{\tau}\right) - \alpha(\theta) r_{t-1} \right] K\left(\frac{F_n\left(\widehat{X_t}\right) - \tau}{h} \right)$$

Where $\rho_{\theta}[\cdot]$ is the loss function’s quantile. To focus on the local impact of (X) shock at the τ-quantile, the Gaussian kernel function $K(\cdot)$ is used to assign weights to nearby observations based on a bandwidth parameter, h. These weights are determined by the distance between the observation and a reference point X^{τ}. In other words, the further away a data point is from the reference point, the lower its weight will be (see Sim & Zhou (2015).

2.3.2.2. Nonparametric Causality-in-Quantile

The nonparametric causality-in-quantile suggested by Balcilar et al. (2016) uses a hybrid approach based on the methodologies of Nishiyama et al. (2011) and Jeong et al. (2012) to identify nonlinear causal relationships. The nonparametric causality-in-quantile technique has several benefits over both linear and nonlinear models. It can account for asymmetry in causality depending on the state of the FM, which other methods cannot do. Also, it is unique in that it is not affected by outliers, as it characterizes Granger causality across the entire distribution. This makes it well-suited for analyzing financial time series, which often exhibit fat tails and regime shifts due to the occurrence of co-jumps in both the financial and economic data. The test they use combines Nishiyama et al.'s (2011) k-th order nonlinear causality test with Jeong et al.'s (2012) quantile-causality test, resulting in a more comprehensive approach than the former. The developing test for the second moment by combining the frameworks of Nishiyama et al. (2011) and Jeong et al. (2012) is the following:

$$y_t = g(Y_{t-1}) + \sigma(X_{t-1})\varepsilon_t$$

Where ε_t is a disturbance term and $g(\cdot)$ and $\sigma(\cdot)$ are functions with unknown identities possessing certain characteristics that are adequate for establishing stationarity. By converting the equation into a pair of hypotheses, one null and one alternative, to test for causality in variance, the hypotheses can be written as follows:

$$H_0: P\left\{F_{y_t|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} = 1$$

$$H_1: P\left\{F_{y_t|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} < 1$$

By utilizing the method proposed by Jeong et al. (2012), the issue of causality in the conditional first moment (mean) leading to causality in the second moment (variance) can be addressed. To resolve this issue, utilize the following model to interpret causality in higher-order moments:

$$y_t = g(X_{t-1}, Y_{t-1}) + \varepsilon_t$$

Therefore, it is possible to define causality in higher-order quantiles as the follow:

$$H_0: P\left\{F_{y_t^k|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} = 1\, for\ k = 1,2,\dots,K$$

$$H_1: P\left\{F_{k\ y_t|Z-1}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} < 1\, for\ k = 1,2,\dots,K$$

Causality in the fat tail of distribution differs from that at the distribution center. The lag order, represented as P, is established for a VAR model containing the variables by utilizing the SIC criterion (Balcilar et al. 2016; Shahbaz et al. 2017).

2.4. Empirical Result

The descriptive statistics are presented in Table 2.2. The mean values for all variables ranged from 0.30 to 1.120. Additionally, the sample exhibited standard deviations ranging from 0.06 to 0.40. Furthermore, the Kurtosis values of CO_2 in China, FI in the USA, and FM in India were classified as mesokurtic, with values close to 3, while FM in the USA displayed heavy tails, with a value around 5. The Kurtosis values of the remaining variables showed relatively less variation. When tested for normality, all variables exhibited a normal distribution, except for CO_2 in China, FI, and FM in the USA.

Table 2.2: *Descriptive statistics*

Country	Variables	Mean	Median	Standard deviation	Skewness	Kurtosis	Jarque-Bera
China	CO_2	0.937	0.854	0.406	1.026	3.134	5.284*
	FI	0.404	0.378	0.105	0.891	2.506	4.273
	FM	0.487	0.454	0.131	-0.3	1.867	2.053
USA	CO_2	0.478	0.455	0.182	0.279	1.778	2.256
	FI	0.854	0.875	0.052	-1.363	3.471	9.571***
	FM	0.814	0.892	0.169	-1.859	5.002	22.283***
Russia	CO_2	1.12	1.018	0.637	0.183	1.322	3.689
	FI	0.387	0.371	0.135	0.151	1.568	2.677
	FM	0.52	0.542	0.1	-0.22	1.907	1.736
Japan	CO_2	0.309	0.301	0.071	0.246	1.817	2.053
	FI	0.852	0.843	0.041	0.584	2.379	2.185
	FM	0.609	0.686	0.186	-0.561	1.842	3.248
India	CO_2	0.382	0.346	0.09	0.496	1.881	2.794
	FI	0.306	0.304	0.066	-0.086	1.426	3.135
	FM	0.493	0.498	0.069	-0.75	3.139	2.836

*, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

To determine the appropriate approach for analyzing the data and establishing a cause-and-effect relationship between the variables, two tests, namely the BDS test and the Khmaladze test, were conducted. The BDS test, proposed by Broock et al. (1996), was utilized to assess the presence of independent and identically distributed (i.i.d.) residuals for each series in a VAR(1) model. The test was performed for all possible embedding dimensions (n) to examine the presence of nonlinearity. The results of the BDS test, as presented in Table 2.3, clearly and significantly rejected the null hypothesis, even at the 1% significance level. These findings provide robust evidence of the presence of a nonlinear relationship between the variables in all countries included in the study sample.

Table 2.3: *BDS test results*

Dimension	*m*=2	*m*=3	*m*=4	*m*=5	*m*=6
			China		
CO_2	13.578***	14.354***	15.163***	16.367***	18.052***
FI	11.324***	10.279***	8.852***	7.012***	3.441***
FM	16.910***	16.797***	17.550***	17.530***	18.684***
			USA		
CO_2	25.072***	25.877***	27.129***	29.360***	32.632***
FI	9.999***	10.346***	10.714***	11.483***	12.484***
FM	9.664***	9.869***	10.076***	10.441***	10.930***
			Russia		
CO_2	19.945***	20.391***	21.425***	23.028***	25.336***
FI	17.986***	17.533***	17.358***	17.446***	18.762***
FM	11.493***	10.552***	8.806***	6.874***	3.838***
			Japan		
CO_2	22.316***	22.716***	24.464***	26.612***	29.696***
FI	9.538***	8.181***	6.343***	5.279***	7.280***
FM	16.222***	17.641***	19.216***	21.059***	23.549***
			India		
CO_2	20.014***	21.147***	22.367***	24.343***	27.349***
FI	20.849***	21.774***	22.841***	24.359***	26.456***
FM	11.122***	11.767***	11.641***	11.225***	11.239***

*, **, and *** indicate significance levels at 10%, 5%, and 1%, respectively. The terms m1, m2, ..., m6 refer to the embedding dimensions used in the BDS analysis.

The Khmaladze test, as proposed by Koenker & Xiao, (2002), was conducted to assess the heterogeneity of the quantile regression coefficients across all quantiles. Table 2.4 presents the statistical results of the Khmaladze test, clearly indicating the rejection of the null hypothesis of equal coefficient estimates at the 1% and 5% significance levels for both FI and FM in the selected sample. However, an exception was observed for FM in China, which was rejected at the 10% significance level. These findings demonstrate the existence of heterogeneity across quantiles and underscore the superiority of the quantile approach compared to OLS regression when examining the relationship between the variables.

Table 2.4: *Results of Khmaladze test*

Country	FI	FM
China	5.786***	2.015*
USA	2.838**	19.910***
Russia	3.818***	3.255***
Japan	3.525***	3.147***
India	2.343**	2.489**

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

2.4.1. QQ Results

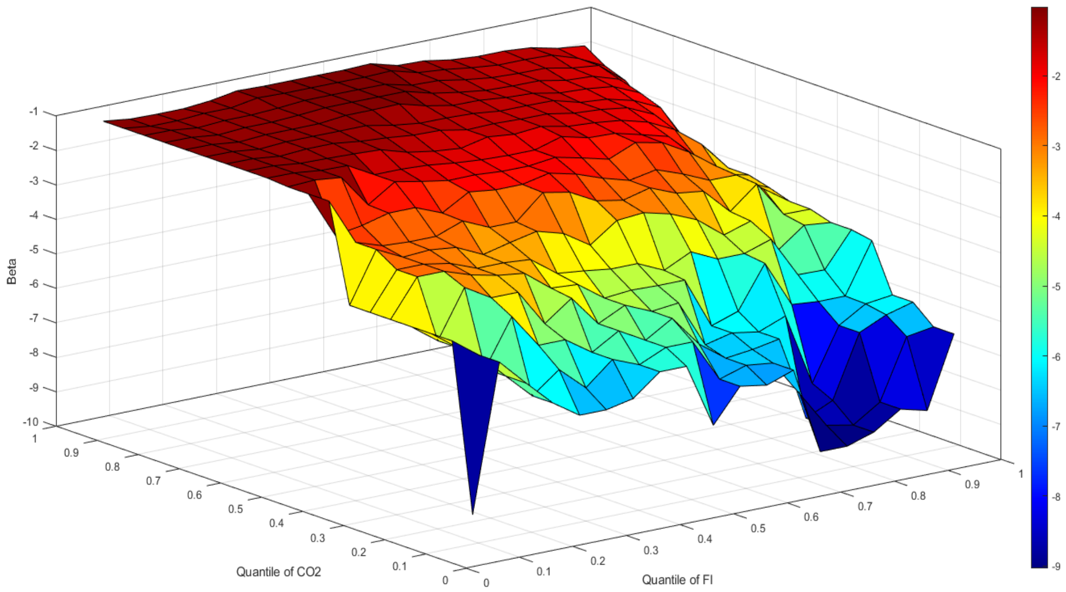
Figures 2.7 to 2.11 present the QQ results of FI and FM supply shocks on CO_2 in the study sample. These figures present the estimated slope coefficients (β), which represent the impact of supply shocks from FI and FM on CO_2. The coefficient β quantifies the size of the shocks generated by various quintiles of the causal variables on the quintiles of the effect variable in significant polluting nations. The subsequent figures present significant and notable findings pertaining to the analyzed sample. The outcomes reveal substantial and non-uniform shocks arising from FI and FM to CO2, exhibiting heterogeneity and asymmetry. Furthermore, it is evident within each country that the extent of shocks transmitted from FI and FM development to CO_2 varies across quintiles and the overall sample.

In the context of FI, CO_2 emissions in India are affected by both positive and negative shocks, whereas in China, only negative shocks are observed across all quintiles. Moreover, the intensity of these shocks is significant, with values of -6, -7, and -9 observed in the USA, Russia, and China, respectively. In contrast, the shocks are relatively smaller in countries like India and Japan, measuring -2 and 2.5, respectively. Regarding FM, there is observable heterogeneity and an asymmetrical relationship, as positive and negative shocks are transmitted from FM to CO_2 in the

United States, Russia, and Japan. The distinction lies in the magnitude of shocks originating from the causal variables towards the effect variable quintiles. For instance, in Russia, FM produces positive shocks that surpass 10, which is greater than the largest shock transmitted by FI to CO_2. These findings indicate that the connection between causal variables and effect variables differs among quintiles and is influenced by the magnitude and direction of the shocks caused by the causal variables. By individually analyzing the countries, additional information can be observed. In the case of China, it is apparent in Figure 2.7a that all shocks transmitted from the FI variables have a negative impact across all quintiles. The magnitude of these shocks on the CO_2 emissions quintiles ranging from 0.6 to 0.9, originating from all FI quintiles, varied between negative two and negative three. Furthermore, the 0.1 and 0.7–1 quantiles of FI delivered stronger shocks to the 0.1 quantile of CO_2, indicating that the higher CO_2 quantiles receive weaker shocks compared to the lower quantiles. Notably, the lower quantiles experienced significant shocks, reaching a magnitude of negative nine. In relation to FM shocks, Figure 2.7b shows that all shocks exhibit a negative impact. The most significant negative shock was transmitted from the 0.1 quantile of FM to the 0.1 quantile of CO_2, amounting to a magnitude of negative seven. In general, the 0.1–0.4 quantiles of FM transmitted comparatively weaker shocks, ranging around negative two, to the upper quantile (0.5–0.9) of CO_2. Conversely, the lower quantile (0.1–0.4) of CO_2 experienced more intense shocks, ranging from negative seven to negative three. In regard to the USA, Figure 2.8a shows that FI has predominantly negative effects on CO_2 levels. The magnitude of these shocks varies between - 2 and -5. Notably, the 0.1 quantile of FI consistently generates stable shocks across all quantiles of CO_2, with these shocks averaging a magnitude of approximately 3. Conversely, the most significant shocks occur between the 0.9-1 quantiles of FI and CO_2. It is worth noting that while all shocks sent from FI quantiles are negative, their strength differs across the quantiles of CO_2. Also, all quantiles of CO_2 experience uniform shocks originating from the 0.1 quantile of FI. In examining the relationship between FM and CO_2 emissions in the USA, as shown in Figure 2.8b, it is evident that there are no significant shocks originating from all FM quantiles towards the 0.1 quantile of CO_2. However, the shocks originating from the 0.9 quantile of FM towards the 0.2-0.4 quantiles of CO_2 are positive and approximately equal to 1 in magnitude. Additionally, positive shocks are transmitted from the 0.4-0.7 quantiles of FM to CO_2, with a slope coefficient ranging from 1 to 2. While the majority of shocks are negative, the most notable negative shocks are transmitted from the 0.2-0.3 quantiles of FM to the 0.8-0.9 quantiles of CO_2, measuring approximately negative two in magnitude. In relation to Russia, there is a notable contrast in the magnitude of shocks transmitted from the 0.1–0.3 quantiles of FI towards the upper and lower quantiles of CO_2 as it shown in Figure 2.9a. Specifically, the shocks emanating from the 0.1–0.3 quantiles of FI towards the 0.1–0.3 quantiles of CO_2 exhibit a slope coefficient value of approximately -7, indicating a weaker effect compared to the shocks sent from the same quantiles of FI to the 0.7–0.9 quantiles of CO_2. The latter shocks possess a slope coefficient ranging between -1 and -2. Consequently, it can be inferred that the lower quantiles of CO_2 (0.1-0.3) experienced more pronounced shocks than the other quantiles.

Figure 2.7:*QQ Results of China.*

a).FI



b).FM

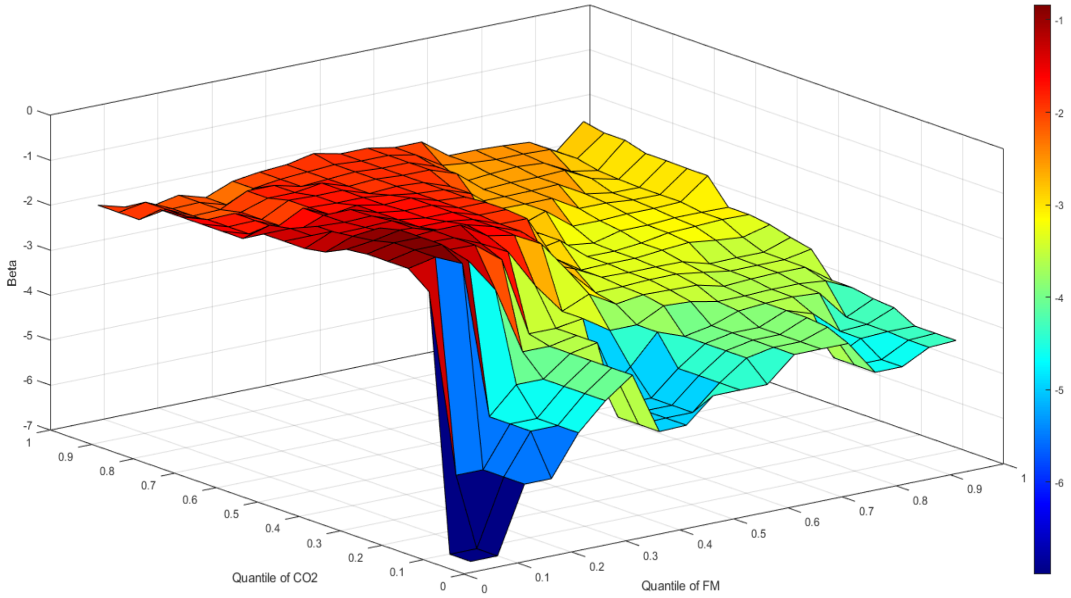
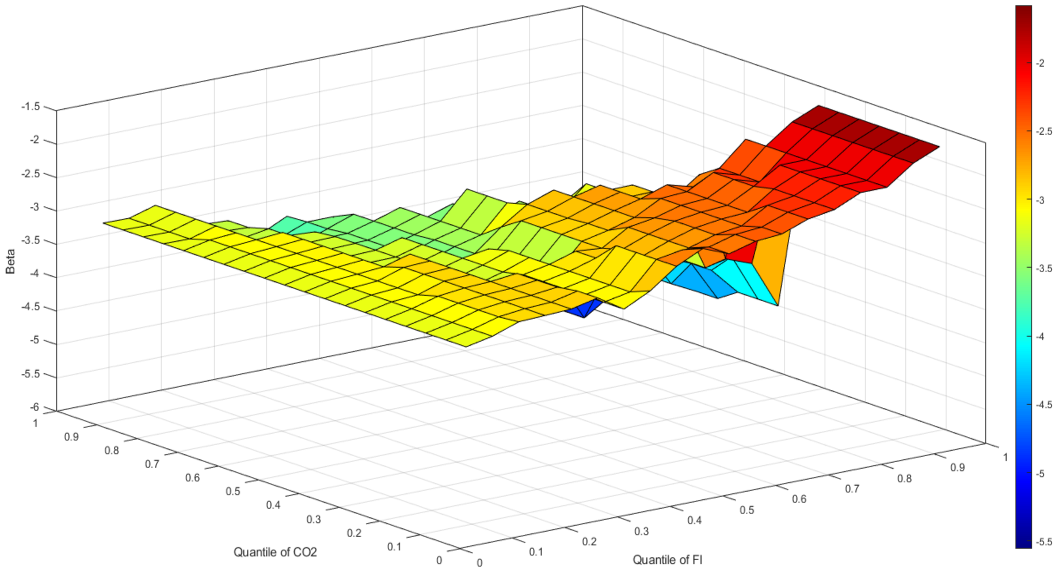
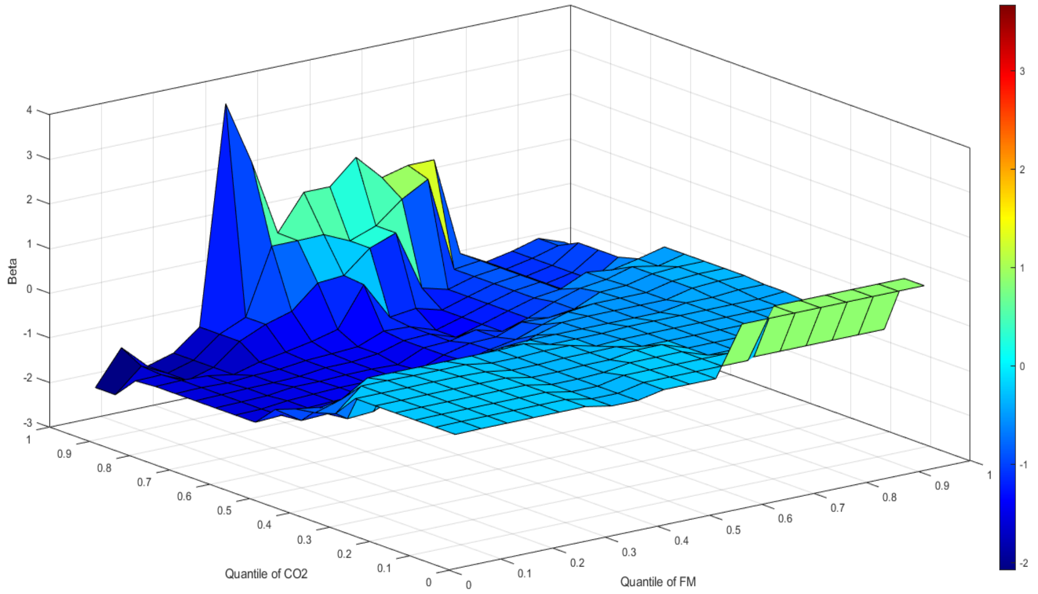


Figure 2.8: *QQ results of USA.*

a).FI



b).FM

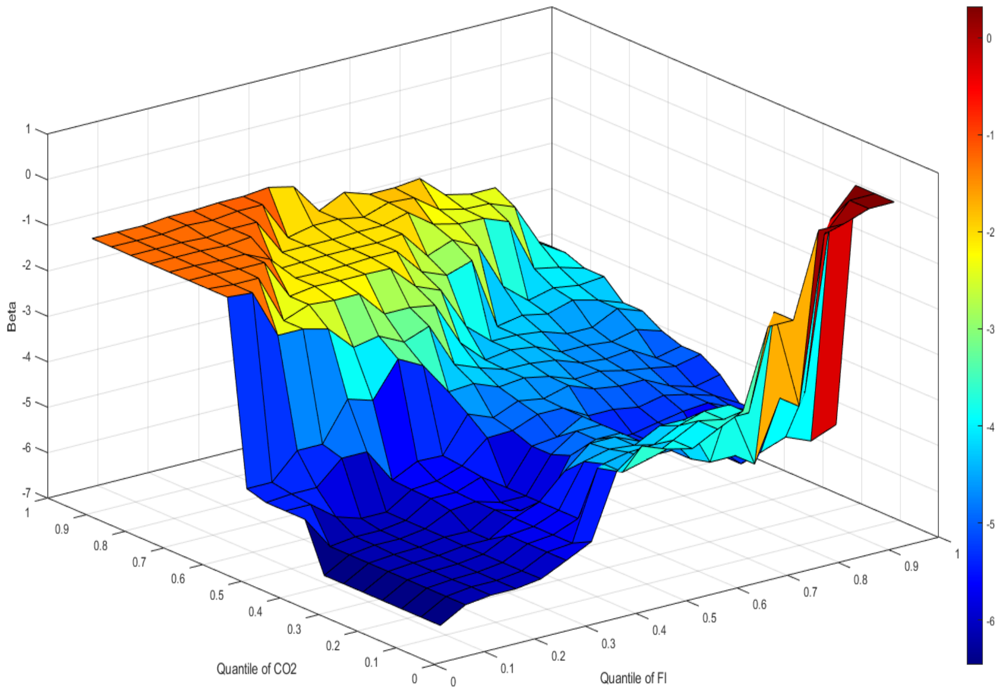


Regarding FM, Figure 2.9b shows that negative shocks solely originated from the 0.9 quantile of FM and targeted the 0.9 quantile of CO_2. Conversely, positive shocks were transmitted from the 0.5–0.9 quantile of FM to the 0.7 quantile of CO_2. as the quantiles of FM increase, these shocks exhibit a gradual increase, ranging between zero and positive 10 at the 0.9 quantile of FM. Figure 2.10a and 2.10b show the QQ results of Japan, it is clear that the impact caused by FI progressively intensifies as the quantiles increase. The least severe impacts were observed from the 0.1 quantile of FI to all quantiles of CO_2, ranging from -0.5 to -1. Conversely, the strongest impacts were transmitted from the 0.7-0.9 quantiles of FI to all quantiles of CO_2, with magnitudes approximately at -2. Regarding FM, it is evident that FM quantiles 0.8–0.9 generate positive shocks. These shocks have magnitudes ranging from 0.1 to 0.2, indicating their relatively small size. Additionally, it is important to note that there are no shocks transmitted from any FM quantiles to the CO_2 quantiles between 0.1 and 0.4. The magnitudes of the shocks transmitted from the 0.2-0.8 quantile of FM to the 0.4-0.7 quantile range between -0.2 and -0.4. Furthermore, there is a slope coefficient of 0.5 present in the shocks transferred from the 0.1-0.7 quantile of FM to the 0.8-0.9 quantile of CO_2. Overall, the FM to CO_2 shocks in Japan are modest and constrained, with a narrow range of slope coefficients between 0.1 and -0.6.

Finally, concerning India, it is clear that FI in Figure 2.11a contributes to uneven impacts on CO_2 emissions. Specifically, the lowest range (0.1 quantile) of FI shows positive influences on the higher ranges (0.6–0.9) of CO_2, with a magnitude of 0.5. Additionally, the quantiles between 0.5 and 0.6 of FI generate positive effects on the higher ranges (0.6–0.9) of CO_2, with a slope coefficient of 1. Conversely, negative impacts are observed when the higher ranges (0.7–0.9) of FI affect all ranges of CO_2. Notably, the most significant impacts occur from the lowest range (0.1) of FI to the lowest range (0.1) of CO_2. Regarding FM in India, it is evident that lower ranges of FM exert weak effects on the higher range of CO_2, while higher ranges of FM produce stronger impacts on the lower range of CO_2. Overall, these impacts are negative, ranging in magnitude from -0.9 to -1.6.

Figure 2.9: *QQ Results of Russia.*

a).FI



b).FM

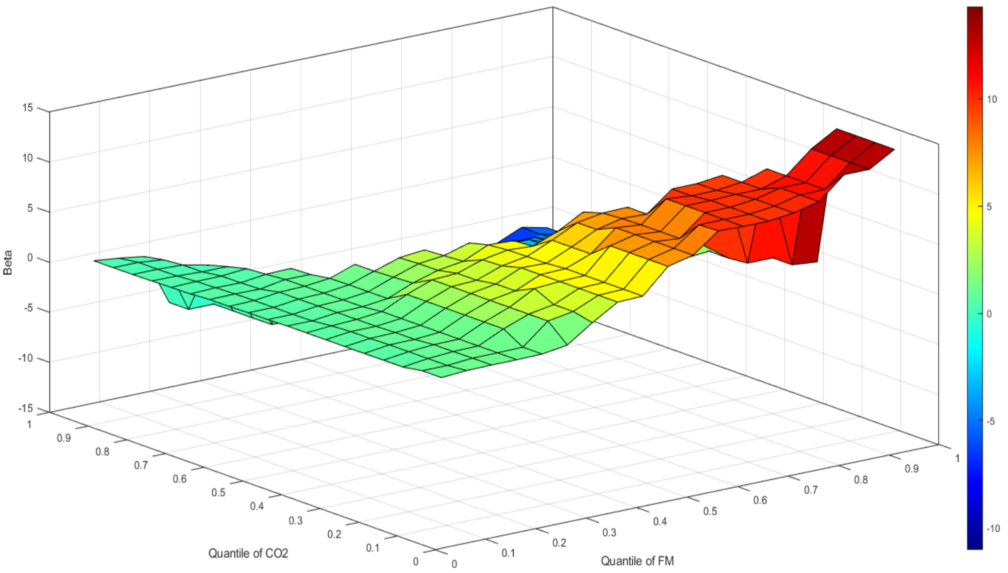
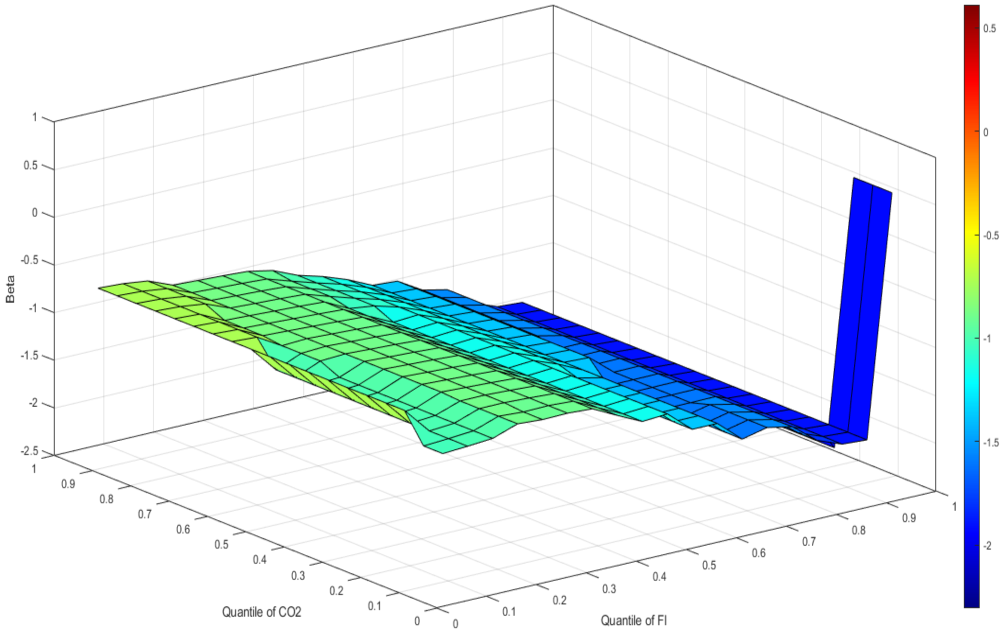


Figure 2.10: *QQ Results of Japan.*

a).FI



b).FM

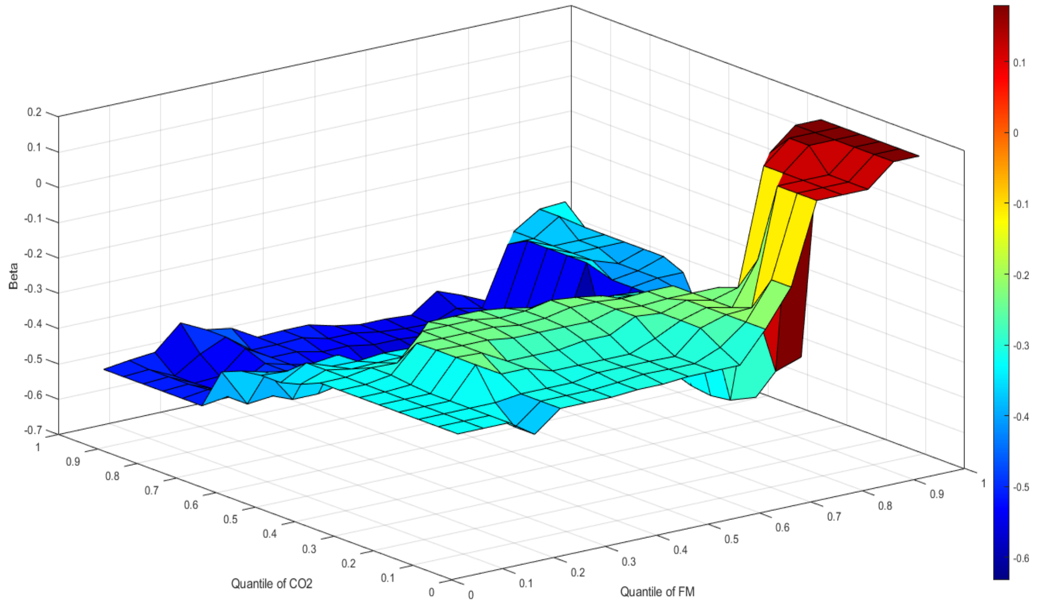
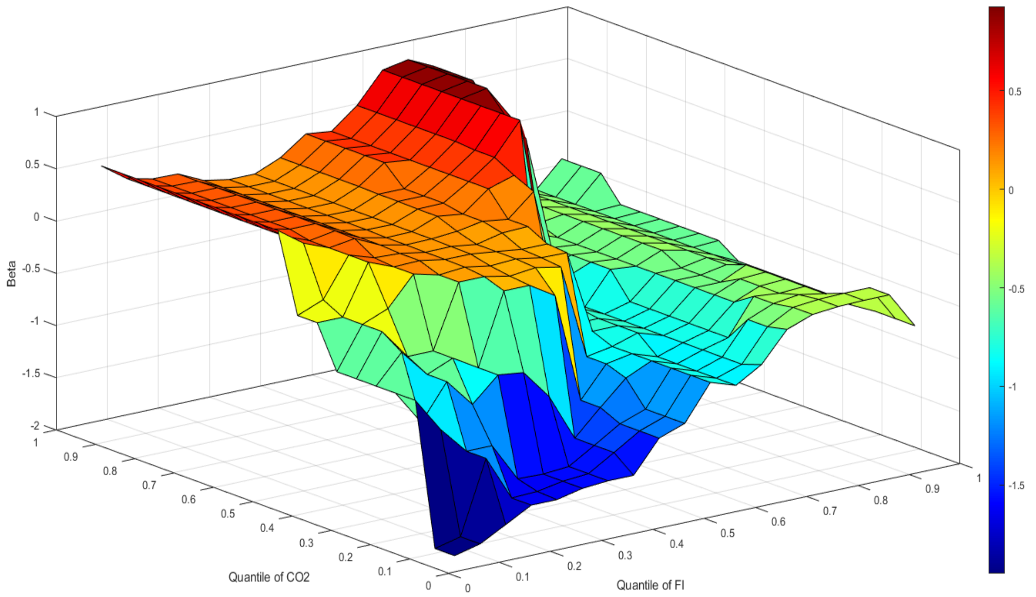
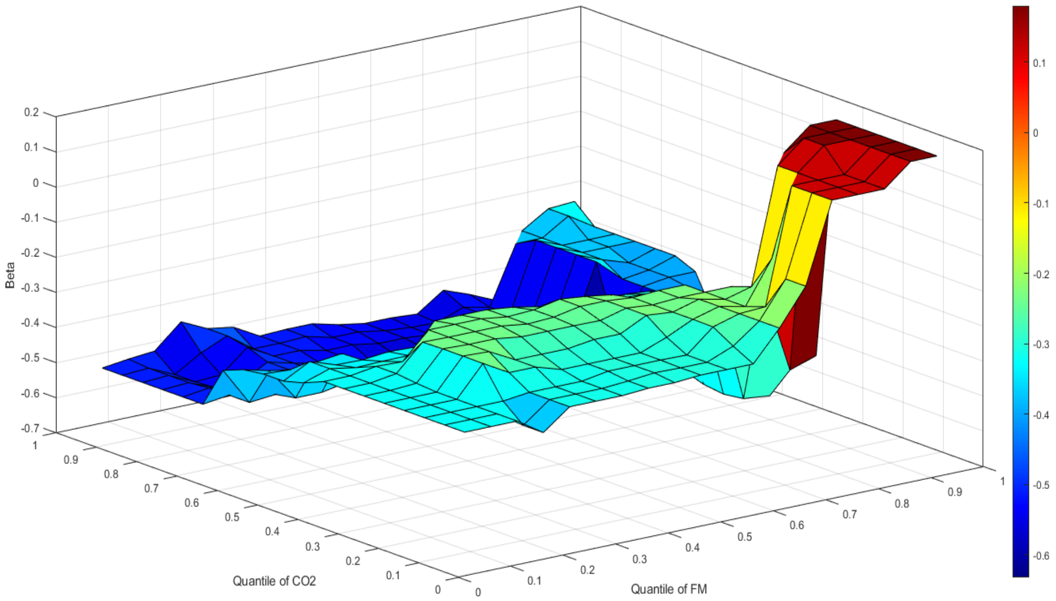


Figure 2.11: *QQ Results of India.*

a).FI



b).FM



2.4.2. Nonparametric Causality-in-Quantiles Results

As nonlinearity has been strongly indicated by the BDS tests, the research will delve deeper to explore the existence of nonparametric causality flowing from FI and FM to CO_2 by using nonparametric quantile causality. The outcomes of the nonparametric causality-in-quantiles analysis between FI and CO_2 are presented in Tables 2.5 and 2.6, respectively. It presents the results of nonparametric causality in conditional mean and nonparametric causality in conditional variance from FI to CO_2 across different quantiles for the study sample. The first column presents the quantiles, and the second and third columns represent the nonparametric causality in mean and nonparametric causality in variance, respectively, for China, as each country has two columns, one column representing the causality in mean and the other showing the causality in variance. The results indicate the existence of the nonparametric causality in the first and second orders across the lower quantiles of China, more precisely at the 0.1–0.45 quantiles, while nonparametric causality in the mean was confirmed at the middle quantile of the USA, specifically at 0.45–0.60, and the nonparametric causality in variance was confirmed at a higher quantile, which is 0.55–0.60.

In regard to Russia, the nonparametric causality in mean and variance was confirmed at the 0.1–0.5 quantiles, while for Japan, it was confirmed at the 0.25–0.45 quantiles. Finally, regarding India, the nonparametric causality was confirmed at 0.30 with a significance level of 10%.

Table 2.5: *Results of FI Nonparametric Causality-In-Quantiles*

	China		USA		Russia	
Quantile	Mean	Variance	Mean	Variance	Mean	Variance
0.10	4.540***	4.540***	0.352	0.352	4.058***	3.415***
0.15	3.504***	3.353***	0.57	0.57	3.090***	3.261***
0.20	2.671***	2.678***	0.877	0.885	2.537**	2.613***
0.25	2.579***	2.377**	1.264	1.18	2.515**	2.828***
0.30	2.087**	2.219**	1.349	1.468	2.351**	2.450**
0.35	1.700*	1.885*	1.017	0.955	2.391**	2.420**
0.40	1.881*	1.914*	0.934	0.613	2.123**	2.151**
0.45	1.978**	1.900*	2.783***	1.48	2.035**	2.011**

Table 2.5 (Continued).

0.50	1.455	1.423	2.162**	1.608	1.818*	1.817*
0.55	1.593	1.433	1.879*	1.955*	1.589	1.613
0.60	1.48	1.36	1.792*	2.578***	1.377	1.425
0.65	1.273	1.102	1.285	1.395	1.166	1.274
0.70	0.992	0.907	1.448	1.448	1.007	1.076
0.75	0.805	1.022	1.497	1.497	0.67	0.806
0.80	0.525	0.659	1.047	1.047	0.459	0.634
0.85	0.415	0.658	0.669	0.669	0.354	0.581
0.90	0.485	0.63	0.361	0.361	0.192	0.497

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

Table 2.6: *Results of FI Nonparametric Causality-In-Quantiles in Japan and India*

	Japan		India	
Quantile	Mean	Variance	Mean	Variance
0.1	0.775	0.775	0.473	0.473
0.15	1.011	1.011	0.624	0.624
0.2	1.573	1.573	1.259	1.259
0.25	1.976**	1.976**	1.595	1.595
0.3	2.698***	2.698***	1.899*	1.753*
0.35	2.980***	2.980***	1.193	1.581
0.4	2.861***	1.822*	0.877	1.181
0.45	1.753*	3.063***	1.037	1.462
0.5	1.041	1.333	1.059	1.1
0.55	1.164	0.926	1.419	0.987
0.6	1.138	1.138	1.478	1.478
0.65	1.224	1.426	0.944	0.96
0.7	0.967	1.104	1.176	1.176
0.75	1.191	1.179	0.748	0.748
0.8	1.251	0.847	0.433	0.433
0.85	0.915	0.572	0.493	0.493
0.9	0.494	0.494	0.463	0.463

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

In general, the nonparametric causality in mean and variance from FI to CO_2 is confirmed for all countries. However, there are differences across the countries in the quantile at which nonparametric causality arises. Nonparametric causality was established at lower quantiles in some countries, such as China and Russia, while in others, such as the USA and Japan, it was confirmed at middle and upper quantiles. We can also observe that the acceptance of nonparametric causality varies across countries. For example, nonparametric causality is accepted at the significance level of 1% and 5% for China, the USA, Russia, and Japan. In comparison, the nonparametric causality in the mean and the variance are accepted at the significance level of 10% for India.

Table 2.7 and 2.8 exhibit the nonparametric causality in the first and second orders across the quantiles from FM to CO_2. The nonparametric causality was confirmed for the first and second orders across different quantiles in all countries. In China, the nonparametric causality in mean and variance was confirmed at lower to middle quantiles. For the USA, it was confirmed at the middle quantiles. Regarding Russia, the nonparametric causality was confirmed at the lower and middle quantiles, while for Japan and India, the nonparametric causality in mean and variance was confirmed only in the middle quantile. Overall, the nonparametric causality in the conditional mean and the nonparametric causality in conditional variance from FM to CO_2 were confirmed only in the lower and middle quantiles, except for China and the USA, where we can notice the existence of nonparametric causality on upper quantiles, specifically at the 0.55 and 0.60 quantiles.

Table 2.7: *Results of FM nonparametric causality-in-quantiles*

	China		**USA**		**Russia**	
Quantile	Mean	Variance	Mean	Variance	Mean	Variance
0.10	3.545***	3.545***	0.299	0.299	4.292***	3.289***
0.15	2.820***	2.701***	0.509	0.509	3.234***	3.503***
0.20	2.220**	2.242**	0.809	0.88	2.621***	2.855***
0.25	2.223**	2.348**	1.191	1.161	2.659***	2.730***

Table 2.7 (Continued).

0.30	1.872*	2.001**	1.296	1.458	2.876***	2.437**
0.35	1.582	1.791*	1.169	1.146	2.743***	2.284**
0.40	1.541	1.515	0.869	0.669	2.187**	2.084**
0.45	2.185**	1.955**	2.987***	1.498	2.170**	2.053**
0.50	1.612	1.826*	2.278**	1.541	1.971**	1.887*
0.55	2.157**	2.015**	1.905*	1.742*	1.766*	1.714*
0.60	1.737*	1.632	1.893*	2.583***	1.298	1.277
0.65	1.44	1.35	1.244	1.431	1.227	1.164
0.70	1.135	1.135	1.442	1.442	1.046	0.989
0.75	0.842	0.968	1.514	1.514	0.59	0.673
0.80	0.668	0.764	1.058	1.058	0.433	0.562
0.85	0.423	0.635	0.675	0.675	0.313	0.5
0.90	0.482	0.604	0.364	0.364	0.167	0.44

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

Table 2.8: *Results of FM nonparametric causality-in-quantiles*

	Japan		India	
Quantile	Mean	Variance	Mean	Variance
0.1	0.463	0.463	0.521	0.521
0.15	0.661	0.661	0.63	0.63
0.2	0.974	0.974	1.346	1.346
0.25	1.325	1.325	1.892*	1.892*
0.3	1.488	1.488	2.605***	2.017**
0.35	1.649*	1.649*	2.001**	2.523**
0.4	1.456	1.106	1.926*	2.012**
0.45	0.86	1.575	1.63	1.706*
0.5	0.928	0.684	1.162	1.13
0.55	1.226	0.528	1.516	1.101
0.6	1.201	1.201	1.478	1.478
0.65	1.028	1.609	0.873	0.987
0.7	1.031	1.196	1.366	1.366
0.75	1.168	1.144	0.941	0.941
0.8	1.348	0.797	0.618	0.618
0.85	0.946	0.536	0.535	0.535
0.9	0.508	0.508	0.428	0.428

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

2.4.3. Hypothesis results

The findings of the study provide compelling evidence of the impact of FI and FM development on CO_2 emissions, revealing both heterogeneous and asymmetric effects across the sample.

Hypothesis 1. The results indicate that FI exerts positive and negative shocks on CO_2 in India, while in China, the USA, Russia, and Japan, FI only induces negative shocks across all quantiles. These results are consistent with prior research (Mar'I et al. 2023; Zhao & Yang, 2020; Salahuddin et al. 2018; Ziaei 2015; Shahbaz et al. 2013; Tamazian et al. 2009), which have demonstrated an inverse relationship between FDV and CO_2. Furthermore, previous studies such as Cochran et al. (2014) have highlighted the positive role of FI in reducing CO_2 emissions through financing environmentally friendly projects. The negative shocks sent from FI to CO_2 underscore the important role of FI in linking low-carbon initiatives with financial support, including enhanced access to capital, risk reduction, capacity building for market actors, and shaping market conditions and practices. However, these findings partially contradict Habiba et al.'s (2021) study, which suggests that FI development contributes to increased CO_2 emissions.

Hypothesis 2. Regarding FM development, both positive and negative shocks are transmitted from FM to CO_2 in the USA, Russia, and Japan, indicating higher financial system volatility compared to China and India, where only negative shocks to CO_2 are observed. These findings align with the results of nonparametric analysis. The negative shocks from FM to CO_2 emissions are consistent with the findings of Alam et al. (2021), who observed a negative effect on CO_2 emissions in the OECD, as well as Paramati et al. (2017), who noted that FM growth leads to reduced emissions in advanced countries. Additionally, Younis et al. (2021) found a negative relationship between FM and CO_2 emissions in India, China, and Russia. This negative relationship can be attributed to the fact that FM development also contributes to the reduction of CO_2 emissions. Listed companies operating within FM frameworks are subject to stringent rules and regulations, particularly in developed countries. These regulations ensure that companies adopt more efficient production processes, employ smarter technologies to manage industrial pollution, and utilize sustainable energy sources. Furthermore, competition among listed companies to be environmentally responsible and attract environmentally conscious consumers further incentivizes companies to reduce emissions (Lanoie et al. 1998; Younis et al. 2021).

The findings of this study align with Li et al. (2020) and Sharma et al. (2021), who found a positive association between FM development and CO_2 emissions in the OECD and four South Asian countries, respectively. This significant relationship can be attributed to the fact that increased CO_2 emissions from the FM significantly contribute to environmental degradation. The growth of enterprises, facilitated by FM, is a major driver of this phenomenon. FM plays a critical role in corporate operations by providing a platform for easy fund exchanges (both equity and debt financing). Increased economic activity resulting from FM leads to greater production, increased energy use, and elevated CO_2 emissions. Additionally, the availability of additional cash through FM allows for risk diversification, which encourages higher corporate activity and energy consumption, further contributing to environmental deterioration (Lanoie et al., 1998; Sadorsky, 2011). However, the contradictory findings regarding the impact of FM development on CO_2 emissions highlight the need for further efforts to integrate global FM systems and promote environmental sustainability. The relationship between FDV and CO_2 emissions is complex and multifaceted, with varying findings across studies. The asymmetric impacts observed in this study highlight the importance of integrating global FM systems and aligning them with environmental sustainability goals. Furthermore, the positive impact of FDV on CO_2 emissions underscores the need for sustainable practices and policies to ensure long-term economic and financial stability. Efforts should be made to promote resource efficiency, technological advancements, and circular economy policies within the framework of economic growth(Alola & Adebayo, 2023b). A summary of hypotheses results is presented in Table 2.9.

Table 2.9: *Summary of hypotheses results.*

Hypothesis	Result
The impact of financial institution development on CO_2 emissions is asymmetric.	✓
The influence of financial market development on CO_2 emissions is asymmetric.	✓

2.5. Conclusion

This study examines the relationship between FI and FM development and their impact on CO_2 emissions in five major polluting countries from 1990 to 2019. The study utilizes the methods of QQ and nonparametric causality-in-quantiles. The findings provide robust evidence of the influence of FI and FM development on CO_2 emissions. The study identifies the presence of shocks and nonparametric causality running from FI and FM to CO_2. However, the effects of FI shocks and nonparametric causality are found to be heterogeneous and asymmetric across the sample countries. Positive and negative shocks are observed in India, whereas only negative shocks are observed in China, the USA, Russia, and Japan. The study supports previous research that indicates an inverse relationship between FI development and CO_2 emissions, highlighting the positive role of FI in reducing CO_2 emissions through financing environmentally friendly projects. The negative shocks suggest that FI plays a crucial role in connecting low-carbon initiatives with financial support, including improving access to capital, reducing and sharing risk, enhancing the capacity of market actors, and shaping market conditions and practices.

The impact of FM development on CO_2 emissions varies across countries, with both positive and negative shocks transmitted to CO_2 emissions in the USA, Russia, and Japan, indicating higher volatility in these countries compared to China and India, where only negative shocks are observed. These negative shocks align with previous research suggesting that FM growth leads to reduced emissions in advanced countries. This is due to the stringent regulations imposed on listed companies in these countries, promoting the adoption of more efficient production processes, smarter technologies for managing industrial pollution, and sustainable energy sources. On the other hand, positive shocks indicate that FM development contributes to environmental degradation through increased CO_2 emissions, primarily driven by business expansion.

2.5.1. Policy Implications

- Promoting Environmentally Friendly Financial Products: Policymakers should prioritize the allocation of funds towards projects and initiatives that have a positive environmental impact.

- Integrating Environmental Risk Analyses: Policymakers should incorporate comprehensive environmental risk analyses into financial decision-making processes.
- Incorporating Environmental Factors into Regulatory Frameworks: Policymakers should revise and enhance regulatory frameworks to ensure the inclusion of environmental factors and sustainability considerations.
- Encouraging Sustainable Investing Standards: Policymakers should actively promote the widespread adoption of sustainable investing practices within the financial system.

2.5.2. Policy Recommendation

Our recommendation is for policymakers to focus on promoting environmentally friendly financial products and take steps to improve the financial system's capacity to mitigate positive shocks that contribute to CO_2 emissions. This involves adopting sustainable financial practices that consider the environmental effects of financial operations. Policymakers should prioritize environmentally friendly projects for funding and encourage the adoption of environmentally friendly investing standards within the financial system. This can be achieved through incentives and support for initiatives that utilize low-carbon and renewable energy sources, as well as the inclusion of environmental risk analyses in financial decision-making processes. Additionally, by incorporating environmental factors into regulatory frameworks and providing financial incentives for carbon reduction activities, decision-makers can work towards reducing the positive shocks from FM. This approach enables the financial system to support sustainable economic growth while lowering CO_2 emissions.

2.5.3. Limitations and Future Research

The findings of this study are subject to limitations due to the focus on five major polluting countries from 1990 to 2019. Therefore, caution should be exercised when generalizing these findings to other countries and different time periods. Future research should expand the scope by including a broader range of countries and examining longer timeframes to enhance the generalizability and comprehensiveness of the findings regarding the relationship between FDV and CO_2 emissions on a global scale. Furthermore, it is recommended to explore the role of different types of FI and their practices in promoting CO_2 emissions. Future research could delve into the specific actions and policies implemented by banks, insurance companies, and investment funds to support low-carbon initiatives. Assessing the effectiveness of these initiatives and identifying areas for improvement can contribute to the adoption of more sustainable financial practices.

CHAPTER 3

The Tail Dependence and Lead-Lag Relationship in Financial Markets

3.1. Introduction

Following the global financial crisis in 2008, economic uncertainty has prompted investors to seek alternative investment assets that offer risk diversification and hedging capabilities (Huynh et al., 2020). Understanding the relationship between EGS, BRT, GLB, CRY, and ISM is crucial for asset allocation in portfolios, risk assessment, and risk management. Investor behavior varies in periods of bullish and bearish markets, leading them to allocate investments towards a combination of stocks that offer significant diversification benefits to their portfolios (Taghizadeh-Hesary et al., 2019). Numerous studies have examined the link between different assets, particularly the interaction between Brent and global markets, as well as more recent assets such as cryptocurrencies and green investments, in order to identify the optimal markets for hedging. Green investments have emerged as a viable option for risk diversification and hedging, gaining international prominence. Green bonds, in particular, have gained popularity among investors due to their ability to address both financial and environmental sustainability concerns (C. W. Su et al., 2023; K.-H. Wang et al., 2023). On the other hand, GLB has traditionally been viewed as a safe haven for investors seeking stability. Unlike certain markets, such as BRT, which are particularly sensitive to political pressures and global crises, GLB has shown resilience during challenging times. Its dependability makes it an appealing choice for risk-averse investors seeking consistent returns on their investments (Ji et al., 2020; Tiwari et al., 2019). Recently, CRY has emerged as a new channel for investment and hedging strategies. Its decentralized structure and extreme volatility have attracted a significant number of investors seeking high returns. The ability to trade CRY 24/7 and the potential for rapid price swings make it an enticing option for investors looking to capitalize on market movements (Ahmed, 2021b, 2021a; Aliu et al., 2021).

ISM, from different perspective, has gained appeal among Sharia-compliant investors. These markets operate in accordance with Islamic finance principles, which prohibit interest-based transactions and promote ethical investment practices. By investing in Sharia-compliant assets, individuals can align their financial actions with their religious convictions, contributing to the growth of these specialized markets (Akinlaso et al., 2023; B. H. Chang et al., 2020; Sensoy, 2016). Based on the foregoing, Understanding the lead-lag relationship and tail dependencies among different financial markets is crucial for investors, policymakers, and market participants. This academic paper aims to explore the lead-lag relationship and tail dependency of oil with respect to green investment, CRY, GLB, and ISM.

The purpose of this study is to analyze the dependency between a network of financial markets, including BRT, RGS, GLB, ISM, and CRY. Additionally, the study aims to determine the bivariate lead-lag relationship between these financial markets based on the relationships identified in the dependency analysis. The importance of the study stems from its analysis of the multivariate relationships and interactions between the financial markets with each other in the bullish and bearish markets, identifying the dominant markets and the influence of other markets on their movement. Investors look for suitable markets to hedge and avoid investment risks. Various techniques were utilized in the existing literature to examine the interdependence of regional exchange rates. In this particular research, we utilize two approaches: (1) the Regular Vine copula approach, which involves the application of multivariate copula functions. This approach offers advantages over conventional correlation analysis by incorporating tail dependence coefficients to evaluate the interdependence between variables, encompassing both extreme positive and negative cases (Loaiza Maya et al., 2015). The Regular Vine copula represents a recent and reliable advancement in Copula types, as it allows for flexible dependency modeling and the measurement of both linear and nonlinear correlations. To establish the Multivariate Copula among the variables, we follow the methodology proposed by Dissmann et al. (2013), while the marginal distribution is modeled using GARCH (1,1) with t-student innovation. (2) The wavelet transform and phase difference. Wavelet analysis is considered the most commonly employed technique for association analysis. It offers a significant advantage by allowing the simultaneous extraction and analysis of information in both the time and frequency domains. This functionality is crucial since relevant data is often available only in the frequency domain (Mar’i & Tursoy, 2022).

3.2. Literature Review

3.2.1. The relationship between BRT and financial markets

3.2.1.1. BRT and EGS

Several studies have investigated the interaction between the BRT and EGS markets from different perspectives, including oil price dynamics, asset co-movement, and forecasting potential. These research efforts have yielded diverse and sometimes contradictory findings. In this subsection, the study presents the most recent and significant studies on the relationship between BRT and EGS.

Lee et al. (2021) investigated the relationship between BRT and EGS in the USA from 2013 to 2019. Their empirical findings reveal significant bi-directional causality from oil price to EGS, particularly in the lower quantiles. Li et al. (2022) investigated the interaction relationship between BRT and EGS and found that BRT has a negative impact on EGS.

Azhgaliyeva et al. (2022) investigated the effects of BRT shocks on EGS by examining the influence of BRT on firm environmental bond issuance. The study found that BRT has a significant and positive impact on the probability of firm environmental bond issuance. However, shocks to BRT did not have a meaningful impact on the percentage of firm environmental bond issuance.

X. Wang et al. (2022) examined the dynamic relationships between various assets, including EGS. The key findings reveal complex relationships between these assets, with alternating positive and negative trends observed throughout the sample period. Additionally, BRT emerges as a strong predictor across diverse distributions of cross-market links, highlighting the sensitivity of asset co-movement to external risks, especially during normal market conditions.

K.-H. Wang et al. (2023) utilized a Granger-causality test to investigate the relationship between BRT pricing and EGS. The analysis reveals positive, negative, and uncorrelated effects of BRT on EGS. The positive impacts indicate that high BRT enhances the profitability of the EGS market, suggesting that EGS can withstand BRT shocks. However, due to the high profitability of the EGS industry and the abundant supply in the oil market, a negative impact between BRT and EGS is also identified.

Su et al. (2023) utilized a QQ analysis to examine the effects of BRT on EGS from 2011 to 2021. The study concludes that in the short run, the effects of BRT on EGS are positive and beneficial. These findings suggest that a high BRT can stimulate the growth of the EGS market, indicating that EGS can serve as an asset to mitigate BRT shocks. However, in the medium and long term, there is a negative effect due to BRT overstock and an increase in EGS industry earnings.

Rehman et al. (2023) examined the forecasting potential of BRT shocks for EGS markets. The study investigated the extent to which BRT shocks can be used to accurately predict EGS returns. The findings of the study indicate that BRT shocks are reliable predictors of EGS indices. Furthermore, Umar et al. (2023) examined the effects of BRT shocks on various fixed income asset classes, including ISM and EGS, and identified a strong link between BRT shocks and these asset classes.

3.2.1.2. BRT and CRY

Many studies have examined the relationship between BRT and CRY. The majority of these studies have investigated whether CRY can serve as a hedge, safe haven, or diversifier for BRT price swings, with the effectiveness depending on specific market conditions and the state of the BRT market. However, CRY has not been found to be the optimal asset for hedging BRT-related uncertainty, and alternative investments have been suggested.

Selmi et al. (2018) examined the roles of CRY as a hedge, safe haven, and/or diversifier against excessive BRT price swings, similar to the roles of gold. According to the study results, both Bitcoin and gold can serve as a hedge, safe haven, and diversifier for BRT price swings. However, this characteristic appears to be contingent upon the specific market conditions of CRY and gold, as well as the state of the BRT market (bearish, sideways, or bullish). The analysis provides robust evidence of the usefulness of both CRY and gold in diversified BRT portfolios, offering opportunities for diversification and mitigation of downside risk.

Das et al. (2020) investigated the hedging and safe-haven characteristics of CRY in relation to BRT implied volatility and structural shocks. The study also compared the hedging and safe-haven performance of CRY to that of gold, commodities, and the US dollar. The analysis revealed that CRY is not the optimal asset for hedging BRT-related uncertainty. Furthermore, the hedging effectiveness of different assets is contingent upon the nature of BRT risks and the prevailing market conditions. Consequently, investors may consider alternative investment products to mitigate negative risks under diverse economic and market circumstances.

Yin et al. (2021) investigated the impact of BRT market shocks on the long-term volatility of CRY. The research findings of the study indicate that BRT has both adverse and favorable effects on CRY's long-term volatility. Additionally, the study revealed that a negative BRT market shock enhances the attractiveness of CRY as it provides refuge from unsystematic risk.

Heikal et al. (2022) aimed to investigate the impact of BRT prices on the returns of CRY. The findings of this study reveal that BRT accounts for 27.9% of the variability in the CRY return variable. Moreover, BRT has a significant influence on the CRY return. The movements of BRT in the global market have an effect on the return of CRY. The study found that changes in BRT prices in the global market positively affect the CRY return. For instance, an increase in BRT prices stimulates an increase in the return of CRY.

Musialkowska et al. (2020) investigated whether assets such as gold, BRT, or CRY can be considered safe havens for investors in crisis-ridden Venezuela. The findings of the study indicate that gold is a more reliable safe haven for Venezuelan traders compared to BRT, while CRY is considered a weaker safe haven. However, the study suggests that CRY can still serve certain monetary functions in a country experiencing a crisis.

Salisu et al. (2023) examined the potential impact of BRT prices on the realized volatility of CRY returns. The study finds that higher BRT prices have a dampening effect on the profitability and volatility of CRY. Specifically, as BRT prices increase, the cost of producing CRY rises, leading to reduced profits and subsequently lower trading activity and volatility. The study suggests that investors in the CRY market who take into account BRT price changes when making investment decisions are more likely to achieve favorable outcomes compared to those who overlook this factor.

3.2.1.3. BRT and GLB

The scholars provide substantial evidence of an association between BRT and GLB. The findings indicate bidirectional spillovers between the two markets, with the majority of the association being driven by transmissions from the BRT market to GLB markets. The dependency and risk spillover between GLB and BRT exhibit varied behaviors depending on the types of BRT shocks. For example, Maghyereh et al. (2016) examined the directional association between BRT and GLB in major stock markets worldwide. The study found consistent results across the sample nations, indicating bidirectional information spillovers between the two markets, thereby establishing the association between oil and equity. However, the analysis revealed that the majority of the association is driven by transmissions from the BRT market to the GLB markets, rather than the other way around. The transmission pattern was found to be variable over time.

Phan et al. (2016) investigated the relationship between the volatility of BRT and GLB. The study's main findings provide substantial evidence suggesting a connection between BRT and GLB.

Attarzadeh & Balcilar (2022) empirically investigate the association between CRY, GLB, and BRT. According to the analysis, GLB transfers shocks in terms of return to CRY and BRT, while receiving shocks in terms of volatility from CRY and BRT. Additionally, during turmoil, BRT and GLB exhibit a weak relationship. However, their correlation significantly strengthens during financial crash, such as the 2018 CRY meltdown and the 2020 COVID-19 pandemic.

Tiwari et al. (2019) investigated the risk associated with BRT and GLB. The research discovered a significant long-term dependent between GLB and BRT. Almost all of the BRICS stock markets (excluding the Indian market) exhibited immediate dependency in both directions on BRT.

Liao et al. (2019) examined the effects of BRT on GLB. The findings suggested a positive and substantial dependency on BRT returns for both G-7 and BRICS nations, with the G-7 countries exhibiting an even greater dependence on GLB. Additionally, the study found that some countries demonstrated a tail relationship during a low or bear market, but neither group showed a connection with BRT returns when GLB was in a booming market.

Ji et al. (2020) analyzed the dynamic reliance and risk spillover between GLB and various BRT shocks. The major findings indicated that the dependence between GLB and BRT exhibited varied behaviors depending on the types of shocks in the BRT market. Furthermore, there was significant risk spillover from BRT-specific demand shocks to GLB returns across all sample nations.

4.2.1.4. BRT and ISM

There have been numerous studies contributing to our understanding of the relationship between the BRT and ISM markets. These studies have shed light on the presence of interaction and asymmetric spillovers between the two markets, particularly during times of global crises. One notable study in this regard is conducted by Shahzad et al. (2018) investigated the spillovers and interaction between the ISM and BRT markets. The findings highlighted the presence of interaction and asymmetric spillovers between the two markets, particularly in the lower tail dependency. The study also revealed an increase in interaction and asymmetric interaction during global crises.

Narayan et al. (2019) examined the sensitivity of ISM indexes to changes in BRT prices. The analysis indicated that only around 32% of these indexes demonstrated a statistically significant reaction to BRT prices, challenging the notion that oil prices uniformly impact the stock market. The study also revealed that trading based on BRT price sensitivity could lead to annual gains ranging from 5.8% to 13.6%.

B. H. Chang et al. (2020) investigated the influence of BRT prices on the ISM. The results showed a negative impact of lower and higher quantiles of BRT prices on the upper and lower quantiles of the ISM. Additionally, there was a positive association between the top or lower quantiles of both markets.

A. B. Khan et al. (2022) examined the relationship between BRT pricing and the performance of ISM and traditional market indices. The results demonstrated a strong reaction of both indices to BRT prices. Initially, this reaction was detrimental in the short and medium run but became beneficial in the long term.

M. A. Khan et al. (2023) investigated the dynamic connections among ISM, BRT, gold prices, and global policy uncertainty. The findings revealed positive connections between gold prices and ISM, negative coherence between gold prices and ISM during times of turmoil, and positive connections between BRT and ISM.

3.2.2. The relationship between EGS and financial markets

Several studies have explored the relationship between EGS, CRY, GLB, and ISM in the context of volatility spillovers and causal linkages, as well as complex asset connections. In this subsection, we present the most recent studies that have examined the relationship between EGS and these markets.

Huynh et al. (2020) found greater volatility transmission in the short run between robotics stocks, EGS, CRY, and gold, indicating that short-term shocks contribute more to volatility.

Yadav et al. (2023) examined the volatility spillover effects of EGS on renewable energy and the CRY market, revealing evidence of volatility spillovers from EGS to both sectors, with spillovers being more prominent in the medium and long runs. Additionally, Lee et al. (2023) explored the causal linkages between CRY and EGS, discovering a significant tail connection and two-way Granger-causality between these variables.

The relationship between EGS and GLB has also been investigated. Laborda & Sánchez-Guerra (2021) studied the impact of EGS offerings on company share prices in GLB markets, finding that the announcement of an EGS issuance generates a positive market effect.

Park et al. (2020) examined the volatility dynamics and spillovers between EGS and GLB, uncovering asymmetric volatility in the EGS market and volatility spillover effects between the two sectors.

Recently, Jiang et al. (2022) employed QQ approaches to examine the interconnections between EGS and GLB. To cover the COVID-19 pandemic, the researchers utilized daily data from five representative markets. The research findings indicate a positive association between EGS and GLB, highlighting their significance as diversifiers, especially at the extreme lowest quantiles of the treasury market and green bonds. In the medium term, EGS demonstrate superior hedging capabilities for currency and stock markets. The portfolio analysis further confirms the hedging and diversification advantages offered by green bonds. In the context of ISM, the relationship between EGS and ISM has been explored.

Ejaz et al. (2022) investigated the market risk, dependency structure, and portfolio diversification advantages of EGS in comparison to ISM and GLB, finding symmetric upper and lower tail dependency between EGS and ISM.

Furthermore, Billah et al. (2023) investigated the return association between ISM and EGS, observing fluctuations in the return relationship over time, with a significant influence detected during the COVID-19 pandemic. Regarding EGS and financial markets, there are volatility spillovers from EGS to renewable energy sectors and CRY, particularly in the medium and long runs. Causal linkages are identified between CRY and EGS. EGS also influences GLB, and ISM markets, with positive effects observed upon the announcement of EGS issuance and volatility spillovers between the two sectors.

3.2.3. The relationship between CRY and financial markets

Several studies have investigated the relationship between CRY and GLB, as well as ISM, in terms of risk sensitivity, diversification potential, and spillover effects. These studies contribute to our understanding of the relationships between CRY, GLB, and ISM, providing insights into risk sensitivity, diversification potential, and spillover effects in these markets.

Regarding the relationship between CRY and GLB, Aliu et al. (2021) examined the diversification risk of a CRY portfolio compared to a GLB portfolio and found that CRY has a larger positive connection and is more volatile than GLB.

Bouri et al. (2020) studied the capacity of prominent cryptocurrencies to diversify against GLB and found evidence that CRY can be used as a hedge against GLB, particularly in Asian Pacific and Japanese equities. The study also highlighted the time-variability in the diversification potential of CRY, suggesting that their effectiveness as hedges may change over time.

Hanif et al. (2022) investigated the spillovers between CRY and GLB, discovering risk spillovers from CRY to GLB.

In the context of ISM, Rehman et al. (2020) examined the risk sensitivity of the CRY and ISM markets, finding substantial long memory capabilities and a time-varying correlation between ISM and CRY.

Ahmed (2021a) explored the reactivity of ISM stocks to realized volatility in CRY and observed that CRY's upside volatility has immediate and delayed negative effects on ISM in developed markets, particularly during down market situations. The study also found that the correlation patterns between CRY volatility and ISM are asymmetric and have strengthened in recent years.

Akinlaso et al. (2023) investigated whether ISM can provide portfolio diversification benefits for CRY investors and concluded that ISM can offer diversification alternatives for CRY investors, although ISM may be inefficient and prone to short-term speculative behaviors. The relationship between CRY and financial assets reveals their larger positive connection and higher volatility compared to global equity markets. CRY offer diversification potential against GLB, although the effectiveness of this diversification may change over time. Risk spillovers are detected from CRY to GLB. In the context of ISM, CRY offer diversification alternatives but may exhibit inefficiency and short-term speculative behaviors.

3.2.4. The relationship between GLB and ISM

There have been several studies contributing to our understanding of the relationship between GLB and ISM markets from various perspectives, including systematic risk, interdependence, dynamics, and efficiency. These studies have shed light on the presence of interaction and asymmetric spillovers between the two markets, particularly during times of global crises.

One notable study in this area is conducted by Sensoy (2016), who utilized dynamic risk indicators to compare the systematic risk levels of GLB and ISM markets. The analysis revealed that, for the majority of the sample period, GLB markets exhibited slightly higher levels of systematic risk compared to ISM markets. However, this difference in systematic risk was substantial in less than 3% of the sample period, indicating that ISM shares may not offer lower market risk than their GLB counterparts during financial turmoil.

Hammoudeh et al. (2014) examined the interdependence and dynamics between ISM and key GLB indexes. Their study found that the ISM demonstrated significant dependence on GLB, particularly during periods of economic turmoil. The relationship between ISM and GLB was shown to change over time, with certain circumstances leading to an unbalanced relationship between the two markets, especially in bear and bull market conditions.

Similarly, El Khamlichi et al. (2014) investigated the efficiency and diversification potential of ISM compared to GLB. Their findings indicated that ISM and GLB exhibited similar levels of efficiency or inefficiency. Furthermore, the analysis of cointegration revealed that ISM from the GLB did not have cointegrating relationships with their respective benchmarks, suggesting that the two markets may operate independently of each other.

The relationship between GLB and ISM is examined in terms of systematic risk, interdependence, dynamics, and efficiency. GLB generally exhibits slightly higher systematic risk levels compared to ISM. The interdependence between Islamic equity markets and global equity markets is evident, especially during economic turmoil, with changing relationships over time. Efficiency and diversification potential show similar levels between ISM and GLB. In the following, Table 3.1 summarizes the previous studies.

Table 3.1:*Summary of Previous Studies*

Authors	Variables	Period	Method	Result
Ahmed (2021a)	CRY and ISM	2014-2021	Quantile regression	Negative relationship
Azhgaliyeva et al. (2022)	BRT and EGS	2010-2021	Structural VAR	Positive relationship
B. H. Chang et al. (2020)	BRT and ISM	1996-2019	QQ	Asymmetric relationship
Billah et al. (2023)	EGS and ISM	2014-2021	Quantile-based connectivity	bi-directional causality
Ejaz et al. (2022)	EGS and ISM	2014-2020	Copula model	Dependency
Hammoudeh et al. (2014)	GLB and ISM	199-2013	Copula model	Dependency
Hanif et al. (2022)	CRY and GLB	2015-2019	Copula model	Positive relationship
Ji et al. (2020)	BRT and GLB	1994-2016	SVAR and Copula model	Asymmetric relationship
Jiang et al. (2022)	EGS and GLB	2014-2020	QQ	Positive relationship
Lee et al. (2021)	BRT and EGS	2013-2019	Granger-causality in quantile	bi-directional causality
Lee et al. (2023)	EGS and CRY	2014-2022	Granger-Causality in quantiles	bi-directional causality
Li et al. (2022)	BRT and EGS	2017-2021	TVP-VAR	Negative relationship
Liao et al. (2019)	BRT and GLB	2000-2018	Copula model	Positive relationship
M. A. Khan et al. (2023)	BRT and ISM	1996-2018	Wavelet coherence	Positive relationship
Park et al. (2020)	EGS and GLB	2010-2020	GARCH model	Asymmetric relationship
Phan et al. (2016)	BRT and GLB	2009-2012	GARCH model	Positive relationship
Shahzad et al. (2018)	BRT and ISM	1996-2015	Copula model	Asymmetric relationship
Su et al. (2023)	BRT and EGS	2011-2021	QQ	Positive in short run, negative in medium and long run

Table 3.1 (Continued).

X. Wang et al. (2022)	BRT and EGS	2012-2022	DCC-MIDAS and causality in quantiles	Asymmetric relationship
Yin et al. (2021)	BRT and CRY	2013-2018	GARCH-MIDAS	Asymmetric relationship

TVP-VAR stands for Time-Varying Parameter Vector Autoregression

3.2.5. Hypotheses of the study

Based on the literature, the study tests the following hypotheses:

- Hypothesis 1: There is a tail dependency between EGS and BRT.
- Hypothesis 2: There is a tail dependency between EGS and CRY.
- Hypothesis 3: There is a tail dependency between EGS and GLB.
- Hypothesis 4: There is a tail dependency between EGS and ISM.
- Hypothesis 5: The dependency between two financial assets extends to other assets.

3.3. Data and Methodology

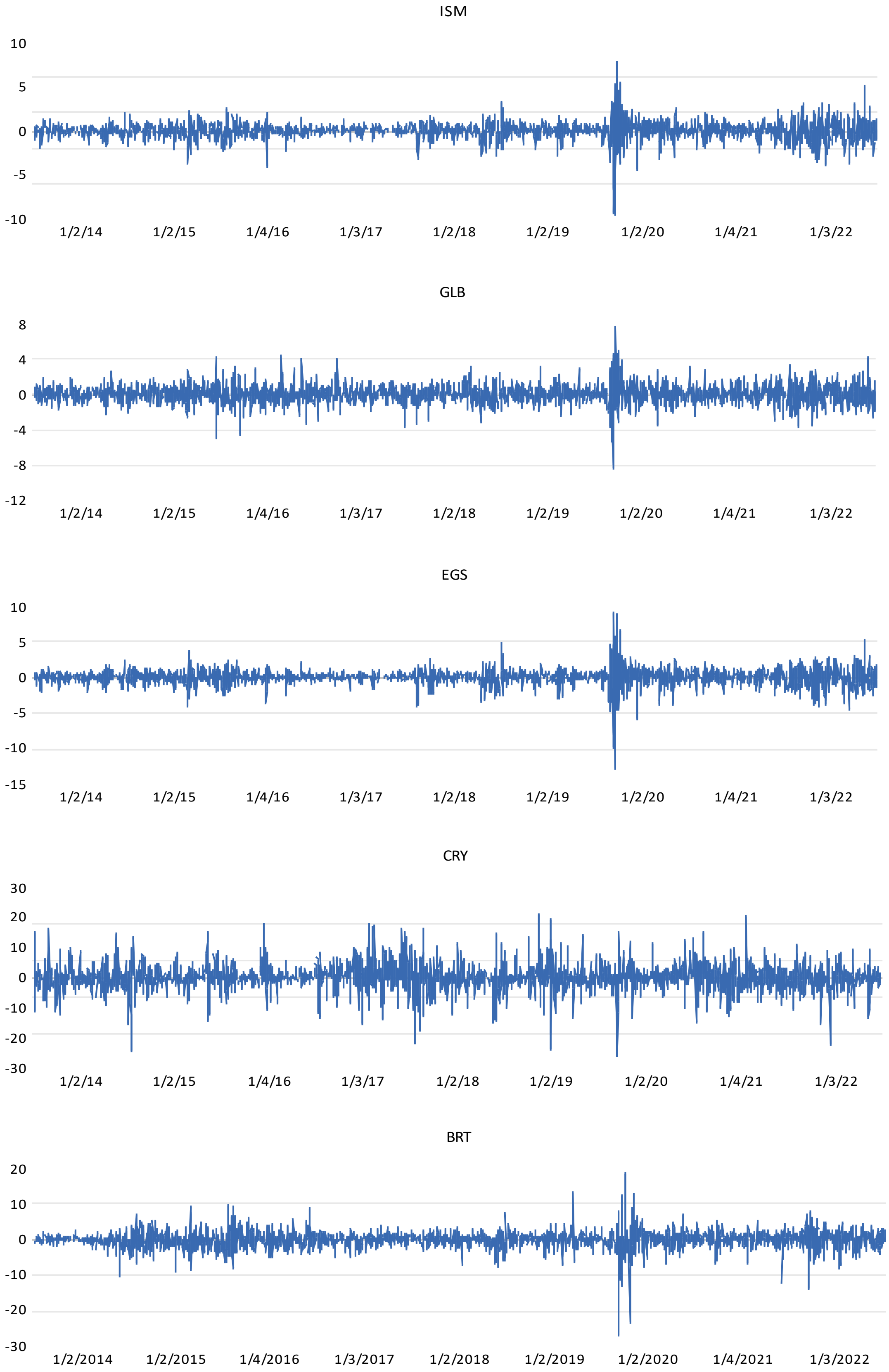
3.3.1. The Data

To examine the dependency relationship between different financial assets, this study selected an index of green financial assets represented by EGS. The EGS index measures the performance of financial assets that prioritize sustainability. Additionally, a representative index of cryptocurrencies, CRY, was included. This index tracks the performance of the most valuable cryptocurrencies in the market. Furthermore, an index for Islamic assets, ISM, was chosen to track the performance of financial assets that comply with Islamic sharia. Finally, the GLB indicator, representing 70% of the global market capitalization, was incorporated. The data covers the period from January 1, 2014, to December 30, 2022. The data was obtained from S&P Global Market Intelligence (2023). Financial data is influenced by a range of economic and political factors, which can introduce noise. To mitigate this noise, the data has been transformed into continuous returns, as illustrated in the following equation:

$$R_t = 100 * ln\left(\frac{P_t}{P_t} - 1\right)$$

Where R_t represents the continuous returns, P_t indicates the price at time t, and $P_t - 1$ represents the previous price (Brooks, 2019). The operational workdays of financial markets vary across different markets. While the digital currency market operates continuously throughout the week, other markets function for five days only, resulting in gaps in the study data. To address this issue, the operational schedules of all financial markets were standardized to five days, resulting in a total of 11,330 observations for each variable. Figure 3.1 displays the study's data in the form of continuous returns. The figure clearly illustrates the volatility within the study data. CRY exhibits the highest intensity, fluctuating between 20 and -30. BRT follows with volatility ranging approximately from 10 to -20. It appears that EGS is the least volatile.

Figure 3.1: *The Continuous Returns of the Variables*



3.3.2. The Methodology

3.3.2.1. GARCH (1, 1)

Financial data is well-known for its reliance on past values, which gives rise to a statistical concern known as autocorrelation when analyzing the data (Brooks, 2019). To address this issue, the GARCH (1,1) model is commonly employed, particularly when utilizing the copula approach ((Liu, 2011). The study employs a two-step estimation procedure. In the first step, the conditional variance for the marginal distributions is estimated by applying the GARCH (1,1) model, and the standardized residuals are obtained. In the second step, copula data is defined based on the standardized residuals derived from the GARCH model(Mar'i & Tursoy, 2021). The initial step involves modeling with GARCH (1,1). However, it is recognized that the original assumption of GARCH assumes normality in the disturbance term, which does not align with financial data exhibiting fat tails (Czado, 2019). Therefore, in this domain, the Student's t-distribution is typically utilized as follows:

$$Y_t = \sigma_t Z_t$$
$$\sigma_t = \omega + \alpha Y^2{}_{t-1} + \beta \sigma^2{}_{t-1}$$

Where $\sigma_t = var(Y_t | Y_1, \dots, Y_{t-1})$, the innovation Z_t is assumed to follow student t-distribution.

3.3.2.2. The R-vine Copula

The copula method is commonly used in finance and economics research, particularly in studies exploring the dependence between financial markets, economic contagion, and the transfer of financial risks between markets (Mar'i & Tursoy, 2021). For example, Hammoudeh et al. (2014) employed the copula approach to investigate the dynamic dependence between ISM and GLB. Similarly, Rehman et al., (2020) utilized time-varying copulas to examine the risk spillover between CRY assets and ISM. Huynh et al., (2020) employed copula to study the interaction between EGS and CRY. Ejaz et al. (2022) utilized copula to investigate the risk spillover, dependency, and diversification benefits of EGS in relation to ISM and GLB. Furthermore, Hanif et al. (2022) explored the interaction between CRY's assets and GLB using copula. In the subsequent step, the copula data is established utilizing the standardized residual obtained from the preceding GARCH(1,1) model. This process generates pseudo-observations, which are subsequently employed for estimating the copula. The generation of pseudo-observations is accomplished through the following equation:

$$u_{it} = F\left(\frac{y_{it}}{\hat{\sigma}_{it}}; \hat{v}_i\right)$$

Where $\hat{\sigma}_{it}^2$ is estimated conditional variance for market i= 1,2,..,6, $\hat{\nu}_i$ is degree of freedom, and t refers to time 1,2,…,T. According to Sklar’s (1959) theorem, the copula refers to a specific joint distribution formed by given marginals. Sklar (1959) states in his theorem that for an n-dimensional random vector $X = (X_1, \dots, X_n)$ with each X_i having a univariate marginal continuous distribution function F_i defined on the interval [0,1], the joint distribution function can be expressed as:

$$F(X_1, \dots, X_d) = C\big(F_1(X_1), \dots, F_n(X_n)\big)$$

Where, C represents the copula function, which combines the individual marginal distribution functions $F_1(X_1)$, $F_2(X_2)$, ..., $F_n(X_n)$ to determine the joint distribution $F_1(\mathrm{X}_1, \dots, \mathrm{X}_n)$. By generating an initial pair of copulas to construct a multivariate copula in terms of distribution functions, Joe (1997) proposed conditioning as the optimal method for building multivariate distributions using bivariate structures alone. Additionally, Bedford & Cooke (2001) and Bedford & Cooke (2002) developed new copula designs that were more representative and introduced a comprehensive framework for defining all possible structures. The density function $f(x_1, \dots, x_n)$, which represents the Pair-Copula Decomposition (PCCs), can be factored as follows:

$$f(x_n).f(x_{n-1}|x_n).f(x_1|x_2, \dots x_n)$$

The marginal distribution in the preceding equation can now be expressed as follows:

$$f(x_i|k) = c_{x_i v_l|v-l}(f(x_i|k_{-l}), F\left(k_j\middle|k_{-l}\right)). f(x_i|k_{-l})$$

Where, $k = x_{i+1}, \dots, x_n$ represents the marginal distribution of x_i, and k_l is a variable in the set k. The term $f(x_i|k)$ represents the bivariate density copula and the product of the marginal density function of x_i. k_{l-1} represents the remaining variable(s) still present in k after removing k_l. The index i refers to {1,…,(n-1)}, and the density function c is defined as:

$$\frac{\partial C(u_1,u_2)}{\partial u_1 \partial u_2}$$

The normal vine copula is one among several types of the PCCs, which calculates c as the product of bivariate copulas (n(n-1))/2. This approach is valuable for modeling dependencies as it accommodates asymmetry and variable reliance on upper and lower tails (Loaiza Maya et al., 2015). The R-vine copula was initially introduced by Bedford & Cooke, (2001, 2002) and is described as follows:

$$f(x) = \prod_{k=1}^{n} f_k(x_k) \prod_{i=1}^{n-1} \prod_{j=1}^{n-i} c_{mi,i,mj,i|m_j+1,i,\dots,m_{n,i}}\left(f_{mi,i|mj+1,i,\dots m_{n,i}}\right), F_{mj,i|mj+1,i,\dots,m_{n,i}}(x_{mj,i|mj+1,i,\dots,m_{n,i}})$$

Where $m_{n,i}$ represents the R-vine matrix element in the m matrix. Tail dependency indicates the extent to which bivariate variables depend on each other in extreme situations. In other words, tail dependency illustrates the probability that a particular variable will exceed a given threshold if the other variable does. The study estimates the upper and lower dependency tails using Joe’s (1997) definition:

$$\lambda_u = \lim_{u \to 1^-} p\left(X_1 > F_1^{-1}(u)\middle|X_2 > F_2^{-1}(u)\right) = \lim_{u \to 1^{-1}} \frac{1-2u+C(u,u)}{1-u}$$

$$\lambda_m = \lim_{u \to 0^-} p\left(X_1 < F_1^{-1}(u)\middle|X_2 > F_2^{-1}(u)\right) = \lim_{u \to 0^{+1}} \frac{1-2u+C(u,u)}{1-u}$$

3.3.2.3. Cross-Wavelet Transform

Financial time series data present several unresolved issues regarding their behavior across different frequencies. As a result, researchers have employed a range of techniques to enhance their understanding of this behavior. Currently, wavelet analysis stands out as the most commonly utilized tool for this purpose. Its primary advantage lies in its capability to simultaneously capture information from both the time domain and the frequency domain (Tursoy & Mar'i, 2020; Tursoy & Mar'i, 2022). Wavelet transforms utilize a fundamental function called the mother wavelet, which is stretched and shifted to capture local characteristics in both time and frequency domains. By combining various permutations of shifting and stretching the original wavelet, the wavelet transform captures all information in a time series and associates it with specific time horizons and positions in time (Gençay et al., 2001). Cross-wavelet analysis is considered an effective tool for evaluating potential connections between two time series. The continuous wavelet transform can be extended to incorporate time series and construct cross-wavelet transforms, which identify regions of significant joint influence and provide additional information on phase relationships (Grinsted et al., 2004). When two wavelet transforms are applied to the same mother wavelet, the cross-wavelet transform displays the degree of similarity between the initial wavelet transforms or signals. The magnitude of the cross-wavelet transform can be used to infer the presence of mutual signals or to determine the source of these shared signals. Similarities can arise due to various reasons, and different approaches may provide distinct explanations for this similarity. The magnitude of the cross-wavelet transform will exhibit a peak that indicates this similarity (Young, 1993). The cross-wavelet transform provides valuable information for the interaction between two time series, x and y, in the time and frequency domain, through bivariate analysis. It can be defined as follows:

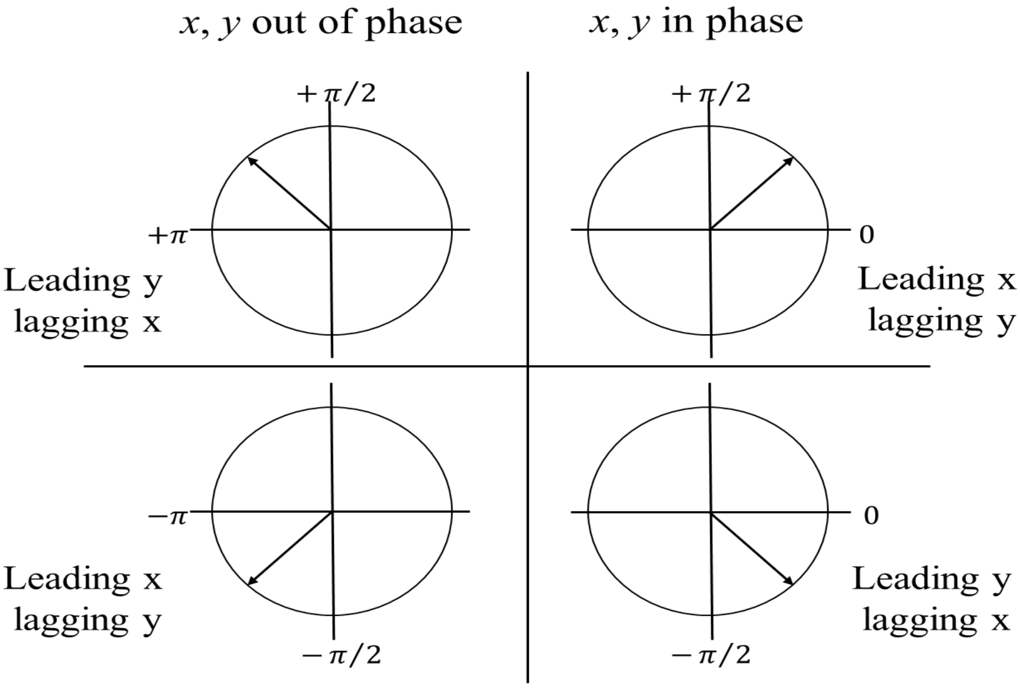
$$wxy\ (t,s) = wx(t,s).\overline{w}y(t,s)$$

Where wx and wy represent the wavelet transformations of x and y, respectively. The cross-wavelet power is determined by $|wx, y(t,s)|$and can be defined as an indicator of the local variance of a time series. The cross-wavelet power of two time series indicates the local co-variance between the two series at each time and frequency. In this study, we follow the approach of (Veleda et al., 2012), who utilize the cross-wavelet transform to avoid introducing any inaccuracies by giving equal importance to large-scale connecting phenomena and small-scale phenomena. To examine the lead-lag relationship between the variables, the study utilizes the phase difference approach proposed by Torrence & Compo (1998), following the methodology Rösch & Schmidbauer (2016)). The phase difference is determined as follows:

$$Angle(\mathcal{T},\mathcal{S}) = Arg(Wave.xy(\mathcal{T},\mathcal{S}))$$

The x-over-y phase difference at each time and scale can be interpreted as the difference between individual local phase angles when translated into an interval angle $[-\pi,\pi]$. If the absolute value of the phase difference at a specific scale is less than or greater than π/2, the two series are considered to be in phase (anti-phase). Figure 3.2 displays the interpretation of phase differences.

Figure 3.2: *Interpretations of phase differences*



3.4. Results and Discussions

3.4.1. Descriptive statistics

Table 3.2 presents the descriptive statistics for the study sample. The table highlights the mean values of variables. Notably, GLB exhibits the highest mean value of 0.135, while ISM displays the lowest mean value, which is negative at -0.014. This negative value could suggest the presence of negative returns. However, the median values tell a different story, with ISM having the highest median of 0.107, while CRY possesses the lowest median of 0.047. The significance of the median lies in its robustness against extreme values, providing a more reliable measure in such cases. The standard deviation values indicate that GLB is the most volatile, with a value of 4.420, followed by ISM with a value of 2.487. On the other hand, BRT exhibits the least volatility, with a value of 0.986. Regarding the deviation and distributional asymmetry of the data, Table 3.2 indicates that all variables exhibit a left-skewed distribution, as evidenced by their longer left tails compared to the right tails. Specifically, ISM and BRT display the greatest leftward deviation, with values of -0.840 and -0.801, respectively. Similar patterns are observed for kurtosis, where ISM and BRT exhibit heavy tails with values of 17.167 and 15.591, respectively. Additionally, EGS exhibits the most pronounced heavy tails, with a value of 18.933, while GLB exhibits the least significant heavy tails, with a value of 7.086.

Table 3.2: *Descriptive statistics*

	BRT	CRY	EGS	GLB	ISM
Mean	0.025	0.041	0.035	0.135	-0.014
Median	0.064	0.047	0.063	0.099	0.107
Standard deviation	0.986	1.092	1.154	4.420	2.487
Skewness	-0.801	-0.112	-0.788	-0.186	-0.840
Kurtosis	15.591	8.424	18.933	7.086	17.167
Jarque-Bera	15202.755 ***	2780.922 ***	24192.893 ***	1588.686 ***	19206.632 ***
ARCH test	512.060 ***	191.840 ***	940.140 ***	570.270 ***	815.280 ***
ADF test	-18.351 ***	-23.832 ***	-20.437 ***	-18.897 ***	-20.336 ***

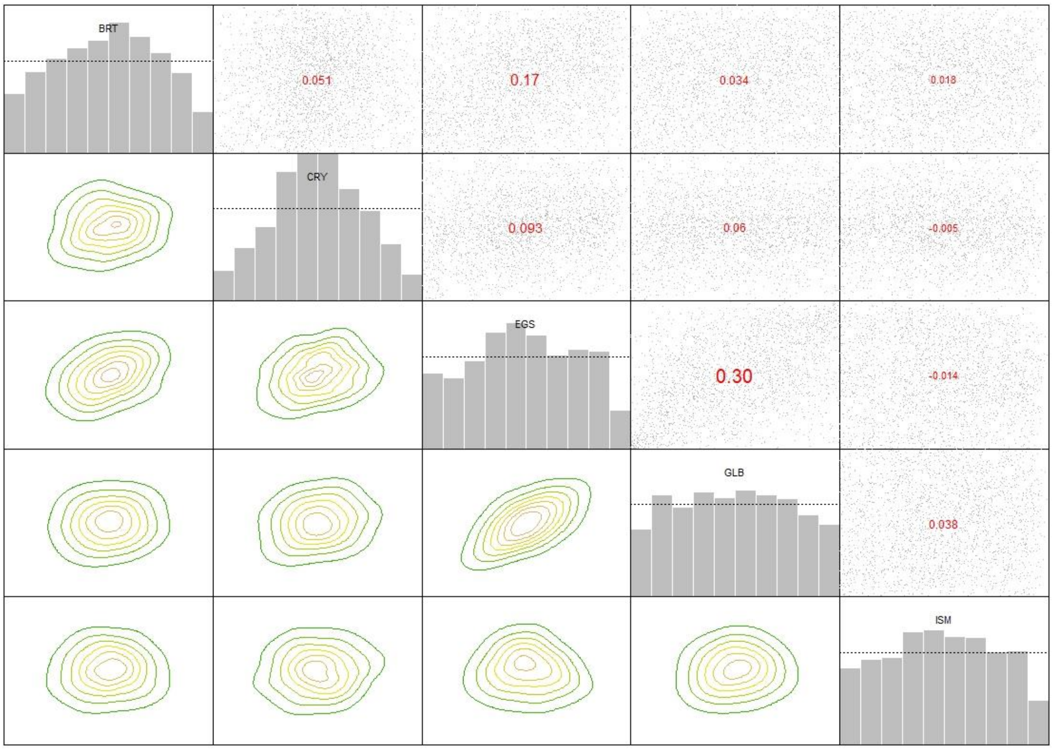
*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

With regard to normality, the data does not conform to a normal distribution, as indicated by the Jarque-Bera test. Additionally, the Arch test suggests that the data's variance is not constant, indicating the presence of heteroscedasticity. To address this issue, the GARCH (1, 1) model was employed, as explained in the methodology section. The augmented Dickey-Fuller test (ADF) unit root test proposed by Dickey & Fuller, (1979) indicates that the variables are statistically significant, thereby accepting the alternative hypothesis that the data does not contain a unit root.

3.4.2. Copula Analysis

The analysis of the R-Vine copula begins by examining the pairwise relationships among the research variables, as shown in Figure 3.3. The contour shapes suggest the presence of bivariate dependencies between the variable pairs. The right side of the plot displays the copula dependence values between the variables, with the diagonal histogram depicting the copula margins. On the left side, normalized contour plots represent the variables. Overall, it is evident that the dependencies among variables are predominantly positive, except for the dependence between ISM and EGS, as well as between ISM and CRY. According to Kendall's correlation coefficient, the range of dependence values varies between -0.014 and 0.40.

Figure 3.3: *The dependence between the variables*



The left-hand side represents the copula shape, the diagonal represents the copula distribution, while the right-hand side indicates the dependence across the sample.

Table 3.3 and Figure 3.4 to 3.7 present the results of multivariate copula dependency using R-vine copula. Tree 1 in Figure 3.4 indicates dependencies between BRT and EGS, with values of 0.38 in the upper tail and 0.07 in the lower tail. There is also a dependency between CRY and EGS, with a value of 0.19 in both the upper and lower tails. Furthermore, the first tree also reveals a dependency between EGS and GLB, with a value of 0.25 in both the upper and lower tails. And finally, there is a dependency between ISM and GLB in the lower tail, with a value of 0.12, while no dependency (independence) is observed in the upper tail. Tree 2 in Figure 3.5 illustrates dependencies between BRT and CRY with EGS in both the upper and lower tails, each with a value of 0.05. However, there is no observed dependency between BRT and GLB with EGS. Likewise, no dependency is observed between ISM and EGS with GLB.

Figure 3.4: *Tree 1*

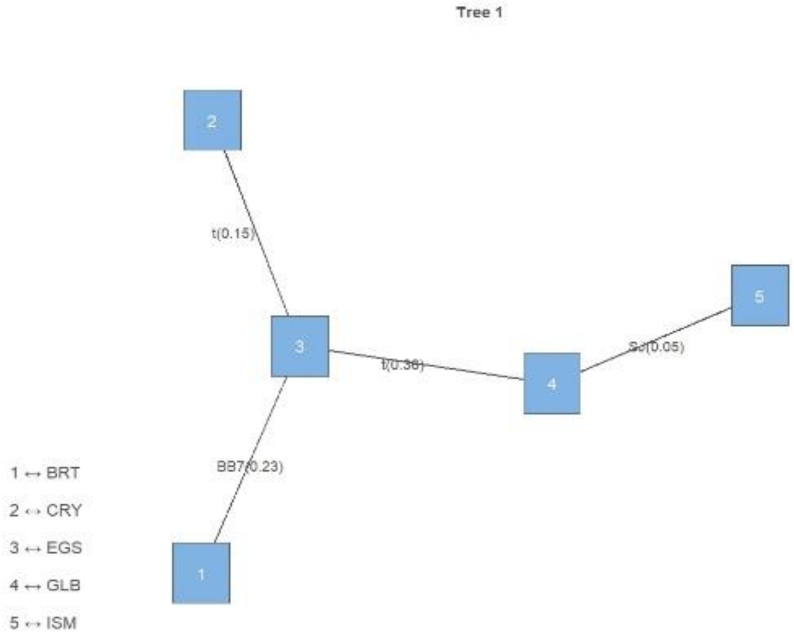
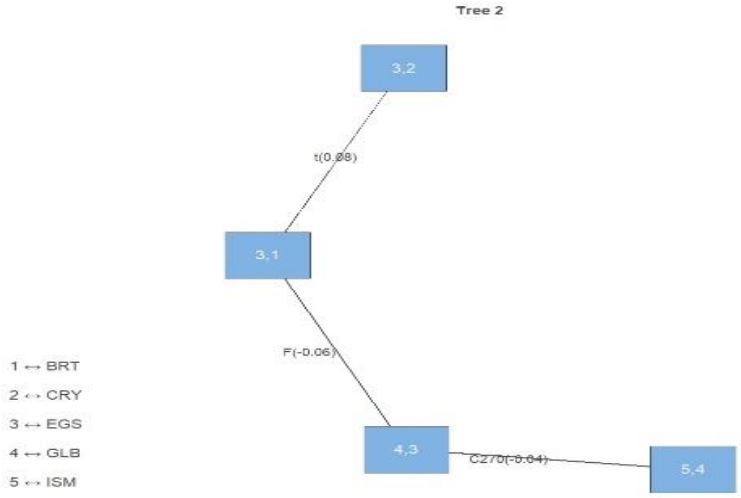


Figure 3.5: *Tree 2*



Tree 3 in Figure 3.6 reveals no dependence between GLB and CRY with BRT and EGS index. Additionally, it indicates no dependence between BRT and Islamic investment (ISM) with EGS and GLB. Similarly, Tree 4 in Figure 3.7 demonstrates no dependency between CRY and ISM with BRT, GLB, and EGS. Moreover, the interaction between these markets among themselves is not significant.

Figure 3.6: *Tree 3*

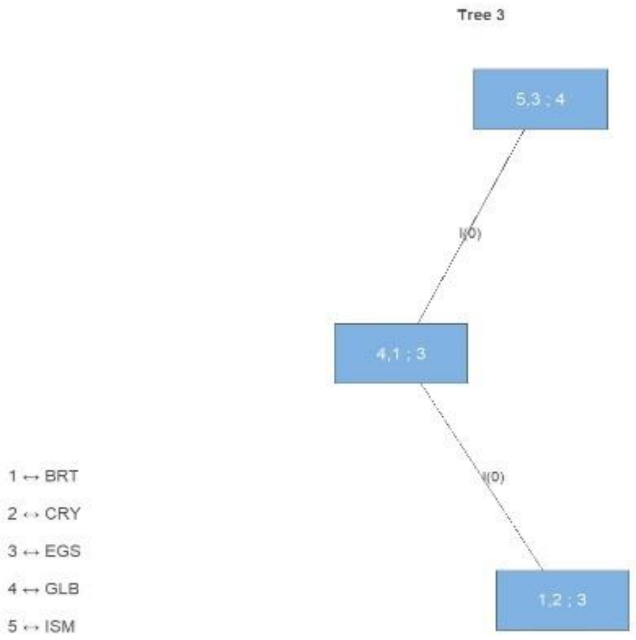


Figure 3.7: *Tree 4*

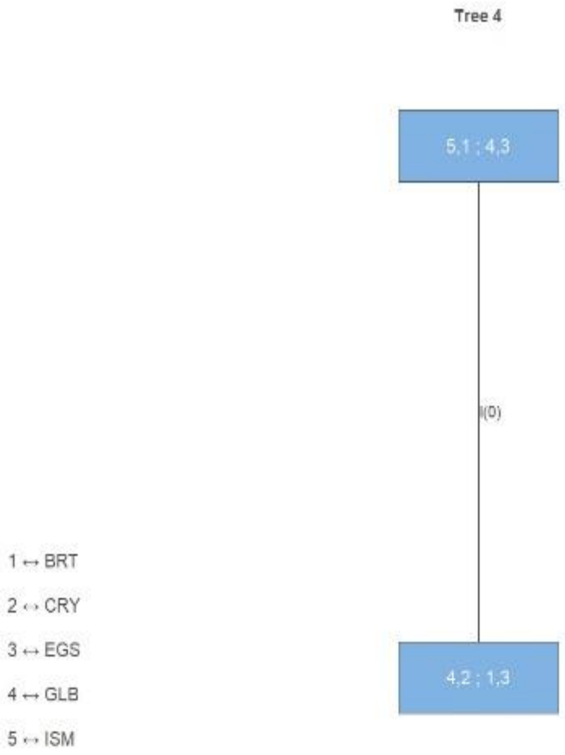


Table 3.3: *Results of R-vine Copula*

Tree	Edge	COP	Par	Par2	UTD	LTD
1	3,2	t	0.24	3.04	0.19	0.19
	3,1	BB7	1.43	0.26	0.38	0.07
	4,3	t	0.55	4.58	0.25	0.25
	5,4	SJ	1.09	0	-	0.12
2	1,2;3	t	0.13	6.2	0.05	0.05
	4,1;3	f	-0.46	0	-	-
	5,3;4	C270	-0.08	0	-	-
3	4,2;1,3	I	-	-	-	-
	5,1;4,3	I	-	-	-	-
4	5,2;4,1,3	I	-	-	-	-

Edge indicates the dependency relationship, where 1, 2, 3, 4, and 5 represent BRT, CRY, EGS, GLB, and ISM, respectively. COP denotes the copula family, while Par and Par2 indicate the parameters of the upper tail (UTD) and lower tail (LTD), respectively.

3.4.3. Cross-Wavelet Transform.

After analyzing the dependency relationships among different markets, the study further examined the interaction and lead-lag relationship between the markets in a bivariate form, using the results obtained from copula analysis. Figure 3.8 to 3.11 show the cross-wavelet transform between financial markets, along with the phase difference. The contour lines represent the 5% significance threshold against red noise, with lighter shades indicating the cone of effect. The cone of effect is determined through Monte Carlo simulations using phase randomized surrogate series. The color code for power ranges from blue (low power) to red (high power). Additionally, arrows are used to indicate phase shifts. In terms of the bivariate relationship between EGS and CRY, Figure 3.8 shows an interaction between the two variables observed over time and at different frequencies. Specifically, at low frequencies (2-32) around 2016, CRY lags behind EGS. However, the relationship switches, and EGS becomes the leading variable while CRY lags around 2018. In 2020, EGS continues to lead, but there is no clear pattern in 2022 at low frequencies. At medium frequencies (32-128) and high frequencies (>120), EGS consistently leads while CRY lags, except for the year 2022. Regarding the bivariate relationship between BRT and EGS, it is observed in Figure 3.9 that BRT leads at medium and high frequencies, while EGS lags, except for the year 2016. At low frequencies, EGS leads while BRT lags, except for the year 2020. With respect to the bivariate relationship between EGS and GLB, it is observed in Figure 3.10 that EGS has a dominant role, with GLB lagging and EGS leading at all different frequencies (low, medium, and high). Finally, Figure 3.11 shows the relationship between GLB and ISM, there is a changeable role between the variables at low frequencies. However, there is no lead-lag relationship at medium and high frequencies until 2020. After that, it is observed that GLB leads while ISM lags at all frequency horizons.

Figure 3.8: *Wavelet analysis- EGS & CRY*

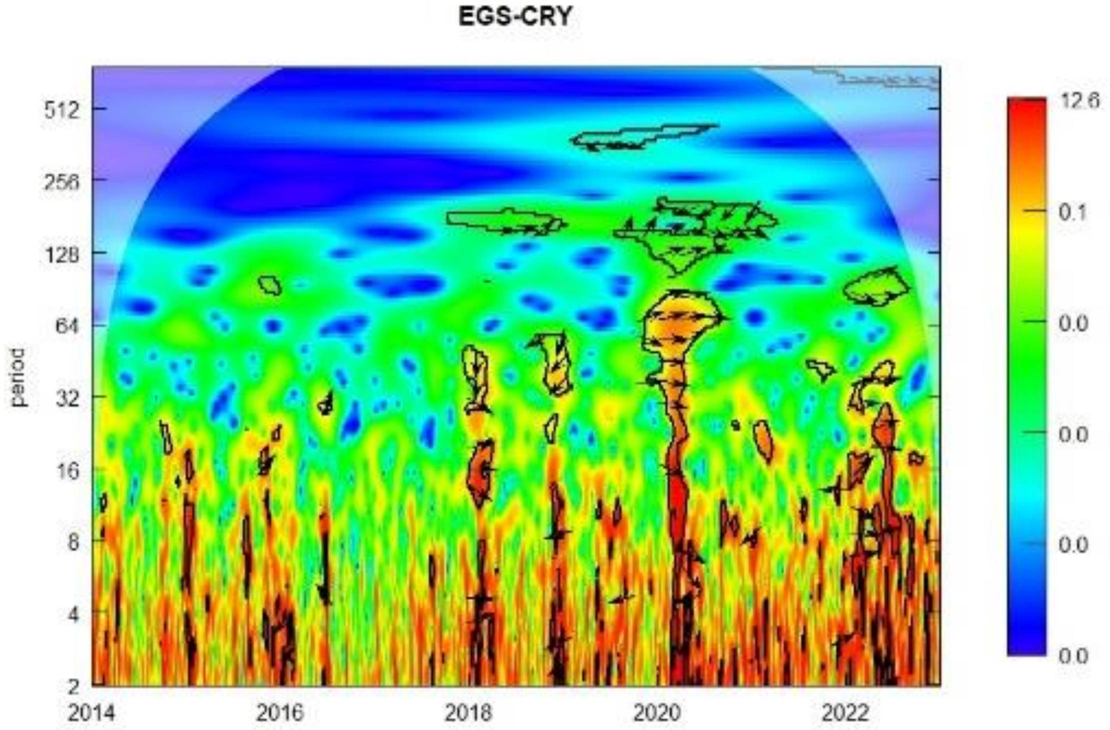


Figure 3.9: *Wavelet analysis- EGS & CRY*

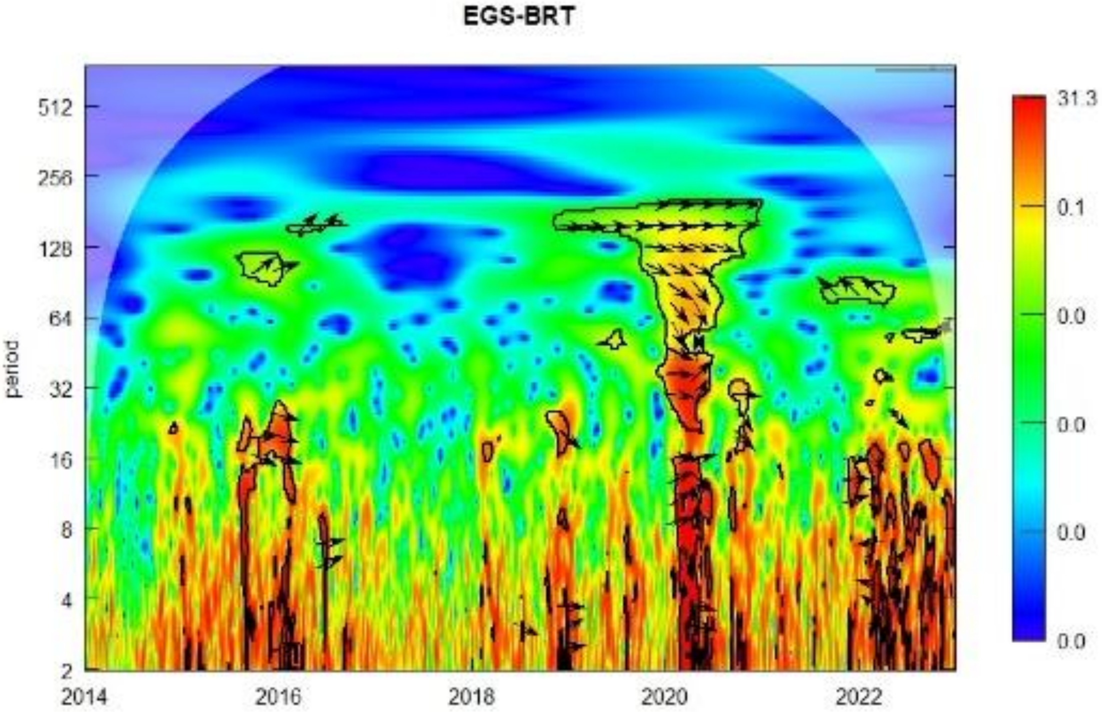


Figure 3.10: *Wavelet analysis- EGS & GLB*

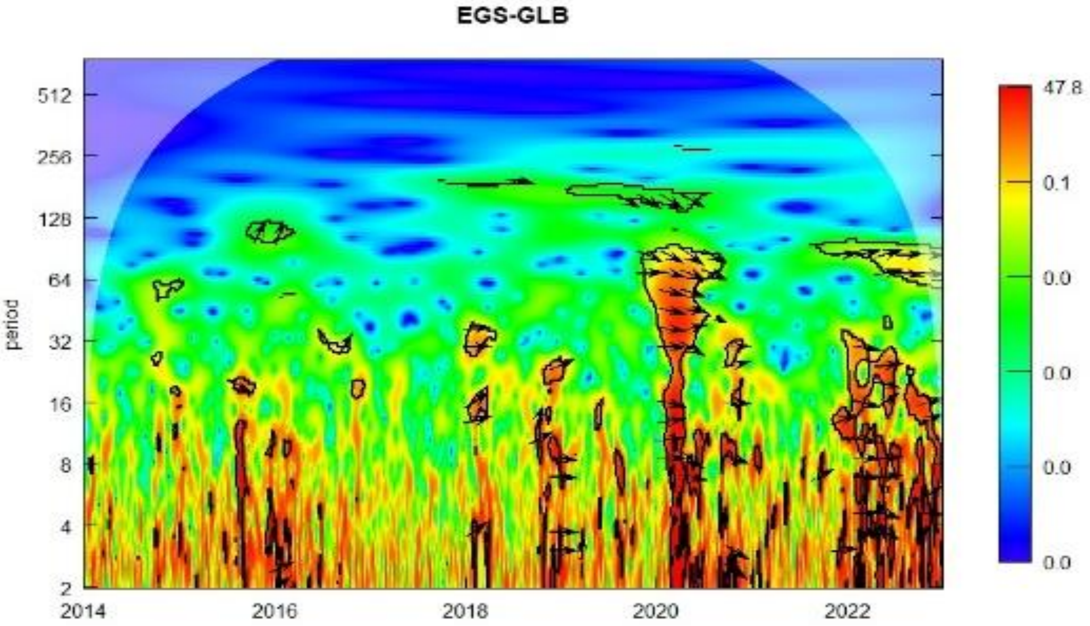
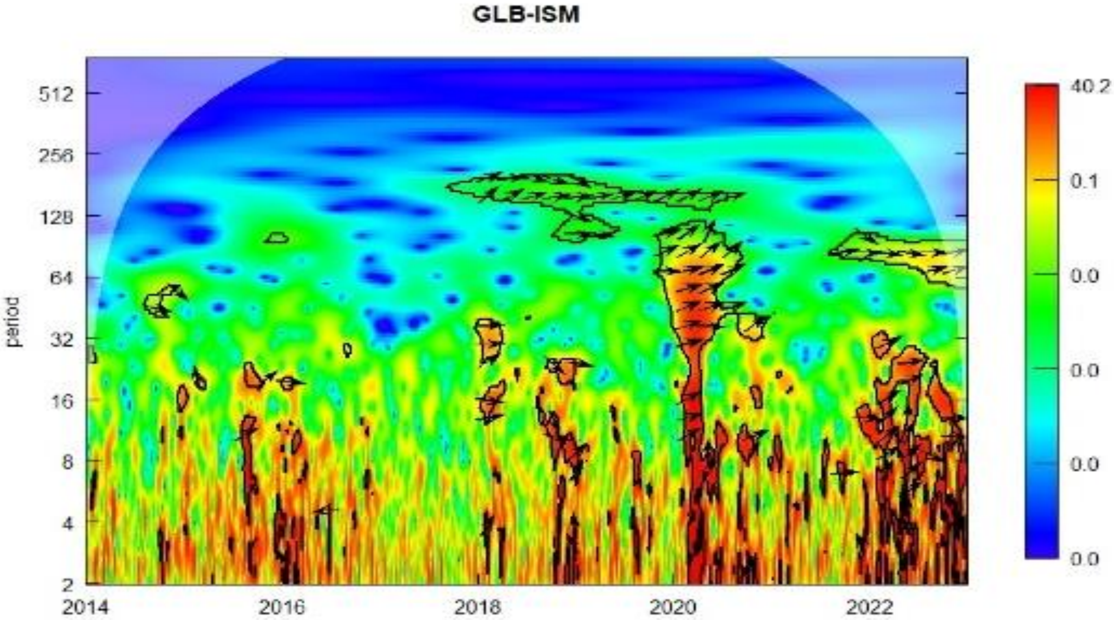


Figure 3.11: *Wavelet analysis- GLB & ISM*



3.4.4. Hypothesis results

Hypothesis 1. Regarding the bivariate dependency, the results confirm the existence of a dependency between EGS and BRT. This finding is consistent with previous research (Azhgaliyeva et al., 2022; Rehman et al., 2023; C. W. Su et al., 2023) that confirms a positive relationship between BRT and EGS. However, it is not fully aligned with the study by (X. Wang et al., 2022), which indicated a negative relationship between BRT and EGS. Overall, this result demonstrates that the relationship between EGS and BRT strengthens during bearish market conditions, while it weakens during bullish periods. This can be attributed to the differential response of the two variables to market shocks and news, whether positive or negative, as concluded by Lee et al. (2021) and indicated by Das et al. (2019). The reason for this may be related to theories concerning investor psychology, which suggest that investors react more strongly to negative shocks compared to positive shocks, as noted by Gupta et al. (2019). The cross-wavelet transform analysis shows that BRT tends to lead EGS at medium and high frequencies, except for certain time periods, while EGS tends to lead BRT at low frequencies. The lack of a specific pattern in the lead-lag relationship confirms the bidirectional causality concluded Lee et al. (2021) and can be justified by the complexity of the nature of the BRT market and the way the market reacts to economic turmoil, as indicated by K.-H. Wang et al. (2023).

Hypothesis 2. The tail dependence between EGS and CRY, and EGS and GLB remains equivalent regardless of market movements, indicating that the bivariate relationship between these variables is not influenced by bullish or bearish market conditions since they have a sizeable effect in the lower and upper tails. The results regarding EGS and CRY confirm the existing dependency between these markets in bullish and bearish cycles. This indicates that their movements can interact endogenously (Huynh et al., 2020). This interaction can be attributed to the fact that they are volatile markets and are simultaneously affected by economic turbulence (Yadav et al., 2023). The wavelet analysis shows that EGS and CRY switch their roles in leading and lagging at different times and different frequency horizons. This confirms the bidirectional relationship between these variables, as noted by Lee et al. (2023) and Syed et al. (2022).

Hypothesis 3. Regarding EGS and GLB, the results confirm the dependency between the lower and upper tails and a positive relationship. The wavelet analysis shows that EGS leads at all frequencies and at all times. This could be the result of recent global trends towards environmentally friendly projects, thus increasing the impact of EGS volatility on the GLB. These results are consistent with Laborda & Sánchez-Guerra (2021), Park et al. (2020), and Verma & Bansal (2023).

Hypothesis 4. The study results don't confirm the tail dependency between EGS and ISM, instead, the copula analysis confirms the existing dependency in the lower tails between GLB and ISM, while the upper tail shows independence. This is further supported by the wavelet analysis, which shows that the lead-lag relationship exists only at lower frequencies until 2020. This may be attributed to the increased interaction of investors and their reactions in the financial markets during negative circumstances in bearish periods, while this interaction decreases during bullish periods, as previously indicated. These results are consistent with Rahman et al. (2021), who found independence between GLB and ISM in bullish markets.

Hypothesis 5. The results of the study indicate that the dependency between the two financial markets does not extend to other markets. This means that the interaction between the two markets, whether during bullish or bearish times, does not have an impact on or interact with the performance of other markets. The influence of the interaction between these markets remains bilateral. However, there is an exception in the case of the dependency between BRT and CRY, where the effect may be transmitted to EGS during both bullish and bearish periods. A summary of hypotheses results is provided in Table 3.5.

Table 3.4: *Summary of hypotheses results.*

Hypothesis	Result
There is a tail dependency between EGS and BRT.	✓
There is a tail dependency between EGS and CRY.	✓
There is tail dependency between EGS and GLB.	✓
There is tail dependency between EGS and ISM.	X
The dependency between two financial assets extend to other assets.	X

3.5. Conclusion

In this study, we analyze the network of dependence between financial markets, specifically Brent, global, green, crypto, and Islamic, in order to verify the existence of tails dependence between these financial markets in bullish and bearish markets. In addition to determining the lead-lag relationship between these markets, depending on the dependency results. This study covers data from January 1, 2014 to December 30, 2022. copula and wavelet analysis was used to obtain the results. The results of this study provide interesting results about the dependency and interaction between various financial assets. The findings indicate that the dependency between two specific markets does not extend to other markets, suggesting that the influence of their interaction remains bilateral and does not impact the performance of other markets. However, an exception is observed in the case of the dependency between BRT and CRY, where the effect may be transmitted to EGS during both bullish and bearish periods. Regarding the bivariate dependency, the results confirm the existence of a positive relationship between BRT and EGS, consistent with previous research. However, this relationship is found to strengthen during bearish market conditions and weaken during bullish periods, potentially due to the differential response of the variables to market shocks and news. This pattern aligns with theories of investor psychology that highlight stronger reactions to negative shocks. The lead-lag analysis reveals that BRT tends to lead EGS at medium and high frequencies, while EGS leads BRT at low frequencies, indicating a bidirectional causality between the two variables.

The tail dependence analysis indicates that the bivariate relationship between EGS and CRY, as well as EGS and GLB, remains consistent regardless of market movements. The dependency between EGS and CRY is observed in both bullish and bearish cycles, suggesting an endogenous interaction between these volatile markets. The relationship between EGS and GLB is also confirmed, with EGS leading at all frequencies and times, potentially due to global trends favoring environmentally friendly projects. Regarding GLB and ISM, the copula and wavelet analyses reveal a dependency in the lower tails but independence in the upper tail. The lead-lag relationship is found to exist only at lower frequencies until 2020, indicating increased interaction and reactions of investors during negative circumstances in bearish periods. These results are consistent with previous research that found independence between GLB and ISM in bullish markets.

3.5.1. Policy Implications

The study's findings suggest that certain financial markets exhibit dependencies and lead-lag relationships, especially during bearish market conditions. Also, the results indicated stronger reactions to negative shocks in bearish markets. During these times, police should be on the lookout for potential market manipulation, as attempts might be made to exploit the observable interdependence and causality for unfair trading advantages. Additionally, policymakers should also give more attention to green bonds, develop their mechanism of action, and set regulations that would accurately regulate their relationship with other markets, especially since they are the most interactive with other markets.

3.5.2. Policy recommendation

Investors must be well-aware of the risks and vulnerabilities inherent in financial markets, particularly during downturns. By enhancing their understanding of potential hazards and promoting informed decision-making, the likelihood of falling prey to fraudulent schemes can be reduced. To combat financial fraud effectively, cooperation between law enforcement agencies and financial institutions is essential. Creating channels for information sharing and reporting suspicious activities can greatly assist in detecting and preventing illicit behaviors.

3.5.3. Limitations and Future Research

The study's limitation is attributed to the restricted time period resulting from the limited availability of data. Extending the time frame could potentially yield crucial findings that would enrich our long-term comprehension. Furthermore, this study is restricted by the markets under examination. To achieve more comprehensive outcomes, the study suggests exploring the relationships among a greater number of financial markets. As a result, it is recommended to conduct further research that builds upon the current investigation by encompassing extended time periods and a broader range of financial markets.

CHAPTER 4

The Impact of Financial Stress and Uncertainty on Green and Conventional Bonds and Stocks: A Nonlinear and Nonparametric Quantile Analysis

4.1. Introduction

Over the past two decades, there has been a significant increase in the use of energy products, leading to a rise in carbon emissions and concerns about global warming. To address these concerns, alternative energy sources, such as clean energy, have gained importance, particularly in developed countries (An et al., 2021). This shift towards green investments is driven by the need to protect the environment and ensure sustainability. However, meeting the growing demand for energy requires significant capital investments in green sectors. Therefore, the importance of green projects has been highlighted for governments, investors, and producers (He et al., 2021; Maghyereh et al., 2019; Razzaq et al., 2021). Green bonds were introduced in 2007 by the European Investment Bank to fund environmentally friendly projects and have since gained popularity among corporations, municipalities, public sector entities, and supranational institutions. Similar to conventional fixed-income bonds, they offer investment opportunities for individuals and institutions interested in diversifying their portfolios with sustainable green assets (Jiang et al., 2022). However, the financial performance of green bonds in response to market fluctuations is uncertain. Green investments, like conventional investments, are affected by macroeconomic factors, including financial stress and instability. Market conditions that impact investment in renewable and clean energy are influenced by financial networks, innovations, and lending opportunities. Financial stress can slow down economic activities, causing global panic in equity markets and leading to damage to the financial systems and economy. Measuring the severity of financial stress in such circumstances is considered a challenging mission due to the sophisticated nature of markets (Battiston & Martinez-Jaramillo, 2018; Duprey et al., 2017; Fu et al., 2022; Polat & Ozkan, 2019). While identifying times of systemic financial stress, such as the recent global crises, is relatively simple, identifying other times of high or low, potentially systemic, financial stress is more complicated (Liang, 2013). Therefore, it is important for investors to comprehend the diverse repercussions arising from such stress and uncertainties in the economy on both green and conventional investments. This enables them to assess the potential benefits of diversifying their portfolios and managing portfolio risks, while accounting for such circumstances (Reboredo 2018).

This research explores the relationship between financial stress and uncertainty in the United States and their effects on different types of financial assets. The study’s main objective is to assess the impact of financial stress and uncertainty on both green and conventional financial assets and compare their sensitivity to such impact by examining the shocks that financial stress and uncertainty send to the financial assets under consideration. The research also aims to compare investment portfolios that include the variables being studied to determine which portfolios can effectively minimize risk in the current economic environment and determine the optimal assets for diversifying risks based on the empirical results in the context of modern portfolio theory. Broadly speaking, examining how green investments can function as a hedge against financial stress and uncertainty has significant implications for portfolio diversification. Such insights can increase investor interest in green bonds, potentially leading to more financial support for sustainable development (Pham & Nguyen, 2022).

The selection of an appropriate test for analyzing the effect of financial stress and uncertainty on financial assets is a crucial factor that requires careful consideration. Bahloul et al. (2018) emphasize the importance of modeling nonlinearity, higher-order moments, and quantiles of returns when predicting such a relationship. In this context, the present study utilizes two econometrics techniques: (1) The quantile-on-quantile (QQ) approach offers a comprehensive evaluation of the relationship between financial stress, uncertainty, and investments. Specifically, this method enables an assessment of how the different quantiles of financial stress and uncertainty may impact the conditional quantile of financial assets ((Sim & Zhou, 2015). (2) The nonparametric causality-in-quantile technique has benefits including accounting for market state asymmetry, characterizing Granger causality across the distribution and immunity to outliers, making it suitable for analyzing financial time series (Balcilar et al., 2016).

4.2. Literature Review

4.2.1. Previous studies

Green bonds are similar to conventional bonds, but their proceeds fund environmentally friendly projects. Their popularity has grown since their inception in 2007, with issuance increasing from $4.2 billion in 2012 to $258.9 billion in 2019, issued in 62 countries (Pham & Nguyen, 2022). As the green bond market continues to expand rapidly, it becomes crucial to analyze its risk and return characteristics. This would provide investors with valuable insights into the market and enable them to make informed decisions. Although green investments have gained considerable speed, their long-term viability is largely dependent on the financial security, financial risk, and profitability of clean energy projects. As a result, researchers and investors are now interested in observing the returns of green investment projects (Reboredo & Ugolini, 2018). In this context, Reboredo and Naifar (2017) conducted a study to examine the relationship between Islamic bond prices and financial and policy uncertainty. The empirical results of the study showed that US bond prices had a negative impact and causality effects on Islamic bond prices. The study also found that financial uncertainty had a negative effect that was limited to intermediate Islamic bond price quantiles.

Pham and Nguyen (2022) aimed to explore how stock volatility, oil volatility, and economic policy uncertainty influence the returns on green bonds. The study examined four main green bond indices and three uncertainty indices. The findings suggested that the relationship between green bonds and uncertainty is not constant and depends on the prevailing conditions. When uncertainty is low, there is a weak link between green bonds and uncertainty, making green bonds an effective hedge against uncertainty during such periods. However, during periods of high uncertainty, the benefits of diversification from green bonds are not as significant.

Lin and Su (2022) examined the interdependence of the green bond markets of the USA and China on three uncertainty indicators. The findings indicated that the three uncertainty indicators significantly impact the returns and volatilities of green bond markets. However, the role of each indicator differs between the two nations, with financial uncertainty being the primary driver of US green bonds and economic policy uncertainty being the primary driver of Chinese green bonds. Moreover, the impact of these uncertainties on green bond returns varies across different market states, and green bond volatilities may respond abnormally to extreme increases in these uncertainties.

Financial stress and uncertainty can have significant effects on various investment instruments, including energy and metal commodity future prices, Islamic bond prices, and equity in both mature and emerging markets. In the aftermath of a series of financial crises, stock market downturns, and oil price declines, the financial markets underwent a significant period of upheaval known as “Financial Stress.” This phenomenon has emerged as a critical determinant of stock price dynamics during times of stress (Bloom, 2009; Soltani & Abbes, 2022). This has motivated scholars to conduct research on the potential consequences of financial stress and uncertainty on diverse investments. Uncertainty and stress are not limited to the financial market but extend to all other markets and economic variables as well. For example, Reboredo and Uddin (2016) investigated the effects of financial stress and uncertainty on energy and metal commodity future prices in the USA. The study found that financial stress had Granger causality effects in intermediate and upper commodity return quantiles. However, the research suggested that general stock market uncertainty was not a crucial determinant of commodity future prices.

Chuliá et al. (2017) conducted a study to examine the impact of US policy and financial uncertainty on equity of advanced and emerging markets. The findings showed that during episodes of financial distress, an uncertainty shock reduces stock market returns in both advanced and emerging markets. However, the magnitude of the impact is higher for emerging markets. Additionally, the shock increases the highest quantiles of returns for mature markets but not for emerging markets. Policy uncertainty had a less significant impact but still negatively affected the equity dynamics during episodes of financial distress, particularly for emerging markets.

Aziz et al. (2021) examined how financial uncertainty in the US affects equity volatility in India, Sri Lanka, Pakistan, and Bangladesh. The results showed that the spillover effect of financial uncertainty varies with the forecast horizon, and the effect is significant on more countries with a higher forecast horizon. The US’s financial uncertainty has a negative impact on most of the stock markets.

He et al. (2021) study examined the relationship between clean energy stock returns and fluctuations in oil, gold, and financial stress in the US and EU. The study found that financial stress has a negative impact on the clean energy stock indices of the US and Europe in lower quantiles, indicating bearish market conditions. In the short run, the study found a converse relationship between financial stress and clean energy stocks in the extremely higher quantiles of Europe and the extremely higher and lower quantiles of the US.

Another study conducted by Fu et al. (2022) used the quantile autoregressive distributed lag model (QARDL) approach to investigate the dynamic relationship between macroeconomic variables, including financial stress, oil and gold, natural gas, and clean energy stocks. The study found that increased financial stress and oil and gold prices have a significant negative impact on the performance of clean energy stocks in both the short and long term.

In the research conducted by Soltani and Abbes (2022), the aim was to assess the extent to which financial stress can predict the behavior of equity of Middle East and North Africa. The results indicated that financial stress has the strongest predictive power at the lower quantiles, specifically when the market is in a bearish state.

Bloom (2009) investigates the ramifications of financial uncertainty shocks on the economy, aiming to comprehend the effects of such shocks on various economic variables in the aftermath of significant events like the Cuban Missile Crisis, JFK's assassination, the OPEC I oil-price shock, and the 9/11 terrorist attacks. The theoretical model used in the study demonstrates that a macro uncertainty shock triggers a rapid decline and subsequent rebound in aggregate output and employment. When confronted with heightened uncertainty, businesses temporarily suspend their investment and employment activities, leading to a deceleration in productivity growth. However, in the medium run, the amplified volatility stemming from the uncertainty shock results in an overshooting effect on production, employment, and productivity. As a consequence of financial uncertainty shocks, the economy experiences brief and acute periods of recessions and recoveries.

Duprey et al. (2017) aimed to identify episodes of financial stress that exert significant adverse effects on the real economy. To achieve this objective, the researchers employed two Markov-switching models and one threshold vector autoregressive model in their investigation. The study focused on EU. Through the application of this novel approach, the research effectively detected instances of financial stress events that had substantial negative repercussions on the actual economy. This was achieved by integrating data from the Composite Leading Indicator of financial stress and industrial production indicators. In addition to the identification of expert-detected events, the report provided a detailed chronology of systemic financial stress incidents that occurred across the EU.

Das et al. (2019) conducted a thorough examination of the ramifications of US-based financial stress, geopolitical risk, and financial uncertainty on emerging stock markets. The study investigated the responses of developing markets to diverse macroeconomic shocks originating from the United States. The research utilized monthly data spanning from January 1997 to May 2018. The findings indicated that the impact of US-based macroeconomic shocks on emerging stock markets exhibited variations in terms of both causation and severity. Among the three shock indicators analyzed, financial uncertainty exerted the most profound and significant effect on emerging stock markets, surpassing the influences of geopolitical risk and financial stress. Notably, causality-in-mean was demonstrated to possess greater strength and significance compared to causality-in-variance in the relationship between the shock indicators and emerging stock markets.

Gupta et al. (2019) undertook an investigation to examine the asymmetric and nonlinear transmission of GDP and financial uncertainty to insurance premiums in the United States. In this study, the researchers employed the NARDL framework to analyze the relationships under investigation. The sample comprised yearly data from the US economy, covering the period from 1980 to 2014. The empirical findings revealed that both actual GDP and financial uncertainty exert uneven and nonlinear effects on insurance prices. Specifically, the influence of GDP on insurance premiums was found to be asymmetric, with an increase in real output leading to an improvement in insurance rates, while a decrease in real output resulted in a deterioration of insurance premiums.

Syed et al. (2022) conducted a comparative analysis of green bonds against conventional assets concerning environmental degradation and sustainable development. The primary objective of the study was to explore the asymmetric relationship between green bonds, cryptocurrency, and financial uncertainty, as well as their co-movement with other asset classes. The researchers employed the NARDL model to investigate these connections. The empirical investigation confirmed the presence of an asymmetric cointegration between financial uncertainty, green bonds, and cryptocurrency. In the long term, a positive shock in financial uncertainty led to a negative impact on green bonds, while a negative shock in financial uncertainty resulted in a positive impact on green bonds. Furthermore, the study uncovered a bidirectional relationship between green bonds and cryptocurrency, where positive shocks in cryptocurrency performance enhanced the performance of green bonds, and vice versa.

Ayhan et al. (2023) conducted a study examining the asymmetric impacts of financial uncertainty and political stability on CO_2 emissions, while considering the factors of energy consumption and economic development. The investigation was specifically conducted in the G-7 countries, which are major players in the global economy. The analysis utilized yearly data spanning from 1997 to 2021, selected for their wide accessibility and applicability to all countries under consideration. The research findings suggest that economic policy uncertainty exerts a reducing influence on CO_2 emissions in Italy, Japan, and the USA. However, in Canada, France, Germany, and the United Kingdom, the influence of economic policy uncertainty on CO_2 emissions is mixed, signifying variations across different quantiles of the data distribution. As for political stability, its influence on CO_2 emissions is also found to be mixed, with distinct effects observed at different quantiles of the data distribution. Regarding energy consumption, the study reveals an accelerating impact on CO_2 emissions; however, the magnitude of this effect varies across different quantiles of the data. Furthermore, the research highlights that economic growth typically leads to increased CO_2 emissions. However, in specific scenarios, such as lower quantiles in Japan, medium quantiles in France and Germany, and higher quantiles in Italy, economic growth is associated with a decrease in CO_2 emissions.

4.2.2. Hypotheses of the study

Building upon the preceding information, the study examines the following hypotheses:

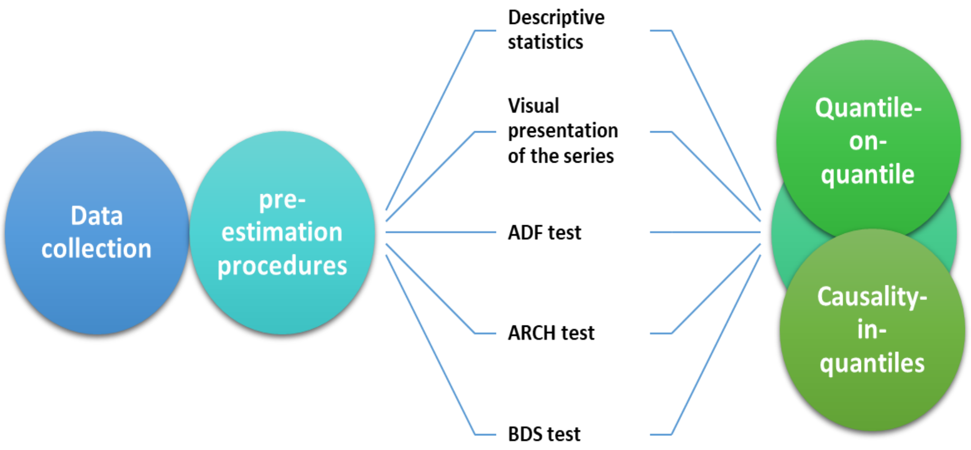
- Hypothesis 1: Green bonds are safer than conventional bonds.
- Hypothesis 2: Green stocks are safer than conventional equity.

To examine these hypotheses, the study measures the reaction magnitudes of both green equity and bonds in comparison to conventional equity and bonds regarding uncertainty and financial stress. The QQ methodology is employed, which offers insights into the extent of sensitivity of financial assets to uncertainty and financial stress.

4.3. Data Description and Methodology

To attain trustworthy outcomes, we have adhered to specific procedures in analyzing this research. These procedures outline the steps that we have pursued in each phase, commencing from data collection and culminating in the extraction of results. Figure 4.1 summarizes these procedures.

Figure 4.1: *Study procedures*



4.3.1. Data Description

This study utilizes data from the United States and divides it into two sets based on data availability. The first set covers the period from March 2010 to December 2022, while the second set spans from May 2013 to December 2022. In order to minimize the effects of randomness, prices have been transformed into continuous returns (Brooks, 2019). The dependent variables include the S&P 500 Index, which is a market-capitalization-weighted index that tracks the performance of 500 large-cap American corporations. Meanwhile, the WilderHill Clean Energy Index is intended to evaluate the progress of clean energy firms. In addition, US government bonds are deemed relatively low-risk investments, backed by the full confidence and assurance of the US government. The S&P Green Bond Index was developed by S&P Dow Jones Indices, comprising bonds designed exclusively to finance projects that have ecological advantages, including sustainable agriculture, renewable energy, and pollution prevention (Spglobal, 2023). The independent variables consist of the financial stress index, a composite index utilized to gauge the extent of financial stress within a given economy, subregion, or region, and it encompasses the four principal financial markets: the banking sector, the foreign exchange market, the equity market, and the debt market (Aric, 2023). Additionally, the financial market uncertainty index is another measure of financial uncertainty, developed by Professors Sydney Ludvigson and Serena. It is based on a dynamic factor model that extracts common movements in stock market volatility, treasury bond yields, and the spread between corporate bond yields and treasury yields ((Ludvigson, 2023). Table 4.1 presents the data used in the study.

Table 4.1: *The study sample, Definition and Source*

The Variables	Periods	Sources
S&P 500 Index	March 2010 to December 2022	Investing (2023)
Invesco WilderHill Clean Energy ETF	March 2010 to December 2022	Investing (2023)
US Government bond	May 2013 to December 2022	Investing (2023)
S&P Green Bond Index	May 2013 to December 2022	Spglobal (2023)
Financial stress	March 2010 to December 2022	Aric (2023)
Financial uncertainty	March 2010 to December 2022	Ludvigson (2023)

Figures 4.2 to 4.7 depict the behavior of the time series, with the first row representing equity, the second row representing bonds, and the third row representing financial stress and financial uncertainty. The figures indicate that the returns of clean energy equity exhibit higher volatility compared to conventional equity, and a similar pattern is observed in bonds, suggesting that investing in clean energy equity and bonds may entail higher risks than investing in conventional counterparts. In terms of financial stress and financial uncertainty, no specific pattern is evident. Further information can be found in Table 4.2, which presents the statistical descriptive data of the study sample.

Figure 4.2: *Financial Stress*

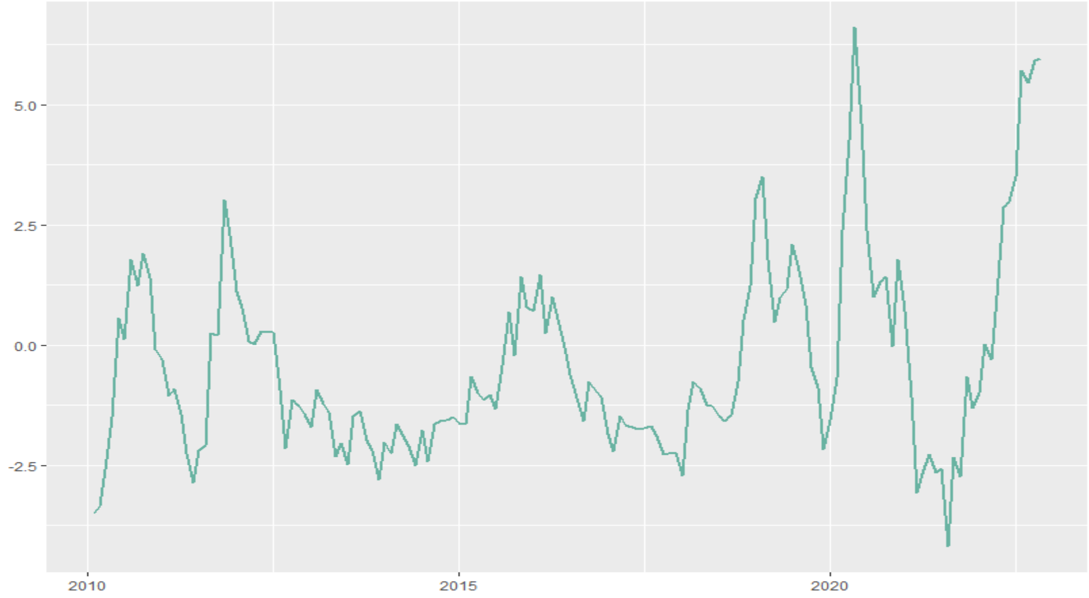


Figure 4.3: *Financial Uncertainty*

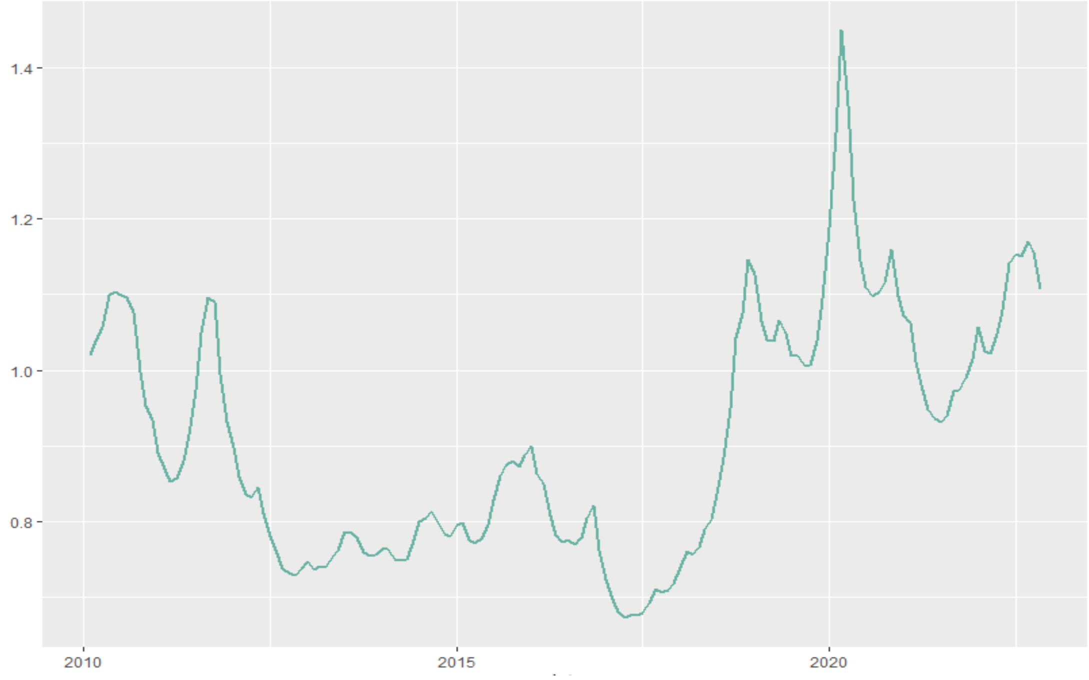


Figure 4.4: *Conventional Equity*

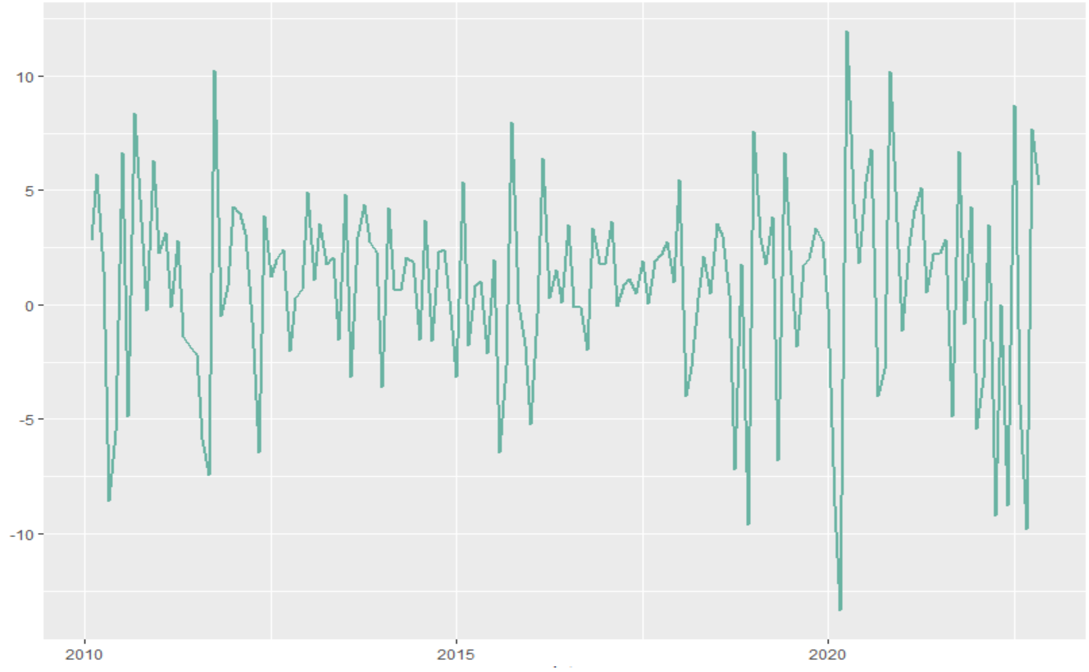


Figure 4.5: *Clean Energy Equity*

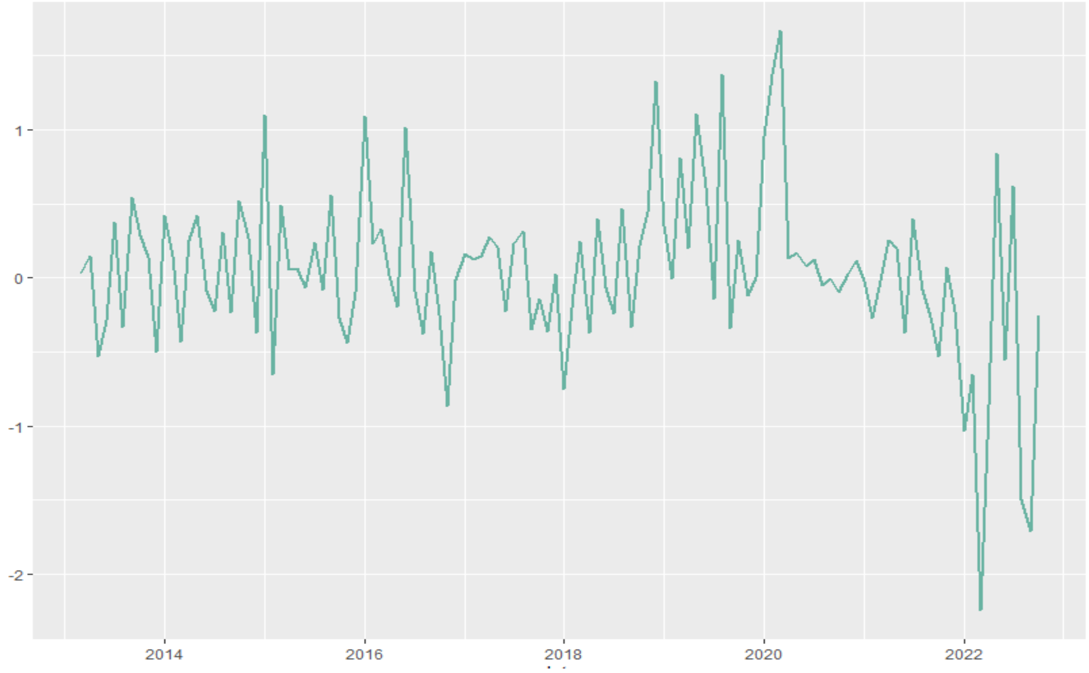


Figure 4.6: *Conventional Bonds*

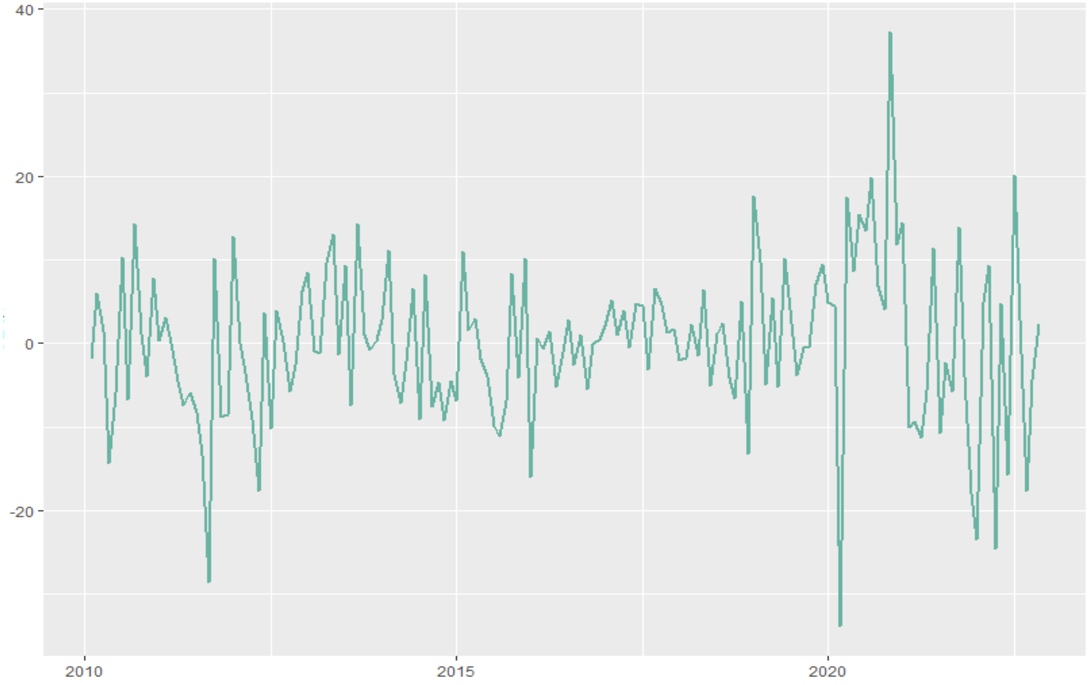
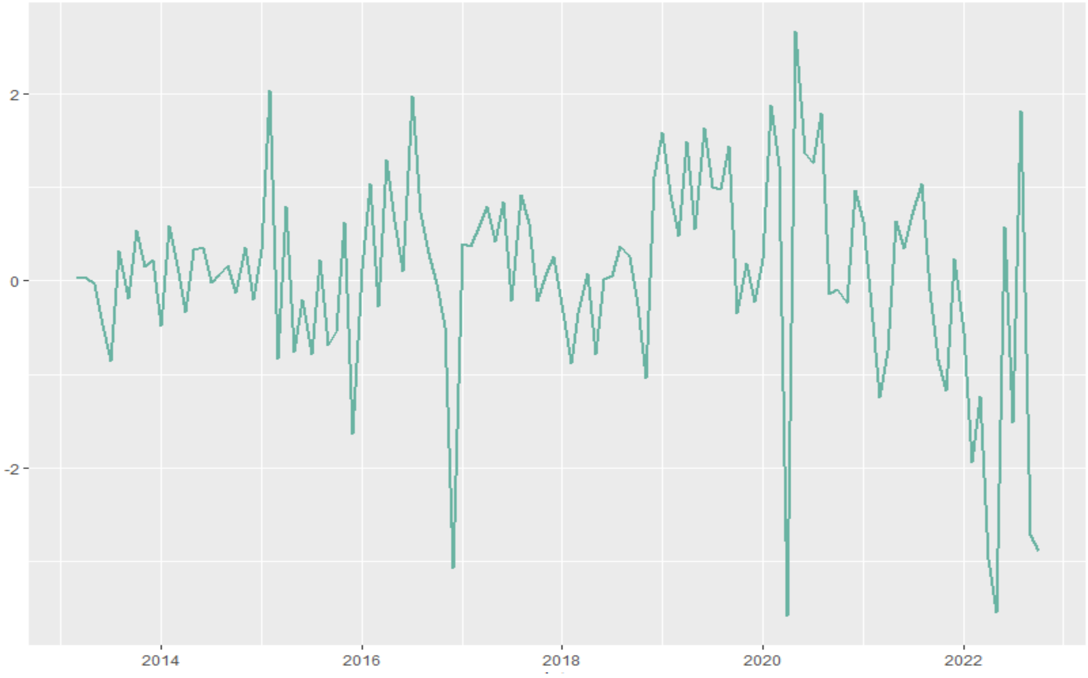


Figure 4.7: *Green Bonds*



In Table 4.2, it can be noticed that clean energy has the highest standard deviation with a value of 9, followed by conventional equity and financial stress with values of 4 and 2, respectively. Based on the Jarque Bera test, we reject the null hypothesis that the data is normally distributed since the *P*-value is significant at a level less than 1%. According to the Augmented Dickey-Fuller test, we can see that equity and clean energy equity are integrated at the level I(0), while bonds, green bonds, financial stress, and financial uncertainty are not stationary.

Table 4.2: *Descriptive statistics*

Variables	Conventional equities	Clean energy equities	Conventional bonds	Green bonds	Financial stress	Financial uncertainty
Obs.	154	154	116	116	154	154
Range	25.309	71.104	3.913	6.239	10.79	0.777
Median	1.612	0.167	0.031	0.151	-0.999	0.873
Mean	0.867	-0.009	0.041	0.049	-0.387	0.91
Std.dev.	4.266	9.6	0.57	1.1	2.033	0.161
Jarque Bera test	10.933 ***	22.564 ***	40.44 ***	38.306 ***	51.535 ***	9.2221 ***
ADF test	-6.064 **	-3.889 **	-2.744	-3.018	-2.849	-2.597
BDS test *m*=6	5.295 ***	19.577 ***	5.743 ***	6.236 ***	122.959 ***	981.987 ***
ARCH test lag(3)	23.537 ***	10.869 **	7.4 *	22.764 ***	107.75 ***	367.23 ***

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

In order to establish a nonlinear cause-and-effect relationship between the variables and determine an appropriate approach for data analysis, we utilized two tests, namely, the BDS and ARCH tests. Specifically, the study employed the BDS test developed by Broock et al. (1996) to examine the residuals of the equations in a VAR(1) model for the cause-and-effect variables. The null hypothesis of the BDS test assesses the presence of independent and identically distributed (i.i.d.) residuals across different embedding dimensions (n) for each series. Our findings, as presented in Table 4.2, strongly rejected the null hypothesis even at the 1% significance level, indicating compelling evidence of a nonlinear cause-and-effect relationship across variables. The aforementioned findings are corroborated by the results of the ARCH test, which reject the null hypothesis of a constant variance of the error term in the residuals. This indicates the presence of heteroscedasticity in the residuals, suggesting that the variance of the error term varies over time.

4.3.2. Methodology

4.3.2.1. QQ Approach

In this study, we employ the QQ approach, proposed by Sim and Zhou (2015) to examine the impact of financial stress and uncertainty on the performance of green and conventional investments. This approach enables us to assess how changes in the quantiles of one variable may affect the conditional quantiles of another variable. The quantile regression approach shares similarities with the ordinary least squares methodology in that it assesses the relationship between independent and dependent variables. However, it goes beyond this by examining the effects of the independent variable on the dependent variable at both the upper and lower quantiles of a distribution. This permits a more comprehensive understanding of the relationship between variables over various time periods (Shahbaz et al., 2018). The QQ approach is considered an enhancement of conventional quantile regression, which places emphasis on the impact of individual independent variable quantiles on distinct quantiles of the dependent variable. The method relies on nonparametric estimations and quantiles to function effectively (Adebayo & Acheampong, 2022). Compared to OLS or quantile regression, the QQ approach has a significant advantage in modeling economic relationships more comprehensively. While OLS regression can only estimate the impact of financial stress and uncertainty shocks on the conditional mean of investments, quantile regression breaks down this effect into the conditional quantile. The QQ approach extends the quantile regression method by examining how the quantiles of financial stress and uncertainty can affect the conditional quantile of investments. Out of the three estimation approaches, the QQ approach provides the most comprehensive information about the relationship between financial stress, uncertainty, and investments.

In fact, through the QQ approach, we can gain insights into the high complexity of this relationship. In order to determine how the quantiles of cause variable shocks impact the quantiles of the effect variable, we utilize a model for the θ-quantile of the dependent variable (r_t) based on the independent variable (X_t) shocks as follows:

$$r_t = \beta^{\theta}(X_t) + \alpha^{\theta} r_{t-1} + v_t^{\theta}$$

The error term v_t^{θ} has a θ-quantile of zero. The link function denoted by $\beta^{\theta}(\cdot)$ does not have prior information about how the independent variables send shocks to the dependent variable. We take the first-order Taylor expansion of the above equation to get:

$$\min_{b_0, b_1} \sum_{i=1}^{n} \rho_{\theta} \left[r_t - b_0 - b_1\left(\hat{X}_t - X^{\tau}\right) - \alpha(\theta) r_{t-1}\right] K\left(\frac{F_n\left(\widehat{X_t}\right) - \tau}{h}\right)$$

The loss function's quantile, denoted by $\rho_{\theta}[\cdot]$, is used in conjunction with the Gaussian kernel function $K(\cdot)$ to assign weights to nearby observations based on a bandwidth parameter h. This enables us to focus on the local impact of (X) shocks at the τ-quantile. The weights assigned to each observation are determined by the distance between the observation and a reference point X^{τ}. Specifically, the farther a data point is from the reference point, the lower its weight will be (see (Sim & Zhou, 2015).

4.3.2.2. Nonparametric Causality-in-Quantile.

Balcilar et al. (2016) proposed a nonparametric approach for identifying nonlinear causal relationships called nonparametric causality-in-quantile. This method employs a hybrid approach based on the methodologies of Nishiyama et al. (2011) and Jeong et al. (2012). Compared to linear and nonlinear models, the causality-in-quantile technique has several advantages. For instance, it can account for asymmetry in causality depending on the state of the market, which other methods cannot. Moreover, it characterizes Granger causality across the entire distribution, thereby making it immune to outliers. This characteristic makes it suitable for analyzing financial time series, which frequently exhibit fat tails and regime shifts due to the occurrence of co-jumps in both the financial and economic data. Balcilar et al. (2016) also developed a new test that incorporates both the k-th order nonlinear causality test of Nishiyama et al. (2011) and the quantile-causality test of Jeong et al. (2012). By combining these two approaches, the new test is more comprehensive than either one alone. Specifically, they have extended the framework to include a test for the second moment using the combined Nishiyama et al. and Jeong et al. methodology, which is presented as follows:

$$y_t = g(Y_{t-1}) + \sigma(X_{t-1})\varepsilon_t$$

The disturbance term in the equation is represented by ε_t. The functions $g(\cdot)$ and $\sigma(\cdot)$ have certain characteristics that ensure stationarity. By converting the equation into a pair of hypotheses, namely, null and alternative, we can test for causality in variance as follows:

$$H_0\colon P\left\{F_{y_t|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} = 1$$
$$H_1\colon P\left\{F_{y_t|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} < 1$$

Jeong et al. (2012) suggested a method to address the problem of causality in the conditional first moment leading to causality in the second moment. To tackle this issue, the following model can be utilized to interpret causality in higher-order moments:

$$y_t = g(X_{t-1}, Y_{t-1}) + \varepsilon_t$$

Therefore, it is possible to define causality in higher-order quantiles as the following:

$$H_0\colon P\left\{F_{y_t^k|Z_{t-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} = 1\ for\ k = 1,2,\dots,K$$
$$H_1\colon P\left\{F_{k_{\,y_t|Z-1}}\{Q_\theta(Y_{t-1}) \mid Z_{t-1}\} = \theta\right\} < 1\ for\ k = 1,2,\dots,K$$

The causal relationship in the tail of a distribution is not the same as that in the center. The lag order (P) is determined for a vector autoregression (VAR) model that includes the variables using the SIC criterion (Balcilar et al. 2016; Shahbaz, Balcilar, and Abidin Ozdemir 2017).

4.4. Empirical Results

4.4.1. QQ Approach

4.4.1.1. Conventional investments.

Figures 4.8 and 4.9 depict the influence of financial stress and uncertainty on conventional equity *respectively*, while Figures 4.10 and 4.11 illustrate the impact of financial stress and uncertainty on conventional and green bonds respectively. The effect of financial stress on investments is presented in the first column, while the effect of financial uncertainty is presented in the second column. It is evident from Figure 4.8 that financial stress has a strong positive impact on equity. In terms of financial stress and conventional stocks, positive shocks can be observed from all financial stress quintiles to the conventional stock quintiles (0.6–0.8). These shocks are severe and reach a peak of about 700, while the negative shocks do not exceed –100. It is noteworthy that shocks resulting from financial uncertainty are less aggressive compared to shocks from financial stress. It can be seen that shocks originating from all over the quantiles of financial uncertainty to the upper quantile of the traditional equities (0.8-0.9) are predominantly negative, with a magnitude of approximately –300. Conversely, the positive shocks have a maximum magnitude of +50.

In the realm of bonds, it is apparent that financial stress sends asymmetric shocks to conventional bonds. Positive shocks emanate from the financial stress quintiles (0.1–0.8) to the bonds' quintiles (0.6), whereas negative shocks are transmitted from all quintiles of financial stress (0.1–0.9) to bond quintiles (0.7). The size of the positive shock to conventional bonds is approximately 200, while the negative shocks to conventional bonds are about 100. As regards financial uncertainty, asymmetry can be observed in the shocks transmitted from financial uncertainty to conventional bonds.

Figure 4.8: *The Impacts of Financial Stress on Conventional Equity*

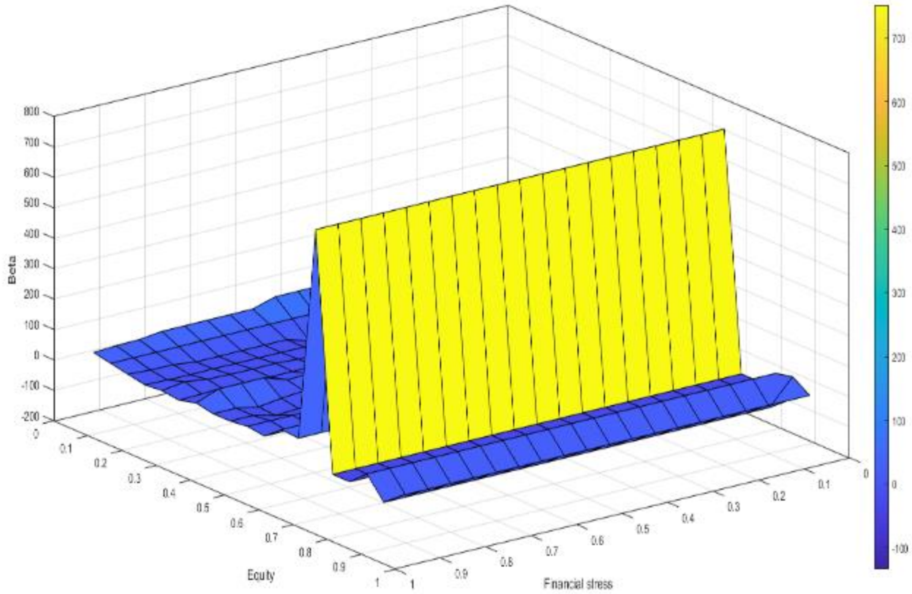


Figure 4.9: *The impacts of financial uncertainty on conventional equity*

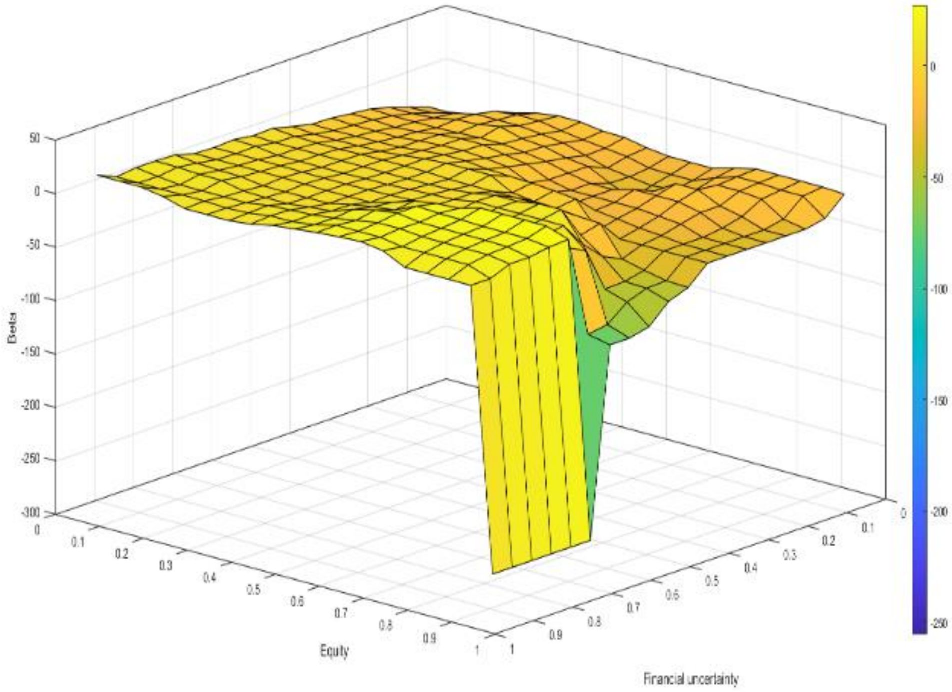


Figure 4.10: *The Impact of Financial Stress on Conventional Bonds*

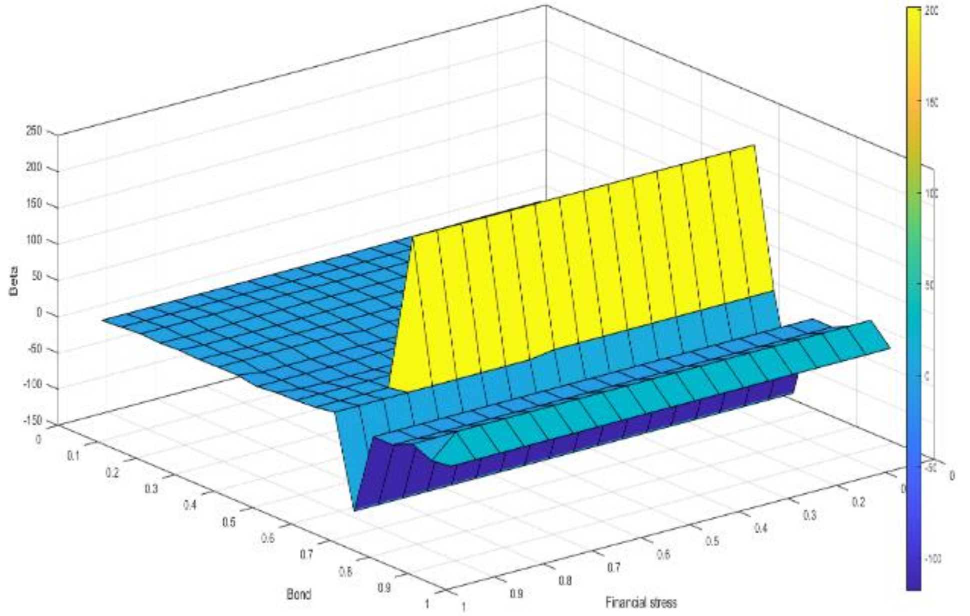
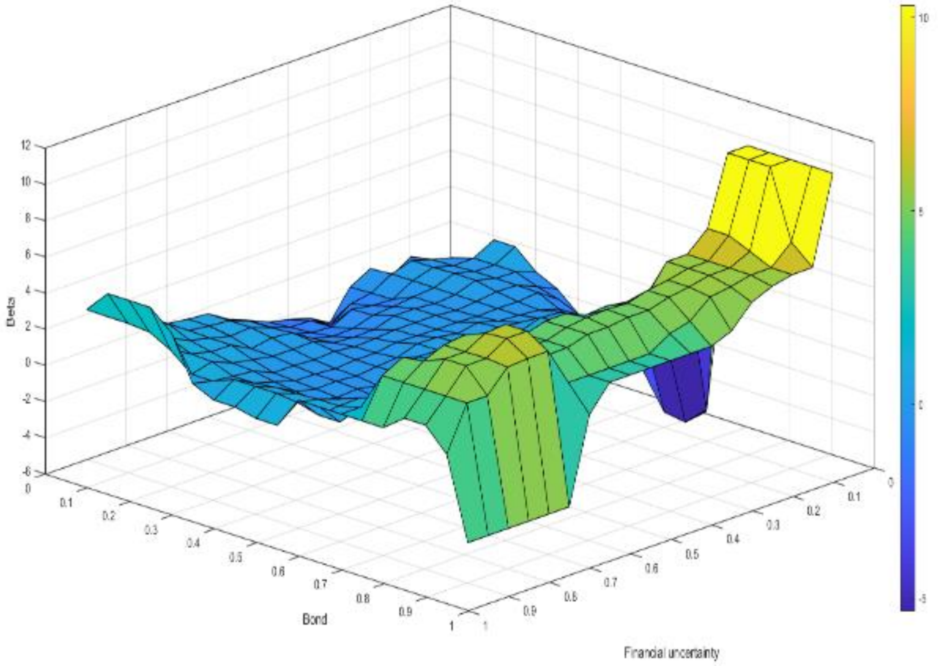


Figure 4.11: *The Impact of Uncertainty on Conventional Bonds*



These shocks range from 12 to –6 in magnitude. It can be observed that the upper quantiles of financial uncertainty transmit negative shocks to the upper bond quantiles (0.9) while simultaneously sending positive shocks to the lower bond quintiles (0.1-0.2). Moreover, it is worth noting that lower quintiles of financial uncertainty transmit more severe asymmetric shocks, particularly the shocks originating from the financial uncertainty quintiles (0.1-0.2) towards the bond quintiles (0.6-0.7) which are negative, reaching a strength of up to –6 and, at the same time, transmitting positive shocks to the bond quantiles (0.8-0.9) with a strength of up to 10.

4.4.1.2. Green investments

Comparing the sent shockwaves of stress and financial uncertainty, it is evident from Figure 4.12 that financial stress has a strong positive impact on clean energy equity. In terms of financial stress, the location of the shocks sent from financial stress to green stocks is similar to shocks sent to conventional equity, but their magnitude is stronger, ranging between 1200 and –200. It is also observed that shocks transmitted from financial uncertainty to clean energy equity in Figure 4.13 are more substantial than those to conventional equity, regardless of whether they are positive or negative. Negative shocks originating from all quantiles of financial uncertainty can be observed in clean energy equity, particularly in the upper quantiles (0.7–0.9). The magnitude of these shocks does not surpass 200, whereas lower quantiles (0.1–0.6) are not affected to the same extent. In regard to bonds, it is apparent from Figure 4.14 that financial stress sends asymmetric shocks to green bonds. These shocks exhibit a similar pattern across both types of bonds (conventional and green). Positive shocks emanate from the financial stress quintiles (0.1–0.8) to the green bonds' quintiles (0.6), whereas negative shocks are transmitted from all quintiles of financial stress (0.1–0.9) to green bond quintiles (0.7). The magnitude of the shocks differs across types of quantiles, with the positive shocks sent to conventional bonds appearing to be more severe than those sent to green bonds. The size of the positive shock to conventional bonds is approximately 200, whereas that to green bonds does not exceed 100. Moreover, the negative shocks to conventional bonds are somewhat comparable to those sent to green bonds, as they reach about 100 in conventional bonds, while they are 120 in green bonds. Green bonds have been found to exhibit higher volatility compared to conventional bonds.

Shocks magnitudes for green bonds range between 30 and –20, with the most severe shocks ranging from low quantile of financial uncertainty (0.1–0.4) to high quantile of green bonds as appears in Figure 4.15. These shocks are asymmetric and are primarily concentrated in the upper quantile of the green bond distribution. Specifically, strong positive shocks are located in the 0.8-0.9 quantile of the green bond distribution and have a magnitude of positive 30, while negative shocks are located in the previous quantile (0.6-0.7) of the green bond distribution and have a magnitude of –10.

Figure 4.12: *The Effects of Financial stress on Clean Energy Equity*

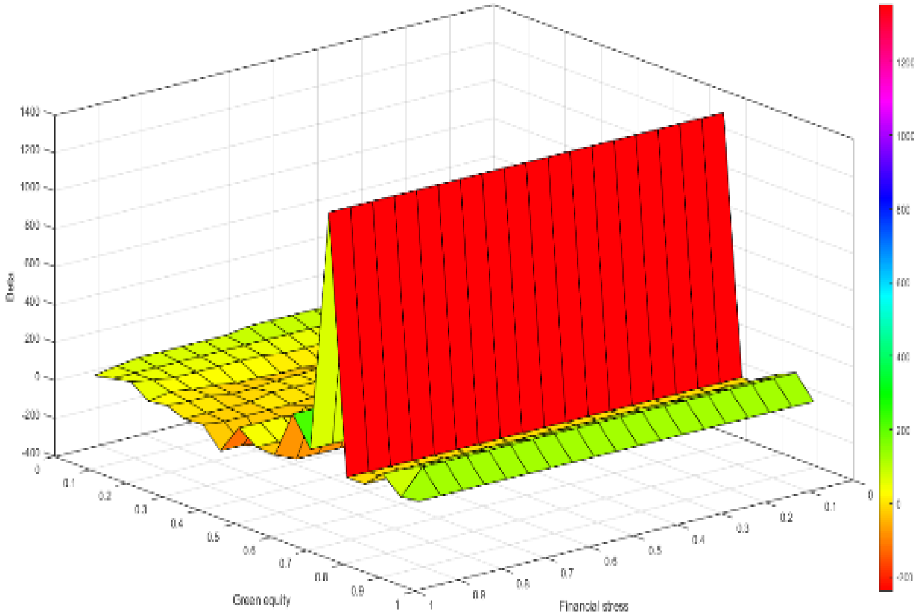


Figure 4.13: *The Effect of Financial Uncertainty on Clean Energy Equity*

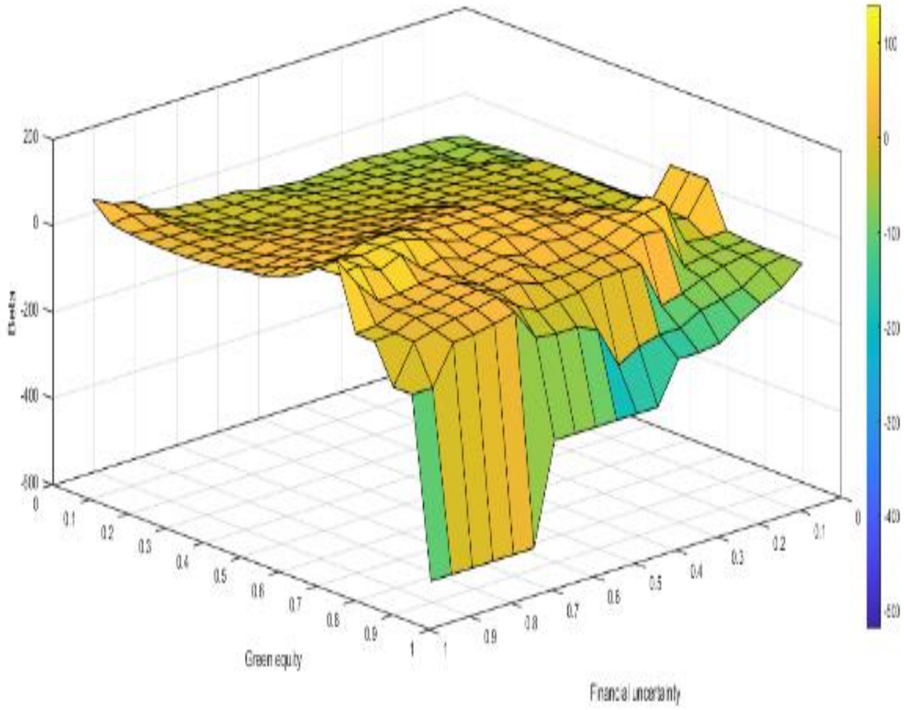


Figure 4.14: *The Effects of Financial Stress on Green Bonds*

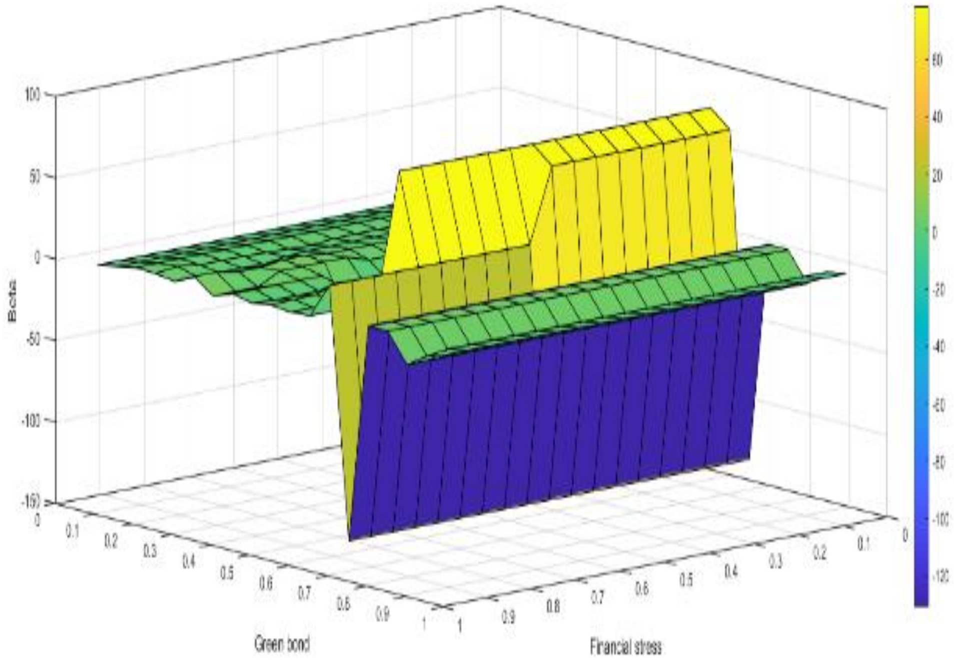
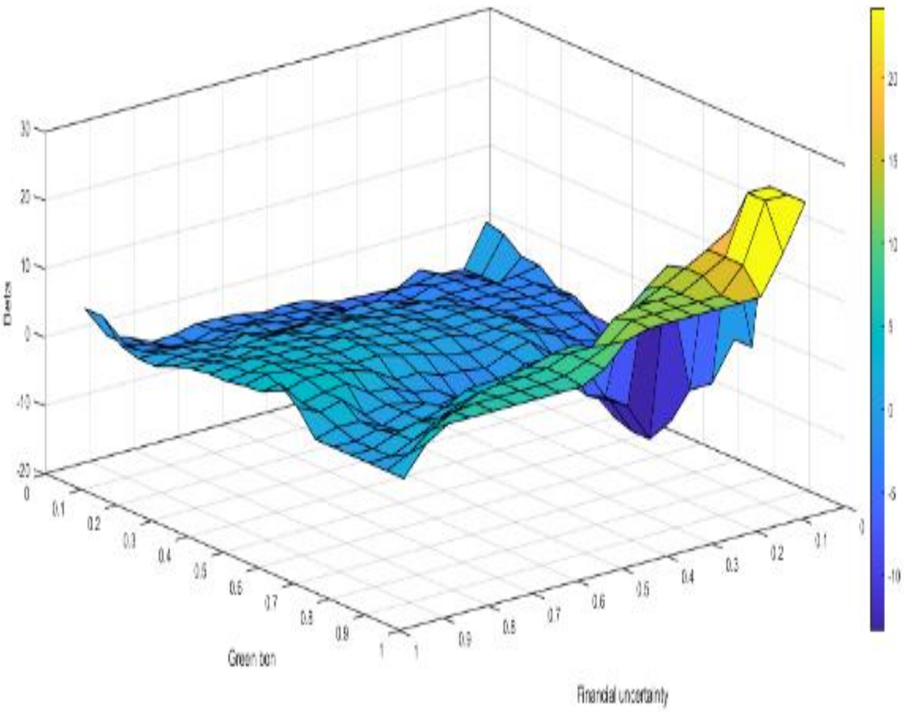


Figure 4.15: *The Effects of Financial Uncertainty on Green Bonds*



4.4.2. Nonparametric Causality-in-Quantile

Given the strong evidence of nonlinearity provided by both the BDS and ARCH tests, we aim to further investigate the presence of a causal relationship flowing from financial uncertainty and financial stress to both conventional and green investments. To achieve this, we will employ a nonparametric quantile causality analysis. The nonparametric causality-in-quantiles analysis results are presented in Table 4.4 and 4.4 which display causality in conditional mean and variance from financial uncertainty to bonds and equity respectively across various quantiles for the study sample. Table 4.5 and 4.6 show causality in conditional mean and variance from financial stress to bonds and equity respectively across different quantiles for the study sample. By examining causality across different quantiles, the nonparametric causality-in-quantiles analysis allows for the assessment of the potential existence of the causal effects across different levels of investments. The nonparametric causality-in-quantile analysis reveals the presence of a causal relationship between financial uncertainty and stress, with investment across a broad spectrum of investment vehicles. This relationship was found to be significant for both conventional and clean energy equity, as well as for conventional and green bonds.

Table 4.3: *The Nonparametric Causality-In-Quantiles from Financial Uncertainty to Bonds*

	Bond		Green Bond	
Quantile	Causality in conditional mean	Causality in conditional variance	Causality in conditional mean	Causality in conditional variance
0.05	4.825***	4.735***	8.013***	7.115***
0.1	4.025***	3.433***	6.234***	5.498***
0.15	4.664***	3.941***	5.052***	4.379***
0.2	4.051***	3.766***	4.835***	4.925***

Table 4.3 (Continued).

0.25	3.813***	3.614***	4.576***	4.341***
0.3	3.718***	3.317***	4.139***	4.169***
0.35	3.446***	3.239***	4.365***	4.059***
0.4	3.040***	3.050***	4.013***	3.635***
0.45	2.921***	3.242***	3.765***	3.661***
0.5	3.162***	3.231***	3.523***	3.619***
0.55	3.039***	3.443***	3.327***	3.441***
0.6	2.863***	3.282***	3.066***	3.162***
0.65	2.833***	2.968***	2.576***	2.940***
0.7	2.562**	2.977***	2.446**	2.690***
0.75	2.652***	2.536**	2.129**	2.340**
0.8	2.164**	2.645***	1.312	1.775*
0.85	1.64	1.669*	1.486	1.987**
0.9	1.325	2.032**	0.948	2.229**
0.95	1.564	1.125	1.073	3.048***

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

Table 4.4: *The Nonparametric Causality-In-Quantiles from Financial Uncertainty to Equity*

	Equity		Clean Energy Equity	
Quantile	Causality in conditional mean	Causality in conditional variance	Causality in conditional mean	Causality in conditional variance
0.05	13.480***	12.819***	6.798***	6.608***
0.1	9.416***	9.086***	5.087***	4.988***
0.15	8.085***	7.678***	5.083***	4.754***
0.2	6.799***	6.855***	4.911***	4.293***
0.25	6.718***	6.169***	4.612***	4.316***
0.3	5.906***	5.461***	4.625***	4.514***
0.35	5.494***	5.250***	4.322***	4.415***
0.4	5.165***	4.987***	4.189***	4.372***
0.45	4.660***	4.621***	3.886***	4.220***
0.5	4.332***	4.262***	3.856***	3.920***
0.55	4.023***	4.050***	3.655***	3.733***
0.6	3.504***	3.753***	3.319***	3.538***
0.65	3.067***	3.532***	3.059***	3.280***
0.7	2.582***	3.235***	2.740***	3.054***
0.75	2.113**	2.989***	2.311**	2.834***
0.8	2.026**	2.773***	2.015**	2.636***
0.85	1.358	2.729***	1.840*	2.093**
0.9	1.197	2.656***	1.025	1.697*
0.95	1.709*	2.609***	0.935	2.350**

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

In general, the results in Tables 4.6 and 4.7 indicate a nonparametric causality in variance stemming from financial uncertainty towards bonds, particularly green bonds, across all quantiles. Additionally, the nonparametric causality in the mean is confirmed at lower and middle quantiles but disappears at higher quantiles. This suggests that financial uncertainty affects the volatility of all types of bonds in both bearish and bullish conditions, while the causality in the mean indicates that financial uncertainty's impact on all types of bonds diminishes in bullish markets. Regarding equities, a similar pattern is observed. The nonparametric causality in variance is confirmed at all quantiles of conventional and clean energy equity, while the nonparametric causality in the mean disappears at the higher quantiles.

Table 4.5: *The Nonparametric Causality-In-Quantiles from Financial Stress to Bonds.*

	Bond		**Green Bond**	
Quantile	Causality in conditional mean	Causality in conditional variance	Causality in conditional mean	Causality in conditional variance
0.05	4.093***	4.452***	7.509***	6.495***
0.10	4.217***	3.459***	5.831***	4.830***
0.15	3.910***	3.844***	4.691***	3.802***
0.20	3.331***	3.702***	4.456***	3.998***
0.25	3.197***	3.381***	4.277***	3.453***
0.30	3.447***	3.124***	4.053***	3.790***
0.35	3.329***	3.210***	4.200***	3.661***
0.40	3.344***	3.007***	4.102***	3.462***
0.45	3.075***	3.034***	3.748***	3.440***
0.50	3.289***	2.864***	3.430***	3.304***
0.55	3.051***	2.714***	2.929***	3.333***

Table 4.5 (Continued).

0.60	2.555**	2.346**	2.530**	3.028***
0.65	2.721***	2.681**	2.451**	2.602***
0.70	2.546**	2.427**	2.453**	2.318**
0.75	2.134**	2.326**	1.972**	2.117**
0.80	1.841*	2.037**	1.372	1.691*
0.85	1.642	1.43	1.538	1.905*
0.90	1.277	1.917*	0.914	2.080**
0.95	1.51	1.142	1.033	2.839***

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

Table 4.6: *The Nonparametric Causality-In-Quantiles from Financial Stress to Equity*

	Equity		**C**lean energy equity	
Quantile	Causality in conditional mean	Causality in conditional variance	Causality in conditional mean	Causality in conditional variance
0.05	13.246***	13.002***	6.827***	6.876***
0.1	9.057***	9.218***	5.027***	5.255***
0.15	7.890***	7.743***	5.042***	4.926***
0.20	6.637***	6.698***	4.807***	4.667***
0.25	6.686***	6.118***	4.576***	4.611***
0.30	5.874***	5.585***	4.595***	5.066***
0.35	5.480***	5.224***	4.431***	4.685***
0.40	5.156***	4.770***	4.162***	4.593***
0.45	4.745***	4.431***	4.049***	4.285***
0.50	4.362***	4.180***	4.565***	4.003***
0.55	3.985***	4.026***	4.251***	3.891***
0.60	3.475***	3.804***	4.056***	3.748***
0.65	3.103***	3.490***	3.738***	3.464***
0.70	2.536**	3.290***	3.104***	3.303***
0.75	2.073**	3.007***	2.564**	2.792***
0.80	1.900*	2.770***	2.188**	2.597***
0.85	1.31	2.744***	1.767*	2.072**
0.90	1.169	2.666***	0.997	1.710*

Table 4.6 (Continued).

0.95	1.695*	2.629***	0.937	2.389**

*, **, and *** indicate significant level at 10%, 5%, and 1%, respectively.

Tables 4.6 and 4.7 present the results of nonparametric causality between financial stress and financial assets. The causality in the mean disappears in the upper quantiles of bonds and green bonds. It also disappears in the higher quantiles of conventional and clean energy equities. However, the nonparametric causality in variance is confirmed at all quantiles of all assets. These results are similar to the results obtained for financial uncertainty. In general, nonparametric causality-in-quantile findings suggest that this causality is consistently strong in the lower and middle quintiles of overall investments, indicating a strong relationship during bearish markets and periods of no trends. However, the strength of this causality weakens in the upper quintiles when considering the conditional mean, rendering it insignificant. Nevertheless, the strength of causality persists in the upper quintiles when considering conditional variance. Overall, results indicate that financial stress and uncertainty can have a significant impact on investment decisions, particularly during challenging market conditions. The fact that financial uncertainty and stress have a causal effect on investment behavior implies that they influence investment decisions directly, regardless of the specific type of investment being evaluated. the nonparametric causality outcome emphasizes the significance of managing financial uncertainty and stress during the investment decision-making process and emphasizes the possible advantages of creating strategies to lessen the impact of these factors.

4.4.3. Discussion and Hypothesis results

The present research investigates the effects of financial stress and uncertainty on two categories of financial assets: conventional and green financial assets. With regard to the comparison of the impact of financial stress and uncertainty on conventional and clean energy equity, it was observed that financial stress induces positive shocks in the 0.5 quintiles of both categories of equity, which represent the turning point at which the market shifts from a bearish trend to a bullish trend. Additionally, our analysis highlights that the effect of financial stress on clean energy equity is stronger than that on conventional equity. Conversely, financial uncertainty exerts a negative impact on both conventional and clean energy equity in the upper quantiles of 0.8-0.9, potentially causing a shift from an upward trend to a downward trend. The outcomes of our investigation align with the results of previous studies conducted by Aziz et al. (2021), Reboredo and Uddin (2016), and Soltani and Abbes (2022), which demonstrate that stress and financial uncertainty impact the returns of financial assets. Moreover, our findings are in line with the results reported in Chuliá et al.'s (2017) study, which showed that financial uncertainty generates negative shocks in the upper quantiles, indicating a potential alteration in the market direction.

Concerning bonds, it is evident that financial stress generates more significant shocks on all types of bonds compared to financial uncertainty. However, it is worth mentioning that the impact of financial stress on conventional bonds is stronger than that on green bonds. In contrast, the opposite trend is observed for financial uncertainty, as it exerts more severe shocks on green bonds than on conventional bonds. Overall, our study reveals that the impact of uncertainty and financial stress on conventional and green bonds differs across quantiles, which is contingent on market conditions. These results are in line with prior research conducted by He et al. (2021), Fu et al. (2022), Pham and Nguyen (2022), and Lin and Su (2022). The findings of the study were corroborated by the nonparametric causality-in-quantile test. In summary, the results can be summarized in the following points:

- Overall, financial stress exerts a more positive significant impact on assets than financial uncertainty does.
- Both financial stress and uncertainty have a greater effect on conventional bonds than on green bonds.
- Financial stress and uncertainty affect conventional stocks more than all types of bonds.
- Financial stress and uncertainty affect green stocks more significantly than any other asset.

It is worth noting that the stress index in financial markets serves a dual purpose: as a measure of stress and as a leading indicator of the economy, helping to forecast macroeconomic trend reversals. Consequently, financial stress can be defined as the impact of uncertainty and shifting expectations of losses on the economic agents of financial institutions and markets (Montassar et al., 2014). In the finance and economics world, researchers have taken an interest in evaluating the stress affecting different types of assets and investments. This is done with the objective of understanding the magnitude and direction of these pressures so that appropriate recommendations can be made to minimize their effects. Thus, it would be beneficial to focus on the effects of financial stress on financial assets and formulate proposals based on its outcomes. Table 4.8 presents the results of the hypothesis.

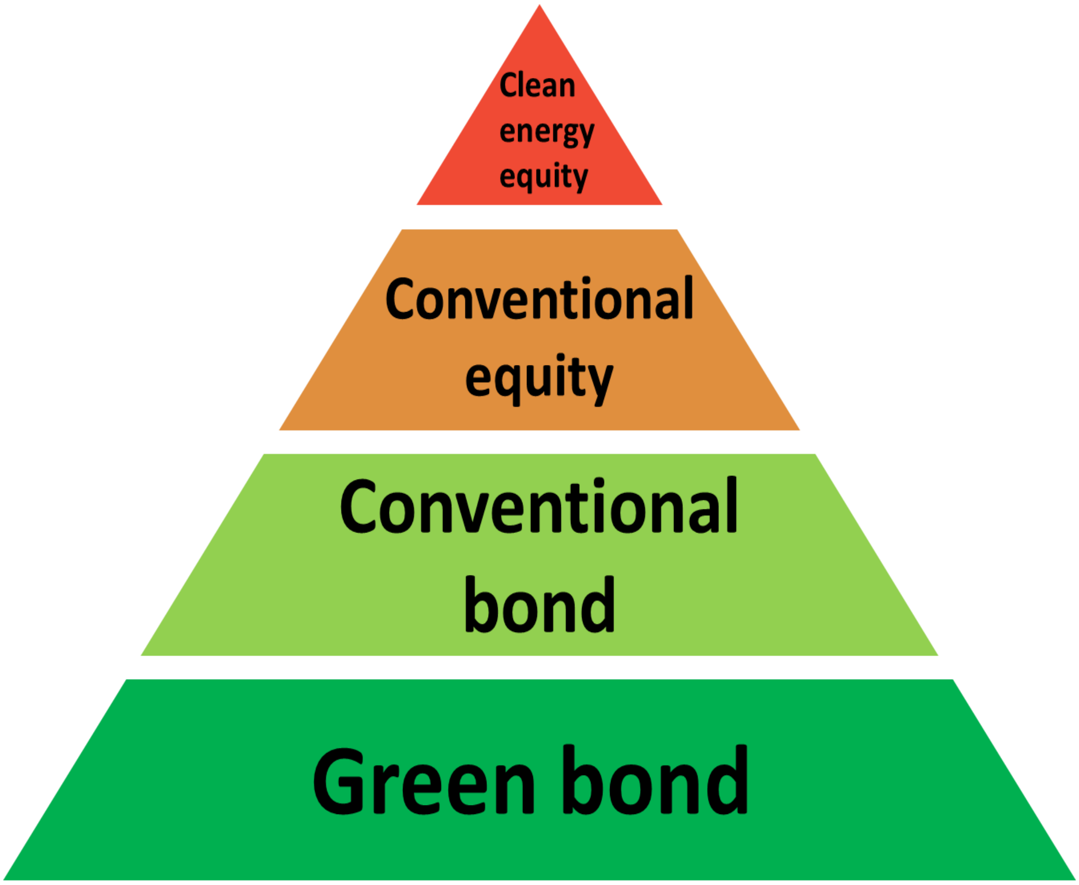
Table 4.7: *Summary of hypotheses results.*

Hypothesis	Result
Green bonds are safer than conventional bonds.	✓
Green stocks are safer than conventional equity.	X

Building upon the stud’s empirical outcomes regarding the effects of financial stress on conventional and green assets, we propose a pyramid (see Figure 4.16) that classifies the assets least and most influenced by financial stress; the assets that are least impacted by financial stress are at the bottom and the most impacted are at the top. We see that green bonds are the least volatile assets due to financial stress, followed by conventional bonds, which are more affected by financial stress than green bonds but less affected than conventional stocks. Finally, at the top of the pyramid, we find green stocks, which are considered the most impacted by financial stress.

This study suggests pyramid categorizes conventional and green financial assets according to their sensitivity to financial stress. This is an essential tool for assessing investment options and highlights the importance of hedging strategies when investing in the riskiest assets. The pyramid also emphasizes the need to increase the efficiency of volatile assets in the market and implement measures and regulations to mitigate their susceptibility to economic shocks. The proposed pyramid is a useful tool for investors to assess the risk levels of different financial assets. It identifies green bonds as the least vulnerable to financial stress, followed by conventional bonds. While conventional bonds are more exposed to financial stress than green bonds, they are still less vulnerable than conventional stocks, which are the most vulnerable asset class.

Figure 4.16: *Assets-based risk*



The proposed pyramid can be utilized by investors to make well-informed investment decisions based on their risk tolerance. Those who prefer lower risk may find green bonds to be a suitable investment, whereas those willing to assume more risk may opt for conventional bonds. On the other hand, investors who are comfortable with higher risk can choose to invest in green stocks. Overall, the proposed pyramid highlights the importance of market efficiency and regulatory measures in mitigating the effects of financial stress on vulnerable assets. By taking measures to enhance the efficiency and resilience of assets in the market, investors can make informed investment decisions and reduce their exposure to financial shocks.

4.4.3.1. An Application in the Context of Modern Portfolio Theory.

The Modern Portfolio Theory, introduced by (Markowitz, 1952, 1959), is a framework that helps investors to construct an optimal portfolio of assets that maximizes returns while minimizing risk. An application in the context of the Modern Portfolio Theory could help investors to build and manage their portfolios. The Modern Portfolio Theory can be utilized in a scenario where an investor is looking to create a portfolio that balances high returns with low risk and contemplating which indices to include in this portfolio. The investor aims to identify the indices that will yield the maximum return while minimizing risk. The application could use historical data and statistical analysis to estimate the expected returns and risks of different assets and then compare them to find the portfolio that offers the highest expected return for a given level of risk. The study conducted a mean-variance analysis to construct six investment portfolios. To identify the optimal asset allocation in each portfolio, we evaluated the standard deviation of returns for each portfolio and selected the portfolio with the lowest expected risk-based standard deviation. Table 4.9 presents the results of our analysis, including the optimal portfolio weight for each asset and the corresponding expected risk-based standard deviation. Table 4.9 indicates that the best portfolio of two investments is the one that contains a mixture of 60% green bonds and 40% conventional bonds, as it offers a very high average return compared to other portfolios of up to 70% with a minimum risk of 0.009 standard deviation. The next least risky portfolio consists of green bonds alone, as it offers a 0.47% return with a risk of 0.012 standard deviation, followed by an investment portfolio consisting of traditional bonds only, as it offers a return of 1.03% with a risk of 0.014 standard deviation, and finally, a portfolio composed of conventional stocks, which only offers a 14.83% return with a risk of 0.089 standard deviation.

Table 4.8: *Optimal portfolio weight-based mean-variance analysis*

Portfolio	Weights	Mean return	Standard deviation
Portfolio 1			
w_{GBND}	60%	70%	0.009
w_{BND}	40%		
Portfolio 2			
w_{GBND}	100%	0.47%	0.012
w_{EQT}	0.00%		
Portfolio 3			
w_{GBND}	100%	0.47%	0.012
w_{GEQT}	0.00%		
Portfolio 4			
w_{BND}	100%	1.03%	0.014
w_{EQT}	0.00%		
Portfolio 5			
w_{BND}	100%	1.03%	0.014
w_{GEQT}	0.00%		
Portfolio 6			
w_{GEQT}	0.00%	14.83%	0.089
w_{EQT}	100%		

These results are consistent with the proposed pyramid, Figure 4.16, which shows the lowest risk assets to the highest risk, and they indicate that the mixture of conventional and green bonds achieves the best return and least risk. It is worth noting that a mixture of green bonds with traditional stocks or a mixture of conventional bonds with green or conventional stocks presents less risk and, at the same time, a lower return than the mixture between green stocks and traditional stocks, which offers a higher return with higher risk.

4.5. Conclusion and Policy Recommendation

This study aims to investigate the impact of financial stress and uncertainty on the returns of green and conventional bonds and stocks in the United States from 2010 to 2022. The research utilizes a quantile-on-quantile approach and nonparametric causality-in-quantiles analysis to examine the relationship between these variables. The study seeks to contribute to the existing literature by providing insights into the extent to which financial stress and uncertainty affect the performance of green and conventional bonds and stocks. The findings reveal that financial stress induces positive shocks in the 0.5 quantiles of both conventional and clean energy equity, with a stronger impact on clean energy equity. In contrast, financial uncertainty exerts a negative impact on both types of equity in the upper quantiles of 0.8-0.9. These results align with previous studies conducted by Aziz et al. (2021), Reboredo and Uddin (2016), and Soltani and Abbes (2022), which demonstrate the significant influence of financial stress and uncertainty on the returns of financial assets. Additionally, our findings are consistent with Chuliá et al.'s (2017) research, which indicates that financial uncertainty generates negative shocks in the upper quantiles and may cause a potential shift in the market direction. Regarding bonds, the study findings indicate that financial stress causes more significant shocks on all types of bonds than financial uncertainty. However, it is worth noting that the impact of financial stress on conventional bonds is more profound than that on green bonds. Overall, our research reveals that the effects of uncertainty and financial stress on conventional and green bonds vary across quantiles, depending on market conditions. These findings are consistent with previous studies conducted by He et al. (2021), Fu et al. (2022), Pham and Nguyen (2022), and Lin and Su (2022).

Building upon the study's empirical outcomes regarding the effects of financial stress on conventional and green assets, the study proposes a pyramid that classifies the assets least and most influenced by financial stress. The presented pyramid in this study is a crucial instrument for evaluating investment choices and emphasizes the significance of hedging strategies when investing in the riskiest assets. Moreover, it is an effective tool for investors to evaluate the risk levels of different financial assets under financial stress conditions. Furthermore, the proposed pyramid highlights the necessity of enhancing the efficiency of volatile assets in the market and implementing measures and regulations to mitigate their susceptibility to economic shocks.

4.5.1. Policy Implications and Recommendations

- Encourage green investments: Green bonds were found to be less vulnerable to financial stress compared to conventional bonds and stocks. Policymakers should encourage green investments by offering incentives to investors, such as tax credits and subsidies, to promote the transition toward a more sustainable and resilient economy.

- Implement measures to mitigate the sensitivity to economic shocks: Policymakers should implement measures to mitigate the susceptibility of financial assets to economic shocks. This can be achieved through the introduction of policies aimed at stabilizing financial markets during times of stress and uncertainty, such as implementing circuit breakers or increasing regulatory oversight.
- Increase the efficiency of volatile assets: Since volatile assets are more susceptible to economic shocks, policymakers should focus on enhancing the efficiency of these assets in the market. This can be achieved by implementing measures, such as introducing new investing rules and regulations.
- Increase awareness and education: Given the importance of financial stress and uncertainty on the returns of financial assets, policymakers should increase awareness and education among investors regarding the risks associated with investing in volatile assets. This can help to reduce the adverse effects of market volatility and improve investor confidence in the long-term performance of financial markets.

CHAPTER 5

The Impact of Renewable Energy, Economic Freedom, and Financial Inclusion on GDP Per Capita: An Empirical Analysis.

5.1. Introduction

The drivers of economic development in all economies are changing due to shifts in knowledge, economic freedom (EF), FDV, and innovation by researchers (J. Wang et al., 2022). Among these drivers, energy utilization has remained a significant factor in the drivers of economic development. Specifically, the incorporation of renewable energy sources has gained substantial recognition (Ahmad & Majeed, 2022). These sustainable energy sources offer numerous advantages, including reduced greenhouse gas emissions, enhanced energy security, and increased trade openness and urbanization levels, thereby contributing to the overall economic growth and prosperity of nations (Sahlian et al. 2021; Su et al. 2022). This integration of renewable energy sources in economic development strategies has garnered attention from policymakers and researchers alike, as it aligns with the global transition towards a more sustainable and low-carbon future (Ahmad & Majeed 2022). Furthermore, the adoption of renewable energy technologies not only promotes environmental sustainability but also fueling economic growth (Su et al. 2022). These benefits underscore the importance of energy utilization, particularly through renewable sources, in driving economic development and fostering a more sustainable future for nations worldwide. In this study we investigate the effects of renewable energy consumption per capita, squared renewable energy consumption per capita, economic freedom, and financial inclusion on GDP per capita. Furthermore, the study aims to explore the potential mediation effect of financial inclusion between renewable energy per capita, squared renewable energy per capita, and GDP per capita. The inclusion of the squared renewable energy per capita variable is motivated by the desire to examine whether there exist diminishing or increasing returns to renewable energy. According to economic theory, it is commonly assumed that the impact of a variable on an outcome follows a pattern of diminishing or increasing returns (J. Wang et al., 2022). The research is motivated by the need to comprehend the mechanisms by which renewable energy influences economic development. By investigating the mediating role of financial inclusion, this study contributes to the existing knowledge on the relationship between renewable energy and GDP. This study employed the panel ARDL with pooled mean group estimators. Additionally, we used a structural equation model to investigate the mediating role of financial inclusion in the relationship between per capita GDP and per capita renewable energy consumption. Examining the mediating effect provides valuable insights into the influence of the independent variable on the dependent variable, as well as enables the dissection of intricate causal relationships to identify potential underlying mechanisms responsible for these relationships (L.-J. Chen & Hung, 2016). Exploring the mediating effect allows researchers to gain a deeper understanding of the indirect pathways through which the independent variable exerts its impact on the dependent variable (Hayes, 2009). This analytical approach allows for a comprehensive examination of the various mediating variables that mediate the relationship between the independent and dependent variables, shedding light on the underlying processes and pathways involved in the causal chain (Baron & Kenny 1986). Overall, testing the mediating effect serves as a valuable tool in uncovering and elucidating the complex causal mechanisms that drive relationships between variables in research studies.

5.2. Literature Review

5.2.1. The relationship between GDP per capita, FNI, and renewable energy

The relationship between renewable energy and GDP has been examined in several studies, providing insights into the potential impact of renewable energy on economic development. Several studies have examined the relationship between renewable energy consumption and GDP growth, shedding light on the complex dynamics between these variables.

Al-mulali et al. (2013) conducted a comprehensive analysis across countries categorized by income levels and found that 79% of the countries exhibit a positive bi-directional long-term relationship between renewable energy consumption and GDP growth, supporting the feedback hypothesis. This implies that increased renewable energy consumption contributes to economic growth, and vice versa.

Sharif et al. (2020) examined Turkey's ecological footprint while conducting a study that examined the consequences of energy usage. They discovered that while economic growth and non-renewable energy have a favorable effect across different quantiles, renewable energy helps reduce the ecological footprint over the long term.

Ahmad & Majeed (2022) also found a significant and positive impact of renewable energy on output growth in their study of South Asian economies, underscoring the importance of investing in renewable energy for sustainable economic development.

J. Wang et al. (2022) explored the impact of different energy sources on output levels in Pakistan and found an inverted U-shaped relationship between fossil fuel usage and output per person, indicating diminishing returns over time. In contrast, they found a U-shaped relationship between renewable energy consumption and output levels in the long run. These findings align with the results of Al-mulali et al. (2013), who observed a unidirectional long-term relationship in some countries, where GDP growth influences renewable energy consumption, supporting the growth hypothesis. Together, these studies suggest that renewable energy becomes increasingly advantageous for both production and the environment in the later stages of economic development. The regional variations have been identified, with a noticeable increase in the correlation between renewable energy production and economic growth in North Africa and oil-producing countries (Abanda et al., 2012). These studies highlight the potential of renewable energy to drive economic growth, suggesting that fostering renewable energy adoption can lead to positive economic outcomes (Ahmad & Majeed, 2022; Al-mulali et al., 2013).

Barrera-Santana et al. (2022) examined the relationship between income and energy usage, striving to provide unbiased estimates and elucidate the link between income and energy consumption, considering bidirectional causality. The study's sample comprises 32 OECD nations, spanning the period from 2000 to 2015. The research findings indicate that the energy efficiency governance index exerts an impact on economic growth primarily through energy consumption, leading to a more efficient utilization of energy in the manufacturing process and stimulating economic growth. The elasticity between energy consumption and income growth resulting from energy governance is approximately unity, which is nearly double the magnitude commonly observed in the literature. Interestingly, the direction of causation from income to energy consumption is found to be negative (approximately -3.0), contrary to the usual negative association observed in literature. The study highlights that energy consumption contributes positively to economic growth due to advancements in energy governance, while income growth, in turn, enhances energy efficiency. Considering that energy consumption stands as the predominant source of carbon emissions in OECD nations, the research underscores the critical role of energy governance in decoupling carbon emissions from GDP growth, offering potential pathways for achieving environmental sustainability.

Turning to the relationship between GDP per capita and financial inclusion, Ozturk & Ullah (2022) found that financial inclusion promotes economic growth but negatively affects environmental quality due to increased CO_2 emissions. This highlights the need for policymakers to balance economic growth and environmental sustainability.

Elmonshid et al. (2022) investigated the determinants of financial inclusion in the Saudi Arabian economy and found that factors such as broad money, domestic credit to the private sector, loan-to-deposit ratio, GDP per capita, money supply, and internet usage significantly impact long-term economic growth and financial inclusion. They emphasize the importance of fostering financial literacy and expanding access to financial services.

Ifediora et al. (2022) examined the influence of financial inclusion on economic growth in sub-Saharan African countries and found that various dimensions of financial inclusion, such as availability and penetration, positively impact economic growth, while the presence of bank branches and ATMs also contribute to economic growth.

L. Wang et al. (2022) focused on the interplay between financial inclusion and sustainable development in China, highlighting how financial inclusion, particularly through credit constraints on highly polluting firms, enhances green economic efficiency.

N. Khan et al. (2022) investigated the impact of financial inclusion on financial sustainability, financial efficiency, GDP, and human development in G20 nations. They found that financial inclusion has a significant long-term impact on financial sustainability.

Cui et al. (2022) conducted a comprehensive investigation into the determinants of economic inclusive development across different countries during the COVID-19 pandemic. The primary objective of the study was to explore the interplay between financial inclusion, renewable energy utilization, and economic inclusion in diverse national contexts. The research utilized panel data encompassing 40 nations over the period from 2010 to 2020. The findings revealed the presence of geographic autocorrelation in inclusive development, indicating variations in the level of inclusive growth among different nations. Moreover, both financial inclusion and renewable energy usage were found to have a positive and significant impact on economic inclusive growth. However, the study also demonstrated that improvements in the industrial structure exerted a negative moderating effect on domestic renewable energy use and inclusive growth. These results provide valuable insights into the factors influencing economic inclusive development during the challenging circumstances of the COVID-19 pandemic, emphasizing the importance of financial inclusion and renewable energy adoption while considering the potential implications of industrial structural changes.

Feng et al. (2022) conducted an investigation to explore the interrelationships among financial inclusion, renewable energy usage, and environmental quality in China. To quantify the effects of these variables, the study employed the ARDL model. The estimations derived from the ARDL model provided compelling evidence that augmenting the number of ATMs and total insurance has a positive and enduring impact on renewable energy utilization in China. However, in the Chinese context, an increase in the number of ATMs and overall insurance led to a negative effect on CO_2 emissions. Overall, the study's findings underscore the role of financial inclusion in China in promoting the adoption of renewable energy sources while concurrently mitigating CO_2 emissions, thus contributing to environmental sustainability.

Recent studies M. A. Khan & Rehan, (2022), and Murshed et al. (2022) suggest that financial inclusion can a critical role in the relationship between renewable energy and GDP. Financial inclusion facilitates access to financial products and services that support green investments and innovations, thereby positively influencing renewable energy consumption and environmental performance. Thus, financial inclusion contributes to the reduction of CO_2 emissions by enhancing energy efficiency and productivity (Feng et al., 2022; M. A. Khan & Rehan, 2022).

The influence of financial inclusion on GDP operates through various channels. Firstly, financial inclusion promotes economic growth by providing access to financial resources, fostering entrepreneurship, and stimulating investment in renewable energy projects. This, in turn, can lead to increased GDP through job creation, income generation, and productivity improvements. Secondly, financial inclusion contributes to globalization by enabling participation in international trade and investment, which can further boost GDP growth. Thirdly, as urbanization progresses, financial inclusion supports the development of renewable energy infrastructure in cities, contributing to both GDP and environmental sustainability. Lastly, financial inclusion affects the industrial structure by encouraging the transition towards cleaner and more sustainable industries, thus influencing both GDP and environmental outcomes (Cui et al., 2022; Feng et al., 2022; M. A. Khan & Rehan, 2022; Murshed et al., 2022).

5.2.2. The relationship between GDP per capita and economic freedom

The studies conducted by Abate (2022); Brkić et al. (2020); Duan et al. (2022); Mahmood et al. (2022); Santiago et al. (2020) collectively contribute to the understanding of the relationships between economic freedom, and economic growth in various regions and contexts. Brkić et al. (2020) focus on European countries and find that increases in economic freedom, as measured by the Index of Economic Freedom, are associated with economic growth. They also explore the moderating effect of EU membership on this relationship. The findings emphasize the importance of promoting economic freedom for fostering economic growth and highlight the vulnerability of European economies to external shocks, such as the subprime crisis.

Duan et al. (2022) extend the analysis to investigate the relationship between human capital, economic freedom, governance performance, and economic growth in BRICS countries. Their findings reveal an inverted U-shaped relationship between human capital and economic growth, indicating a non-linear association. They also highlight the positive moderating role of governance performance on the impact of human capital on economic growth.

Mahmood et al. (2022) expand the scope of investigation to Asia-Pacific economies and examine the interplay between energy intensity, economic freedom, and carbon emissions. They find a positive long-term impact of economic freedom on both the economy and the environment. Their results underscore the importance of implementing structural reforms and fostering a favorable economic and regulatory environment in Asia-Pacific countries to promote sustainable economic growth.

Abate (2022) explores the impact of foreign aid on developing countries and the role of institutional quality and economic freedom in shaping the aid-growth relationship. The study reveals an inverted U-shaped relationship between aid and economic growth, indicating the presence of an optimal aid level. Moreover, they find that institutional quality and economic freedom play a mediating role in this relationship.

Santiago et al. (2020) investigate the effects of globalization and economic freedom on the economic growth of Latin American and Caribbean countries. They find that globalization has a positive long-term impact on economic growth, particularly in its economic and social dimensions. However, economic freedom exhibits a negative impact on long-term economic growth in these regions. Additionally, the study identifies the significance of electric power consumption and social globalization in promoting short-term economic growth.

5.2.3. Hypotheses of the study

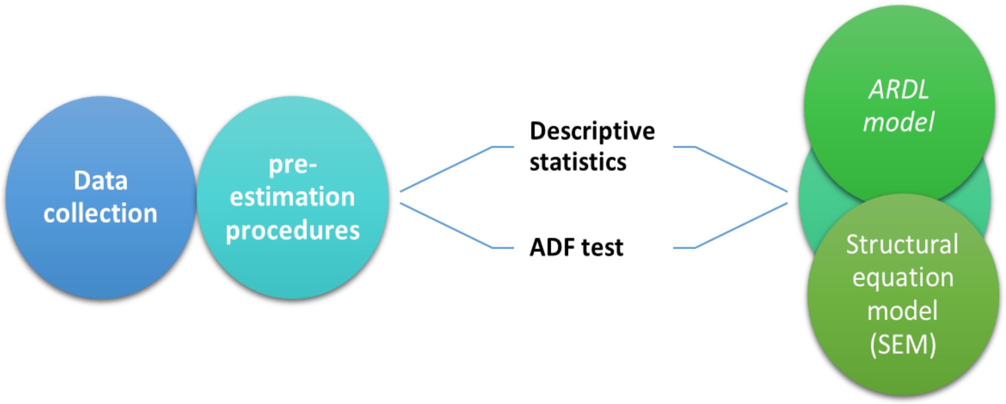
Building upon the preceding information, the study examines the following hypotheses:

- Hypothesis 1: Renewable energy positively affects GDP per capita.
- Hypothesis 2: Economic freedom positively affects GDP per capita.
- Hypothesis 3: Financial inclusion plays the mediation role between Renewable energy and GDP per capita.

5.3. Data Description and Methodology

In order to ensure that the results of our research can be trusted, we followed specific procedures throughout the analysis process. These procedures outlined the steps we took at each stage, starting from collecting the data all the way to extracting the results. Figure 5.1 provides a summary of these procedures, giving a visual representation of the entire process. By following these procedures, we aimed to enhance the credibility and validity of our research findings. It was important for us to stick to a systematic approach in order to maintain the integrity of the study and arrive at reliable and robust conclusions. These steps were carefully designed to ensure that our research was conducted in a rigorous and trustworthy manner.

Figure 5.1: *Study procedures*



5.3.1. Data Description

The research utilizes data sourced from the World Bank and the International Monetary Fund of the Group of Twenty. The study period spans from 1995 to 2019. The data was standardized using the Z-distribution. This approach aims to enhance result interpretability and facilitate comparisons among different variables. The normalization process ensures that the data conforms to a standard normal distribution, denoted as N(0, 1) or the Z-distribution. The Z-distribution serves as a valuable statistical tool for drawing meaningful inferences and conducting statistical analyses on the data. By standardizing the data in this manner, we can mitigate the impact of scale and enable more accurate comparisons and interpretations of the variables under investigation (Fritz et al. 2012). The standardization can be written as the follow:

$$z = \frac{x-\mu}{\sigma}$$

Where, z represents the standardized value, x represents the original value, μ represents the mean, and σ represents the standard deviation. By using this formula, we can transform the data into a standardized format, where the mean is 0 and the standard deviation is 1. The data sources for GDP per capita and renewable energy per capita are derived from the WDI, while financial inclusion derived from IMF, and economic freedom data are obtained from the Heritage Foundation. The dataset consists of 475 observations for GDP per capita, and financial inclusion, 474 for economic, whereas renewable energy per capita has 391 observations. It's notable that the data set is unbalanced and has missing observations. To overcome this issue, linear interpolation has been used.

5.3.2. Methodology

5.3.2.1. Panel ARDL model

The selection of an appropriate model for data analysis, whether dynamic or static, is typically guided by the results of a unit root test. In cases where the variables are mixed or integrated, using a static panel model would result in spurious regression. Therefore, it is preferable to employ a dynamic model, as recommended by Brooks (2019). It is common in the fields of economics and finance to observe that most data points are not integrated at I (0). Consequently, if the study variables are mixed or integrated, or integrated of the first order, the suitable model for analysis would be the panel autoregressive distributed lag model. The panel ARDL model, originally introduced by Pesaran and Smith (1995) and Pesaran et al. (1999), provides an alternative to the vector autoregression (VAR) model and allows for testing cointegration in a single equation model over different time periods, encompassing both the long run and short run.

$$\mathit{\Delta}GDC_{it} = \alpha_i + \sum_{j=1}^{m-1} \beta_{ij}\mathit{\Delta}GDC_{i,t-j} + \sum_{l=0}^{n-1} \varphi_{il}\mathit{\Delta}REN_{i,t-1} + \sum_{r=0}^{n-1} \varphi_{il}\mathit{\Delta}RENS_{i,t-1} + \sum_{v=0}^{p-1} \gamma_{ir}\mathit{\Delta}FI_{i,t-r} + \sum_{w=0}^{s-1} \theta_{iu}\mathit{\Delta}EF_{i,t-u} + \sigma_1 GDC_{i,t-1} + \sigma_2 REN_{i,t-1} + \sigma_2 RENS_{i,t-1} + \sigma_3 FI_{i,t-1} + \sigma_4 EF_{i,t-1} + \varepsilon_{i,t}$$

Where, the variable GDC represents the GDP per capita at time t for unit i. The constant a pertains to the units under consideration. REN, REN square, FI, and EF correspond to the dependent variables. Note that RENS indicates to renewable energy per capita squared. The symbols $\beta_{\mathrm{ij}}, \phi_{\mathrm{il}}, \gamma_{\mathrm{ir}}, \theta_{\mathrm{iu}}, \delta_{\mathrm{iw}}$, and ρ_{iz}, represent the short-run parameters. The term $\varepsilon_{\mathrm{I,t}}$ denotes the identical disturbance term for the model. The error correction model is represented by β, and for it to infer the presence of a long-run relationship and establish variables as cointegrated, it should be significantly negative and less than one.

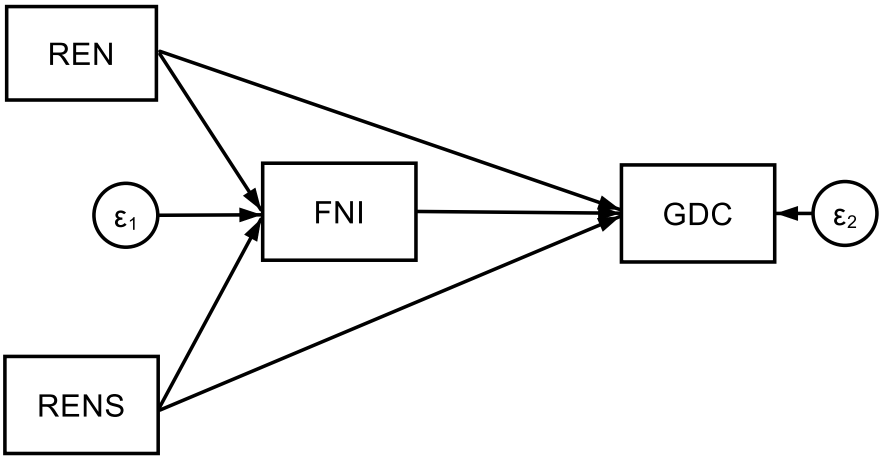
5.3.2.2. Structural equation model (SEM)

The utilization of mediator variables in exploring the influence of an independent variable on a dependent variable, as well as dissecting intricate causal relationships to identify potential underlying mechanisms, has garnered considerable attention among researchers. Within the realm of social science research, the application of multiple mediator variable modeling has gained significant traction, particularly within the framework of Structural Equation Modeling. The SEM approach enables researchers to analyze and quantify the mediating effects of multiple variables simultaneously, providing a comprehensive understanding of how the independent variable operates through various mediators to impact the dependent variable. By employing SEM and integrating multiple mediator variables into the analysis, researchers can gain valuable insights into the complex interplay and causal pathways within the studied phenomena (L.-J. Chen & Hung, 2016).

The primary objective of conducting mediation analysis is to examine whether the relationship between the independent variable X and the dependent variable Y is influenced by the presence of a mediator. Consequently, upon inclusion of the mediator, it is expected that some or all of the associations between the independent and dependent variables will be accounted for. A higher proportion of the indirect effect relative to the total effect signifies a stronger mediating effect.

Mediation analysis aims to investigate whether the relationship between X and Y is mediated by an additional factor known as the mediator variable (M). Consequently, mediation analysis involves the inclusion of at least three variables: the independent variable (X), the dependent variable (Y), and the mediator variable (M). Through this analytical framework, researchers can explore the potential mediating role of M in elucidating the underlying mechanisms through which X impacts Y. The conceptual framework and model structure are illustrated in Figure 5.2. By utilizing SEM, we aim to comprehensively analyze the complex interplay among these variables and explore the indirect influence of financial inclusion on the association between economic development, represented by per capita GDP, and the adoption of renewable energy resources at the individual level. The use of SEM provides a rigorous statistical approach to assess the mediating effect and offers insights into the underlying mechanisms through which financial inclusion may facilitate the transition towards sustainable energy consumption patterns. It is important to acknowledge that the mediation effect of financial inclusion on the relationship between renewable energy and GDP is contingent upon the unique characteristics and circumstances of each country or region. Factors such as institutional frameworks, policy support, technological advancements, and resource endowments can significantly shape this relationship. Therefore, policymakers should consider the specific context when designing strategies to promote financial inclusion, renewable energy adoption, and sustainable economic development. Further research is needed to gain a comprehensive understanding of the mechanisms through which financial inclusion mediates the relationship between renewable energy and GDP and to develop tailored policies that maximize the benefits of financial inclusion for both economic and environmental outcomes.

Figure 5.2: *Model structure*



5.4. Empirical Results

5.4.1. Descriptive statistics

Table 5.1 consists of a summary of statistical data for several variables. These variables include GDP per capita, renewable energy per capita, financial inclusion, and economic freedom.

Table 5.1: *Descriptive statistics*

The Variables	GDC	REN	FNI	EF
Obs	475	391	475	474
Mean	20601.24	3445.909	-2.87E-09	64.466
Standard deviation	17036.87	2164.714	1.23314	9.396
Min	373.7665	385.091	-2.64056	43.8
Max	68156.63	8455.547	2.192705	83.1
CIPS	0.986	0.998	0.308	0.975

Obs indicates number of observations.

Descriptive statistics reveal that the average GDC is 20,601.24, while the average REN is 3,445.909. The mean value for FNI is close to zero, indicating minimal deviation from the baseline. EF is recorded with an average value of 64.466. Standard deviations provide insights into the dispersion of the data, with GDC showing a significant value of 17,036.87, REN at 2,164.714, FNI at 1.233, and EF at

9.3969. The range of the variables is captured by the minimum and maximum values: GDC ranges from 373.766 to 68,156.63, REN ranges from 385.091 to 8,455.547, FNI ranges from -2.6406 to 2.192, and EF ranges from 43.8 to 83.1. Additionally, panel unit root tests using the CIPS method were conducted to assess the stationarity of the variables over time. The reported test statistics for GDC, REN, FNI, and EF are 0.986, 0.998, 0.308, and 0.975, respectively. These results indicate that the variables are integrated in the first order.

5.4.2. Panel ARDL

This study employs the PMG estimator to investigate the long-term relationships among key variables in a panel dataset. The analysis seeks to understand the impact of the independent variables. The findings provide significant insights into the enduring dynamics and equilibrium relationships among these variables. The results presented in Table 5.2 provide several notable insights into the enduring dynamics and equilibrium relationships between the variables. The coefficient estimates reveal a positive and statistically significant effect of REN on GDC, indicating that an increase in REN leads to a rise in GDC. However, the RENS exhibits a negative and statistically significant relationship, suggesting a diminishing marginal effect of renewable energy beyond a certain threshold. Regarding EF, it has a positive and significant effect on the dependent variable, implying that an improvement in economic freedom positively influences the GDC. Moreover, FNI also shows a positive effect on GDC, indicating that an increase in FNI leads to an improvement in the GDC. The empirical analysis provides evidence of the long-term equilibrium relationships among the variables, supported by their respective 95% confidence intervals. The findings enhance our comprehension of the underlying dynamics and interactions between the independent variables and the dependent variable. Regarding the short-run relationships, the analysis reveals several findings. Firstly, the ECT shows a negative and statistically significant coefficient, indicating a mechanism for correcting deviations from long-run equilibrium in the short run. Conversely, the variables REN, RENS, EF, and FNI do not exhibit statistical significance in influencing the dependent variable in the short run. These findings suggest the presence of short-run dynamics characterized by the error correction mechanism represented by ECT. The non-significance of the remaining variables highlights their limited impact on the dependent variable within the short-run context.

Table 5.2: *Panel ARDL results*

Variables	Coefficient	Standard error	P-value
Long run			
REN	3.760	0.893	0.000
RENS	-1.594	0.598	0.008
EF	1.296	0.081	0.000
FNI	0.319	0.101	0.002
Short run			
ECT	-0.111	0.038	0.004
REN	4.013	5.314	0.450
RENS	-5.053	5.064	0.318
EF	0.014	0.100	0.886
FNI	-0.080	0.058	0.165
constant	-0.191	0.147	0.193

5.4.3. SEM analysis

In addition to the PMG analysis, the study employs SEM to investigate the mediating role of FNI in the relationship between REN, RENS, and GDC. The analysis focuses on assessing the direct effects of independent variables (REN and RENS) on GDC and the indirect effects mediated by FI. The results of the SEM analysis are presented in Table 5.3. Regarding the direct effects, the coefficient for FNI on GDC was found to be 0.510, indicating a significant positive relationship. REN showed a significant positive effect on GDC, with a coefficient of 0.615. In contrast, RENS had a significant negative effect on GDC, with a coefficient of -0.303. Moving on to the mediation effects, when FNI acted as the mediator, it exhibited a significant positive influence on GDC through REN, with a coefficient of 1.516. Conversely, the mediation effect of FNI through RENS was significant and negative, with a coefficient of -0.911. Examining the indirect effects of the mediation, it was found that FNI, as a mediator, significantly influenced GDC via REN with a coefficient of 0.773. Similarly, the mediation effect of FNI through RENS was also significant and negative, with a coefficient of -0.465.

Table 5.3: *SEM analysis*

Variables	Coefficient	Standard error	P-value
Direct effects			
Dependent variable: GDC			
FNI	0.510	0.038	0.000
REN	0.615	0.121	0.000
RENS	-0.303	0.111	0.006
Dependent variable: FNI			
REN	1.516	0.138	0.000
RENS	-0.911	0.138	0.000
Indirect effects			
Mediator: FNI			
REN	0.773	0.091	0.000
RENS	-0.465	0.078	0.000
Total effects			
Dependent variable: GDC			
FNI	0.510	0.038	0.000
REN	1.389	0.127	0.000
RENS	-0.768	0.127	0.000
var(e.GDC)= 0.351			
var(e.FNI)= 0.548			
chi2(0)= 0.000			

var(e.GDC) and var(e.FNI) represent the estimated variances of the error terms in GDC and FNI, respectively.

Considering the total effects, which combine the direct and indirect effects, it was observed that FNI had a significant positive total effect on GDC with a coefficient of 0.510. Furthermore, REN exhibited a significant positive total effect on GDC with a coefficient of 1.389, while RENS had a significant negative total effect on GDC with a coefficient of -0.768. The estimated variances of the error terms, var(e.GDC) and var(e.FNI), are 0.351 and 0.548, respectively, indicating the amount of unexplained variance in the model. The model comparison test, comparing the proposed model with a saturated model, shows a non-significant chi-square statistic, implying that the proposed model fits the data well.

Table 5.4 demonstrates a good model fit based on the fit statistics and criteria utilized. The likelihood ratio of chi-square test, comparing the proposed model with a saturated model, yields a non-significant chi-square value, indicating that the proposed model fits the data well. Similarly, the baseline comparison chi-square test reveals a significant difference between the baseline model and the saturated model, supporting the superiority of the proposed model.

Table 5.4: *Diagnosis tests*

Fit statistic	**Value**	**Description**
Likelihood ratio		
chi2_ms(0)	0.000	model vs. saturated
chi2_bs(5)	643.727	baseline vs. saturated
p > chi2	0.000	
Population error		
RMSEA	0.000	Root mean squared error of approximation
90% CI, lower bound	0.000	
upper bound	0.000	
pclose	1.000	Probability RMSEA <= 0.05
Information criteria		
AIC	2810.164	Akaike's information criterion
BIC	2845.883	Bayesian information criterion
Baseline comparison		
CFI	1.000	Comparative fit index
TLI	1.000	Tucker–Lewis index
Size of residuals		
SRMR	0.000	Standardized root mean squared residual
CD	0.537	Coefficient of determination

The population error assessment indicates a perfect fit of the model, as the root mean squared error of approximation is 0.000, with a 90% confidence interval ranging from 0.000 to 0.000. The probability (pclose = 1.000) that the RMSEA is less than or equal to 0.05 further supports the excellent fit of the model. The information criteria, including Akaike's information criterion (AIC) and the Bayesian information criterion, yield values of 2810.164 and 2845.883, respectively. These criteria suggest that the proposed model strikes a good balance between model fit and complexity. The baseline comparison measures, the comparative fit index and the Tucker-Lewis index, both attain perfect values of 1.000, indicating a high degree of model fit. The size of residuals, as indicated by the standardized root mean squared residual, is 0.000, further confirming the excellent fit of the model. The coefficient of determination measures the proportion of variance explained by the model and yields a value of 0.537, suggesting that the model accounts for a significant portion of the variance in the dependent variable (Gunzler et al., 2013). Overall, the findings indicate that the proposed structural equation model exhibits a superior fit to the data, providing a reliable representation of the relationships among the variables. These results enhance confidence in the validity and robustness of the model's conclusions. Furthermore, we conducted a significance testing of the indirect effect using Baron & Kenny’s (1986) approach, as adjusted by Iacobucci et al. (2007). Table 5.5 and 5.6 provide valuable insights into the mediating role of FNI in the relationship between REN and RENS with GDC, respectively.

Table 5.5: *Significance Testing - REN*

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	0.774	0.774	0.774
Standard error	0.092	0.092	0.093
z-value	8.435	8.435	8.329
p-value	0.000	0.000	0.000
Confidence interval	0.594 , 0.954	0.594 , 0.954	0.595 , 0.959

With regards to the mediation role of FNI between REN and GDC, the findings in Table 5.5 reveal that the estimated value of the indirect effect is 0.774, accompanied by a standard error of 0.092. The corresponding z-value is 8.435, yielding a highly significant p-value of 0.000. Moreover, the 95% confidence interval for the indirect effect ranges from 0.594 to 0.954. Applying Baron & Kenny’s (1986) approach to testing mediation involving three steps, we observe the following based on the results presented in Table 5.5:

- Step 1 (X -> M): The relationship between FNI and REN exhibits statistical significance, as indicated by a coefficient (B) of 1.516 and a p-value of 0.000.
- Step 2 (M -> Y): The relationship between FNI and GDC is statistically significant, with a coefficient (B) of 0.510 and a p-value of 0.000.

- Step 3 (X -> Y): The relationship between REN and GDC demonstrates statistical significance, evidenced by a coefficient (B) of 0.616 and a p-value of 0.000.

Given the significant results from all three steps and the Sobel's test, it can be concluded that the mediation in this context is partial, aligning with Baron and Kenny's (1986) framework. Moreover, the ratio of the indirect effect to the total effect value is computed as 0.557, indicating that approximately 56% of the effect of REN on GDC is mediated by FI. Furthermore, the ratio of the indirect effect to the direct effect value amounts to 1.257, suggesting that the mediated effect of FNI on GDC is roughly 1.3 times larger than the direct effect of REN on GDC.

Table 5.6: *Significance testing-RENS*

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	-0.465	-0.465	-0.472
Standard error	0.079	0.079	0.078
z-value	-5.893	-5.893	-6.042
p-value	0.000	0.000	0.000
Confidence interval	-0.620 , -0.310	-0.620 , -0.310	-0.631 , -0.324

In relation to the mediation role of FNI between RENS and GDC, Table 5.6 reveals an indirect effect estimate of -0.465, accompanied by a standard error of 0.079. The corresponding z-value is -5.893, resulting in a highly significant p-value of 0.000. Furthermore, the 95% confidence interval for the indirect effect ranges from -0.620 to -0.310. Applying Baron and Kenny's (1986) approach to testing mediation involving three steps, the analysis yields the following insights based on the results presented in Table 5.6:

- Step 1 (X -> M): The relationship between FNI and RENS exhibits statistical significance, as evidenced by a coefficient (B) of -0.911 and a p-value of 0.000.
- Step 2 (M -> Y): The relationship between FNI and GDC demonstrates statistical significance, with a coefficient (B) of 0.510 and a p-value of 0.000.

- Step 3 (X -> Y): The relationship between squared RENS and GDC is statistically significant, as indicated by a coefficient (B) of -0.304 and a p-value of 0.006.

Considering the significant results from all three steps and the Sobel's test, it can be concluded that the mediation in this context is partial, aligning with the framework proposed by Baron and Kenny (1986). Furthermore, the study use X. Zhao et al. (2010) approach to testing mediation. The results of X. Zhao et al. (2010) confirm existing partial mediation. The ratio of the indirect effect to the total effect value is computed as 0.605, suggesting that approximately 61% of the effect of RENS on GDC is mediated by FNI. Additionally, the ratio of the indirect effect to the direct effect value amounts to 1.532, indicating that the mediated effect of FNI on GDC is approximately 1.5 times larger than the direct effect of RENS on GDC.

5.4.4. Discussion and Hypothesis results

The positive and statistically significant coefficient of REN on GDC in the results is in accordance with the findings of Al-mulali et al. (2013). Their comprehensive analysis across countries categorized by income levels revealed a positive bi-directional long-term relationship between renewable energy consumption and GDP growth, supporting the feedback hypothesis. This implies that an increase in renewable energy consumption contributes to economic growth, and vice versa. The positive and statistically significant coefficient of REN in the results provides further evidence and reinforcement of the findings of Al-mulali et al. (2013), confirming the positive impact of renewable energy on GDP per capita. Additionally, Ahmad & Majeed (2022) conducted a study focused on South Asian economies and found a significant and positive impact of renewable energy on output growth. Their research emphasizes the crucial role of investment in renewable energy for sustainable economic development. The alignment between their findings and the positive coefficient of renewable energy in the results further supports the notion that renewable energy is a vital contributor to GDC. Furthermore, the positive coefficient of FNI on GDC in the results aligns with the Ozturk & Ullah (2022) who found that financial inclusion promotes economic growth, albeit with negative effects on environmental quality due to increased CO_2 emissions. This highlights the importance for policymakers to strike a balance between economic growth and environmental sustainability. The positive coefficient of financial inclusion in the results corroborates these findings and suggests that enhanced financial inclusion positively influences economic growth. However, policymakers must consider the environmental consequences and implement appropriate measures to mitigate potential negative impacts. Similarly, the positive coefficient of EF on GDC in the results aligns with the literature. Brkić et al. (2020) investigated the relationship between economic freedom and economic growth in European countries and found that increases in economic freedom are associated with economic growth. This underscores the significance of fostering economic freedom for promoting economic growth. Duan et al. (2022) further explored the association between economic freedom and economic growth in BRICS countries and reported a positive relationship. The consistency between these findings and the positive coefficient of economic freedom in the results underscores the substantial role of economic freedom in driving economic growth.

SEM analysis reveals a significant and positive direct effect of REN on GDC. This suggests that an increase in the adoption of renewable energy sources leads to enhanced economic growth. In contrast, the RENS exhibits a statistically significant negative relationship, indicating a diminishing effect on GDC. Furthermore, the mediation analysis highlights the role of FNI in mediating the relationship between the independent variables and GDC. The findings demonstrate a significant and positive indirect effect of FNI between REN and GDC, implying that FNI plays a mediating role by enhancing the positive impact of renewable energy adoption on economic growth. Similarly, FNI mediates the negative relationship between RENS and GDC, indicating that FNI partially mitigates the diminishing effect of squared renewable energy on economic growth. More precisely, FNI plays a partial mediating role in the relationship between REN and GDC. Approximately 56% of the effect of REN on GDC is mediated by FI, and the mediated effect is approximately 1.3 times larger than the direct effect of REN on GDC. Similarly, financial inclusion partially mediates the relationship between RENS and GDC. About 61% of the effect of RENS on GDC is mediated by FNI, and the mediated effect is approximately 1.5 times larger than the direct effect of RENS on GDC. In summary, the empirical findings of this study provide insights into the relationships and underlying mechanisms among the variables included in the model. The results demonstrate the significant mediating role of FNI in the relationship between renewable energy adoption (REN and RENS) and GDC. These findings contribute to the understanding of the complex interplay. Table 5.7 presents summary of hypotheses results.

Table 5.7: *Summary of hypotheses results*

Hypothesis	Result
Renewable energy positively affects GDP per capita.	✓
Economic freedom positively affects GDP per capita.	✓
Financial inclusion plays the mediation role between Renewable energy and GDP per capita.	✓

5.5. Conclusion and Policy Recommendation

The research focuses on analyzing the effects of REN, RENS, EF, and FNI on GDC within the context of G20 countries. The study utilizes a dataset spanning from 1995 to 2019. To investigate these relationships and assess the mediating role of FNI between REN, RENS, and GDC, the analysis employs the PMG and SEM techniques. The empirical findings of this study regarding PMG align with and reinforce previous research on the positive impact of REN on GDC. The results are consistent with Al-mulali et al. (2013) and Ahmad & Majeed (2022), confirming that an increase in renewable energy consumption contributes to economic growth and emphasizing the crucial role of investment in renewable energy for sustainable economic development. Furthermore, the positive effects of FNI on GDC in the results are consistent with Ozturk and Ullah (2022), who found that financial inclusion promotes economic growth. This suggests that enhanced FNI positively influences GDC. Similarly, the positive effects of EF on GDC are consistent with Brkić et al. (2020) and Duan et al. (2022), who found that increased EF is associated with GDC. The consistency between these findings and the positive coefficient of economic freedom in the results underscores the significant role of economic freedom in driving economic growth. Regarding the SEM analysis, the results reveal a significant and positive direct effect of REN on GDC, indicating that increased adoption of renewable energy leads to enhanced economic growth. Conversely, the RENS exhibits a statistically significant negative relationship, suggesting a diminishing effect on GDC. Additionally, the mediation analysis highlights the role of FNI in mediating the relationships between the independent variables and GDC.

The findings demonstrate a significant and positive indirect effect of FNI between REN and GDC, suggesting that FNI acts as a mediator by amplifying the positive impact of renewable energy adoption on economic growth. Similarly, FNI mediates the negative relationship between RENS and GDC, indicating that FNI partially mitigates the diminishing effect of squared renewable energy on economic growth. In summary, the empirical findings of this study provide valuable insights into the relationships and underlying mechanisms among the variables in the model. The results emphasize the significant mediating role of FNI in the relationship between REN and RENS with GDC. These findings contribute to a better understanding of the complex interplay between renewable energy, financial inclusion, and economic growth.

5.5.1. Policy Implications and Recommendations

- Encourage investment in renewable energy through subsidies and incentives to promote its adoption, based on the positive impact of REN on GDC.
- Foster financial inclusion by improving access to financial services, particularly for marginalized populations, to enhance its positive effects on GDC.
- Promote economic freedom by reducing regulations, promoting competition, protecting property rights, and ensuring transparent governance, in line with its positive impact on GDP per capita.
- Address the diminishing effect of RENS on GDC by investigating its underlying causes and implementing measures to mitigate its impact on economic growth.
- Recognize the significant mediating role of FNI in the relationship between REN and RENS with GDC and develop strategies to strengthen this link for amplified economic growth.

Conclusion and policy recommendations

The empirical findings of the study unveil a distinct pattern in the connection between CO_2 emissions and economic growth, resembling an inverted U-shaped curve. Initially, during phases of economic expansion, the positive correlation is attributed to the heightened demand for energy to fuel economic progress. However, as economies mature, a significant shift takes place, highlighting the adverse consequences of continuous growth on CO_2 emissions. Regarding fiscal policy, a positive relationship with CO_2 emissions is established, stemming from the policy's role in financing and fostering economic expansion, especially in times of prosperity. Technological advancements and financial development emerge as pivotal factors in addressing CO_2 emissions. Financial institutions (FI) and markets (FM) play a crucial role in this endeavor by supporting environmentally friendly projects and enforcing regulations that promote sustainable production methods reliant on renewable energy sources. Furthermore, the positive impact of FI and FM on reducing CO_2 emissions is connected to their active financing of environmentally conscious initiatives and the implementation of regulations that encourage the adoption of sustainable energy practices. The study reveals an intriguing dynamic among specific markets, uncovering bilateral interactions with limited cross-market spillover, except for a notable connection between BRT and CRY, which affects EGS in both bullish and bearish market conditions. Importantly, no dominant market influence emerges in lead-lag relationships. Additionally, the study reveals a significant impact of financial stress and uncertainty, with conventional bonds showing a more pronounced effect compared to green bonds. Interestingly, green stocks display heightened sensitivity, experiencing a more significant negative impact in the face of financial stress and uncertainty compared to other asset types.

Turning to renewable energy, the research underscores a positive relationship with economic growth, emphasizing the crucial role of investments in renewable energy sources for fostering sustainable economic development. Through mediation analysis, the study reveals the mediating role of FNI, amplifying the positive influence of adopting renewable energy on economic growth. Notably, this mediation partially offsets the diminishing effects resulting from the squared relationship between renewable energy and economic growth, shedding light on a comprehensive pathway to sustainable economic advancement.

Policy Recommendation

The identification of an inverted U-shaped relationship between GDP growth and CO_2 emissions holds substantial implications for policy formulation. Policymakers should integrate this discernment into their strategic frameworks, accentuating the necessity of harmonizing economic expansion with ecological considerations. Given this perceptiveness, a thorough reevaluation and recalibration of fiscal policies across G20 nations become imperative. Environmental apprehensions should be ingrained within the core of fiscal decision-making processes, aligning policies with sustainable paradigms. This entails not merely addressing immediate economic imperatives but also embracing a broader outlook that incorporates the protracted ecological ramifications. In effectively addressing the challenge of CO_2 emissions, policymakers must accord priority to the promotion of environmentally sustainable financial instruments. It is indispensable to augment the financial system's efficacy in counteracting positive perturbations that contribute to heightened emissions. This mandates the adoption of sustainable financial modalities that meticulously factor in the environmental repercussions of financial transactions. A pivotal avenue for advancing progress resides in the encouragement of green investments. Policymakers should actively incentivize investors through mechanisms such as tax concessions and subsidies. These incentives would invigorate the transition toward a more sustainable economy by nurturing investments in ventures that exalt environmental considerations. Concurrently, the promotion of investments in renewable energy sources assumes paramount significance. Policymakers should craft incentives that expedite the adoption of renewable energy technologies, ensuring their central integration into the energy landscape. By aligning financial inducements with sustainable energy practices, policymakers can expedite the trajectory toward a cleaner and more sustainable energy future.

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