

COMPARATIVE STUDY OF FINTECH'S ROLE IN
ENERGY TRANSITION IN DEVELOPED V.S.
DEVELOPING ECONOMIES.

BY

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
BRI	Belt and Road Initiative
BRICS	Brazil, Russia, India, China, South Africa
CBOs	Community Based Organisations
CO2	Carbon Dioxide Emissions
DEVS	Economic Development Status
DV	Dependent Variable
E-7	Emerging 7 Economies
EMT	Ecological Modernization Theory
ESG	Environmental, Social and Governance
ET	Energy Transition
EU	European Union
FAS	Financial Access Survey
FDI	Foreign Direct Investment
FDT	Financial Development Theory
FF	Fossil Fuel Energy Consumption
FinTech	Financial Technology
FT	FinTech
GDPc	GDP per capita
GE	Government Effectiveness
GMM	Generalized Method of Moments
ICT	Information and Communication Technology
IEA	International Energy Agency
IMF	International Monetary Fund
INF	Inflation
IRENA	International Renewable Energy Agency
IV	Independent Variable

MBT	Number of Mobile and Internet Banking Transactions
MBV	Value of Mobile and Internet Banking Transactions
MMQR	Method of Moments Quantile Regression
MV	Moderating Variable
OECD	Organisation for Economic Co-operation and Development
OLS	Ordinary Least Squares
P2P	Peer-to-peer
PAYGo	Pay-As-You-Go
PCA	Principal Component Analysis
PQR	Panel Quantile Regression
QARDL	Quantile Autoregressive Distributed Lag
QRPD	Quantile Regression for Panel Data
RE	Renewable Energy Consumption
SDGs	Sustainable Development Goals
SFT	Sustainable Finance Theory
SSA	Sub-Saharan Africa
UN	United Nations
VIF	Variance Inflation Factor
WETO	World Energy Transitions Outlook

ABSTRACT

The transition from fossil fuels to renewable energy is critically hindered by substantial financial barriers, prompting a growing reliance on Financial Technology (FinTech) to bridge the global funding gap. However, the net environmental sustainability of FinTech remains disputed, as the operational efficiencies of digital finance are often counteracted by the significant energy consumption of underlying infrastructures such as blockchain and data centres. Addressing the limitations of existing scholarship that predominantly relies on mean-based econometric methods and generic proxies, this study investigates the heterogeneous impact of FinTech development on both fossil fuel and renewable energy consumption across 56 developed and developing economies from 2015 to 2024. Methodologically, the research employs Powell's Panel Quantile Regression (PQR) to capture non-linear relationships and distributional effects that standard linear models overlook, while uniquely decomposing FinTech into two distinct dimensions: transaction frequency and transaction volume. The empirical results reveal a critical dichotomy: while higher transaction frequency fosters environmental sustainability through dematerialization, increased transaction volume exacerbates fossil fuel dependence via a distinct "rebound effect." Crucially, the study identifies a structural "Brown Bias" in developing economies, where unregulated digital capital flows disproportionately into established, carbon-intensive industries to fuel rapid industrialization, thereby crowding out renewable energy investments. Conversely, developed economies exhibit a decoupling of financial growth from environmental degradation, utilizing FinTech primarily as an optimization tool. These findings challenge the universality of the Sustainable Finance Theory, suggesting that digital finance is not inherently green but is conditional on economic development status. Consequently, the study rejects "one-size-fits-all" policy frameworks and recommends that developing nations implement specific Green Taxonomies and transparency mandates for digital lending to ensure financial inclusion effectively catalyses, rather than inhibits, the energy transition.

CHAPTER 1 INTRODUCTION

1.0 Introduction

This section is the introduction of the study. Firstly, it describes the background of the research. Next, the problems for the study are identified and relevant research questions and objectives are formulated for the study. The significance of the study then follows with the research outline to end this chapter.

1.1 Research Background

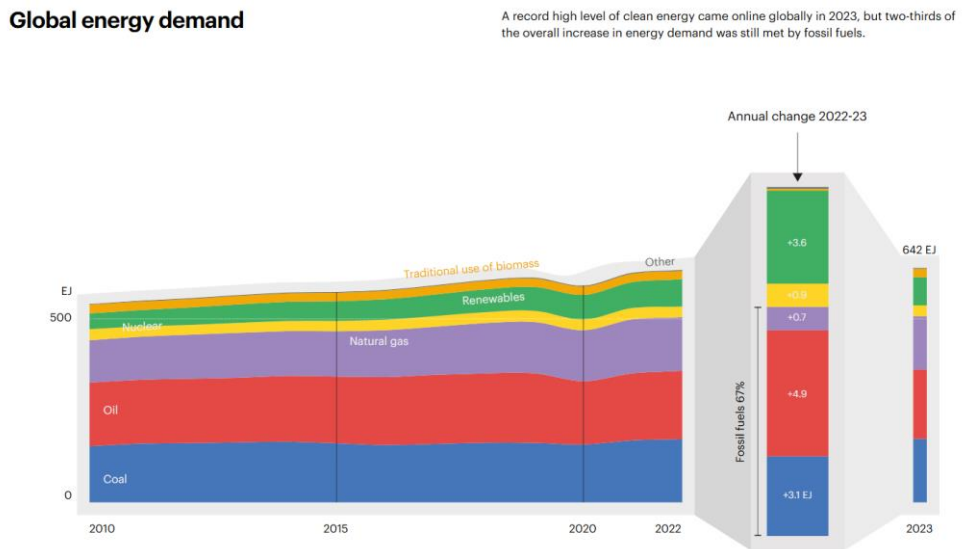
1.1.1 Energy Transition

The ever-increasing human population has led to higher demand for resources and production. Industrialization has made production more efficient with the integration of various technologies powered by electricity. Electricity and energy generation has always been linked to the usage of fossil fuels like petroleum, natural gas and coal, which are unrenowable natural resources of the planet. These resources are depleting at higher speeds due to the development and population growth which accelerates the extraction of such resources to meet the consumption needs of the growing population. In addition, studies have shown the usage of fossil fuels to generate energy has led to serious levels of climate change, exacerbating the state of Earth's deterioration (Karmaker et al., 2020; Khan et al., 2024; Lu et al., 2023; Vo et al., 2023).

Consequently, there arises the urge to develop alternative methods for energy generation, where utilization of renewable resources, such as wind, solar, water and biomass, have been greatly researched and

integrated into the current forms of energy generation technology. However, such efforts seem to be working at sluggish speeds. A study from Vo et al. (2023) states, as global energy consumption continues to grow, with more than 80% coming from fossil fuels, only less than one-fifth comes from renewable sources. Figure 1 shows fossil fuels contributing two-thirds of the total energy demand over the years while renewables, although showing growth, are still less powerful in this energy mix (*World Energy Outlook 2024 – Analysis - IEA, n.d.*). This further illustrates the heavy reliance on fossil fuels to generate electricity and energy overall.

Figure 1.1: Global Energy Mix

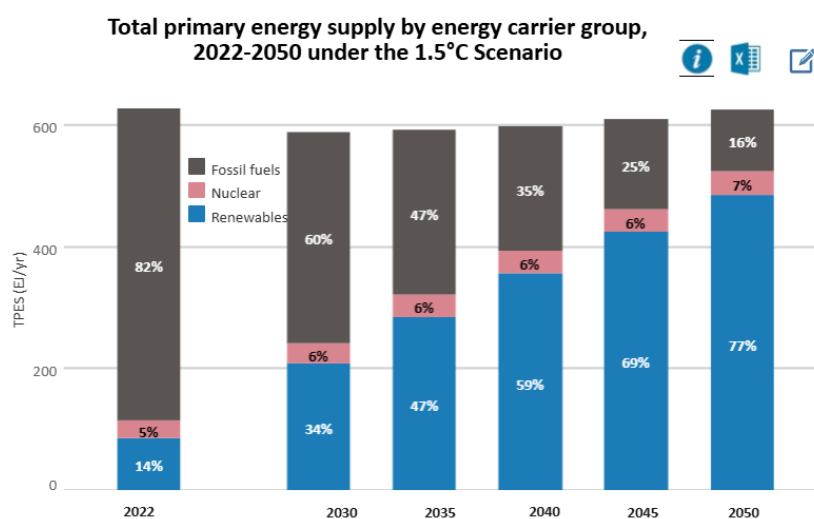


Source: IEA (2024), *World Energy Outlook 2024*, IEA, Paris <https://www.iea.org/reports/world-energy-outlook-2024>, Licence: CC BY 4.0 (report); CC BY NC SA 4.0 (Annex A)

Such initiatives for transition towards renewables are recognized as “energy transition”, which according to Su & Tan (2023) originated in Germany and mainly refers to reducing traditional fossil energy, increasing the consumption of renewable energy and improving energy efficiency. The concept also proposes the ultimate goal of achieving full use of renewable energy. This pathway typically progresses from being coal-dominated to oil-and-gas-dominated, and

then to renewables-dominated (Lau & Tsai, 2024). Figure 2 below shows the International Renewable Energy Agency's (IRENA) World Energy Transitions Outlook (WETO), which gives a forecast on the primary energy supply until the year 2050. The WETO aims for renewable energy to be the dominant energy supplier by 2040 to surpass fossil fuel energy and to reach 77% energy generation by 2050.

Figure 1.2: Energy Mix Forecast



Source: IRENA (2024), *World Energy Transitions Outlook 2024: 1.5°C Pathway*, International Renewable Energy Agency, Abu Dhabi.
<https://www.irena.org/Publications/2024/Nov/World-Energy-Transitions-Outlook-2024>

Several industries have contributed to the transition into cleaner energies including major contributors like energy industries, manufacturing & technology industries and transportation industries. The coordination between such industries is a major factor to facilitating this transition into cleaner energy generation.

1.1.2 Fintech

Along with these industries, another industry has risen along with the 4th industrial revolution, namely financial technology, also more commonly known as FinTech. FinTech, according to the FSB (2017), is defined as technologically enabled financial innovation that could result in new business models, applications, processes, or products with an associated material effect on financial markets and institutions and the provision of financial services. For instance, digital payment platforms and mobile wallets that allow for cashless payments and transactions, Peer-to-peer lending (P2P), Crowdfunding platforms, blockchain and cryptocurrencies. For example, Trine, a FinTech company from Sweden, offers a platform for investing in solar projects, allowing investors to achieve financial returns alongside measurable social and environmental benefits.

Fintech is known for its ability to enhance financial inclusion by allowing financing activities to be accessed virtually, it just demands for strong infrastructure and security. Moreover, the ability to receive financing without the complicated procedures of applying for loans from banking institutions help make many projects possible. In this case, it enables companies to research and develop new technologies that can increase usage of renewable energy or fund projects to strengthen the infrastructure for renewable energy generation. For example, projects like the Resilient Energy Great Dunkilns, UK: A community wind turbine project that crowdfunded £1.4 million from 425 investors over four months, and the Pay-As-You-Go Solar Energy in Tanzania: a crowdfunding platform raised USD \$15,000 loan from 91 investors to produce and sell 1,000 Solar Home Systems for small businesses and families, present themselves as successful usage of FinTech (Lam & Law, 2016).

1.1.3 Fintech in Developed vs Developing Countries

With FinTech's potential of bringing beneficial change to the development for countries, there is however disparities between the development of FinTech in different countries. A great scenario to explain this is the contrast between developed and developing countries. In developed countries, FinTech serves more as an optimization tool, enhancing the already relatively mature financial ecosystems. These countries have digital systems, progressive financial institutions, and even strong systems to endorse the move and integrate the FinTech systems and solutions (*FinTech and Market Structure in Financial Services: Market Developments and Potential Financial Stability Implications - Financial Stability Board, n.d.*). FinTech in developed economies goes beyond the mere financial and provides other services (Dorfleitner et al., 2017). Additionally, other products that aid in economic and energy transition areas innovations, are green bonds, and investment platforms aimed at ESG. Furthermore, the strong data privacy and security regulations in these countries help to build confidence in the FinTech services offered to consumers and investors.

On the other hand, FinTech in Developing countries serves the purpose of creation to construct financial systems and infrastructures. Developing economies are usually digital systems challenges, with unreliable internet and mobile networks, especially in rural areas, these systems create barriers to the adoption of FinTech services (Ozili, 2018). Financial inclusion in these areas is also a challenge, as a large proportion of the population is either unbanked or underbanked, and this situation reduces financial system and services access.

This is where FinTech begins offering its offerings as a foundation for financial infrastructures in developing economies. M-Pesa in mobile

money and digital microfinance services in sub-Saharan Africa (SSA) is one of many services that is crucial for advancing financial inclusion. However, these services still emphasize security gaps, low scalability, and absence of regulatory frameworks (Lu et al., 2023; Ma et al., 2025).

From the “optimization” and “creation” roles that FinTech assumes for developed and developing economies, its impact is difficult to estimate to a “one-size-fits-all” assumption. This is to say that the impact of FinTech adoption on different economies is expected to be on a different scale, depending on their level of development.

1.1.4 The Relationship between FinTech and Energy Transition

The transformation to using cleaner energy generation alternatives is as urgent as it is costly. Implementation of technology like solar panels and wind turbines at an industrial level in power plants would cost fortunes, with initial investments of over 50 million US dollars and millions of operating costs per year (Erdem, 2025; Shahbakhsh & Osanloo, 2025). With average payback periods ranging from 5 to 8 years, such long-term investments are highly risky and might not even be feasible without the help of government support policies or subsidies to incentivise such investments. In some developing countries where governmental stability already poses as major hindrance, such investments could only be supported from foreign investments.

The introduction of FinTech has provided alternative funding opportunities to facilitate such investments. FinTech introduces schemes like Crowdfunding and Peer to Peer lending (P2P). These

platforms allow funding for renewable energy projects from a wider range of investors be it from large firms or small scale and individuals (Alofaysan et al., 2024; Sreenu, 2024). This encourages pluralistic investments and helps close the funding gaps for projects that may be otherwise ignored by conventional financial institutions. By modernizing traditional financing with digital financial systems, the overall cost of external financing for renewable projects is lowered. For instance, better risk assessment using big data and analytics improves the chances of projects being funded (Croutzet & Dabbous, 2021).

FinTech uses blockchain, artificial intelligence and big data to optimally manage and deploy energy systems to improve their transparency and efficiency. An instance of this is the blockchain-based peer-to-peer energy trading (Alofaysan et al., 2024; Delina et al., 2023). Powerledger is an Australian green fintech company that created a platform for trading renewable energy and eco-assets that is powered by blockchain technology. Their software facilitates the tracking, tracing, and trading of renewable energy generated through solar photovoltaic panels in peer-to-peer systems, and aims to establish a green marketplace (Ashta, 2023a). AI is widely used for system modelling, prediction and optimisation in the energy sector. Such technologies help to improve the power generation intensity of renewable energy and allows for better demand forecasting and resource allocation, ultimately creating a more sustainable power grid (Ha, 2024; Sreenu, 2024).

FinTech can be seen as an important enabler in today's age to allow initial capital investments into renewable energy projects and even helping minimize operating costs to make such investments feasible and be able to contribute to energy transition. Hence, there is urgency

in investigating the role fintech plays in supporting such causes to contribute to the ever-deteriorating environment.

1.2 Problem Statement

Global efforts to combat climate change have intensified the urgency of increasing renewable energy consumption. However, many countries continue to face financial and institutional barriers that slow the transition. As renewable energy projects require high entry and upfront cost, conventional financing methods pose as inadequate to fund them, especially in developing economies (Croutzet & Dabbous, 2021; Ofosu-Mensah Ababio et al., 2024; Sreenu, 2024).

Innovative financing options like peer to peer and crowdfunding are making it easier to channel funds into green and Renewable Energy projects (Korkut Pata et al., 2025; Vo et al., 2023). However, some of the aligned technologies for FinTech's engagements that drive sustainability have negative green impacts, like the Blockchain and cryptocurrency paradigms that are coupled with extremely energy demanding mining processes that contribute greatly to the climate change disaster (Lu et al., 2023; Y. Zhang et al., 2024). FinTech also drives the furtherance of consumption and economic growth which in turn leads to the demand for energy that increases the consumption of fossil fuels. This brings us to the question of what the net effect of FinTech in the transition to renewable energy is; is it helping the transition or the increased consumption of fossil fuels outweighs it?

The impact of FinTech on the energy transition is expected to have a country-specific impact most likely to be heterogeneous (Jangid et al., 2025; Rahman et al., 2025b). This differences is primarily attributed to the varying levels of economic structure and financial development of a country. In the preceding discussion, we highlighted that in developed economies' FinTech functions as

an efficiency-enhancing optimizing tool to reflect the advanced stage of policy and framework in the financial system. For instance, to move beyond traditional physical infrastructure by digitalizing finance, allowing for more efficient and transparency with information technology, overall minimizing transaction costs and facilitating flow of funds (X. Li et al., 2024; Udeagha & Muchapondwa, 2023). On the other hand, FinTech in developing economies creates a new infrastructure to solve fundamental problems, mainly of enhancing financial inclusion to unbanked populations by leapfrogging to digitalized finance, which are more accessible with lower costs (Akono & Kemezang, 2024a). This difference between economies suggests that the impact FinTech brings to energy transition will also vary between different economical contexts. It could be that in developed economies energy transition is boosted on top of strong policies and infrastructure but developing economies would take much longer to see this effect take place. Measuring such effects at an average could show bias, where the average result might suggest that FinTech does aid in energy transition but ecological impacts on certain countries in the sample might be neglected.

Existing empirical studies have largely relied on mean-based econometric methods, like various fixed effect models, which overlook the distributional effects of FinTech across different levels of fossil fuel and renewable energy consumption resulting in mixed results (Croutzet & Dabbous, 2021; Okere et al., 2025). This creates a knowledge gap in understanding whether FinTech exerts a stronger influence in lagging and less developed countries compared with countries that are already advanced in their renewable transition (Akono & Kemezang, 2024b; M. Li et al., 2025; Rahman et al., 2025a).

1.3 Research Questions

From the identified problems, this study asks the following research questions:

- I. How does FinTech development influence fossil fuel energy consumption across different quantiles of the consumption distribution?
- II. How does FinTech development affect renewable energy consumption across different quantiles of the consumption distribution?
- III. Does the impact of FinTech on fossil fuel emissions differ between developed and developing economies?
- IV. Does the impact of FinTech on renewable energy consumption differ between developed and developing economies?

1.4 Research Objectives

With the research questions identified, this study's objectives are as follows:

- I. To examine the impact of FinTech development on fossil fuel energy consumption using panel quantile regression.
- II. To investigate the impact of FinTech development on renewable energy consumption using panel quantile regression.
- III. To assess whether FinTech's influence on fossil fuel energy consumption differs between developed and developing economies.
- IV. To assess whether FinTech's influence on renewable energy consumption differs between developed and developing economies.

1.5 Significance of the Study

The knowledge discovered on the relationship between FinTech and Energy transition of developed and developing economies will be significant to academics and practical policy decisions. The multi-dimensional analysis gives a different look into this relationship with distributional and heterogeneous effects being acknowledged.

Academic wise, this research provides new findings towards the theoretical and methodological sides of the relationship between FinTech and Energy Transition. As for theoretical contribution, existing assumption that digital financial development align with environmental sustainability has been challenged. Specifically, the dominant approach in Sustainable Finance Theory (SFT). This study finds a structural Brown Bias by supporting with empirical data in developing economies, which FinTech induces capital flows into existing and carbon-intensive industries instead of new renewable projects. This discovery clarifies SFT by showing that the win-win situation is not a universal principle but a conditional phenomenon. Such shared growth between financial development and sustainability depends on the economic system of a country. Moreover, the dual dimensional study with FinTech demonstrates its contradicting ability to reduce ecological damage. FinTech has been found to support both the dematerialization and rebound effect from the Ecological Modernization Theory (EMT). While digitalization of finance reduces resource exhaustion, capital flows from technological efficiency hinder sustainability efforts.

Methodologically, the study is progressive because it does not rely on the mean-based regression methods, including OLS or Fixed Effects, which prevail in the literature (Croutzet & Dabbous, 2021; Teng & Shen, 2023; Xu et al., 2023a). Although previous researches tend to assume that the influence of FinTech is the same in all countries, this paper uses Panel Quantile Regression to undermine such uniformity. Through the conditional

distribution, the study reveals the crucial effects of a threshold such that the external effect of FinTech does not remain constant. Nonetheless, the impact is quite substantial based on the current state of energy consumption in a given country. In this way more accurate academic modelling can be achieved. This study accounts for the non-linear relationships and heterogeneous dynamics that are often obscured when using studies that are based on average-based estimates only.

Practically, the research results can be of significant use to regulators since they prove that developed and developing economies are structurally divergent in their responses to FinTech. It appears the evidence is that FinTech serves as a process of optimization in developed countries and a process of accumulation in developing ones(Albaker, 2024; Frost, 2020a; H.-H. Lin & Lee, 2025). This means that a homogeneous worldwide policy is inefficient. Rather, policy makers in developing countries should focus on policies that integrate digital financial inclusion with stringent policies that are known as the Green Taxonomies to offset the intrinsic Brown Bias. On the other hand, the international development agencies can decisively propagate retail-level FinTech as a high-impact environmental measure, because the research confirms that it can minimize fossil fuel dependency in the world by pursuing efficiencies. These observations offer a guide on how FinTech architectures can be altered to fit the level of development of any particular nation as opposed to implementing a generic global framework.

1.6 Outline of Research

The structure of the remaining research is as follow: Chapter 2 covers existing literature, formulating hypothesis and highlighting research gap; Chapter 3 shows data collection and methodology for analysis; Chapter 4 provides descriptive statistics, multicollinearity tests and regression results analysis; Chapter 5 provides implications, novelty of the study, limitations and recommendations for future research.

1.7 Summary of the Chapter

Table 1.0 Summary of Chapter 1

Problems	Research Objectives	Significance
FinTech can help channel funds towards green projects, but its power intensive side could increase energy use (Korkut Pata et al., 2025; Lu et al., 2023).	To examine the impact of FinTech development on fossil fuel energy consumption using panel quantile regression.	Theoretical Contribution: Challenges the Sustainable Finance Theory (SFT) assumption that digital finance is intrinsically green with the identification of a structural "Brown Bias" in the developing world.
Past studies using mean-based econometrics (like OLS) neglect distributional heterogeneity of the relationship between FT and ET (Croutzet & Dabbous, 2021)	To investigate the impact of FinTech development on renewable energy consumption using panel quantile regression.	Methodological Contribution: Go beyond the mean-based estimates to employ Panel Quantile Regression which permits identification of non-linear associations and threshold effects that average centred models conceal.
FinTech's different role in different economic development context can cause varied results for this relationship. Where in developed economies FT mainly optimizes financial procedures, while in developing economies it helps to accumulate/leapfrog infrastructure (Udeagha & Muchapondwa, 2023).	To assess whether FinTech's influence on fossil fuel energy consumption differs between developed and developing economies.	Practical Contribution: Challenges the "one-size fits all" view of global frameworks. While developed countries employ FinTech for efficiency purposes, in the developing world, digital financial inclusion needs to be regulated with in developing economies

Source: Constructed by author

CHAPTER 2 LITERATURE REVIEW

2.0 Introduction

This section is the literature review for my study. This section consists of the fundamental theories, relationship between main variables, research gap, hypothesis developed and conceptual framework for this study. This section serves as a summary of previous literature behind FinTech and Energy Transition.

2.1 Theoretical Framework

2.1.1 Ecological Modernization Theory (EMT)

The Ecological Modernization Theory (EMT) simply means that the solution to environmental destruction does not exist in de-industrialization but in an even greater industrialization such as superindustrialization (Buttel, 2000). In contrast to the de-modernization talk, EMT asserts that the late-modern world has the institutional reflexivity to decouple economic growth and environmental destruction by upgrading tech and using market-driven strategies (Adua et al., 2021; York & Rosa, 2003). The central concept of this theory is the idea of dematerialization that supposedly claims that the modern economies are moving towards the services that are information-heavy, where economic value can be created with reduced physical resource throughput (Carolan, 2004a). EMT will provide us with a system of analysing FinTech as a potential source of ecological sustainability in our investigation. Similarly, to urbanisation and modernisation, which have led to more energy-efficient results in the form of innovation and economies of scale,

FinTech may contribute to dematerialisation of financial services and reduction in fossil-fuel intensity (Xue et al., 2022). That is connected to the way FinTech is able to streamline the use of resources and replace physical infrastructures with online ones (Carolan, 2004b).

Nevertheless, the notion that the increase in efficiency automatically leads to environmental sustainability is disputed by the so-called rebound effect and the Jevons paradox (Adua et al., 2021). Opponents of strict EMT state that the modernisation leads to better efficiency but also decreases the effective cost of resources. These gains then promote larger production and consumption which is more than the initial savings (Carolan, 2004a). This may also result in super-materialisation whereby the overall size of the economy activity increases at a rate higher than the efficiency returns (York & Rosa, 2003). Besides, digital consumption cannot be held responsible without large material bases, such as data centres that consume energy, and the environmental burden might simply be transferred, but not lost. The theoretical tension is that FinTech does not affect the use of fossil-fuel in a uniform manner; some processes may lead to dematerialisation, whereas others will lead to a rebound, and a quantile regression method is required to identify those situations.

2.1.2 Sustainable Finance Theory (SFT)

The SFT is a theory that provides an understanding of which financial systems have the ability to align financial practices with long-term sustainability goals. By integrating sustainability practices into financial systems, it is expected to reduce volatility and improve resilience within the financial system (Kashif et al., 2025). The SFT is usually discussed along with ESG (Environmental, Social and Governance) goals, where financial practices should account for ESG practices to achieve sustainable development.

Green bonds are a great example of mechanisms aligned with SFT. It is a type of bond that directly finances projects that aim to promote sustainability, including renewable energy facilities, low carbon transportation and energy efficiency projects (Sreenu, 2024). By integrating FinTech into such mechanisms, it can allow greater accessibility for investors by reducing high transaction costs to let small and medium investors to contribute to supporting these sustainable initiatives. Additionally, energy transition projects would also benefit from this by having easier access to funds to manage these projects. Therefore, the SFT shows FinTech development could be beneficial to increasing renewable energy consumption and align financial development and sustainable practices.

Even with such positive forecasts, financial innovation is not necessarily a solution to a balance between the sustainability objective. Rather, the markets left unregulated tend to collapse to a "Brown Bias," especially in developing economies with capital structures in which carbon-intensive industries are favoured (Central Bank et al., 2022). Traditionally, these sectors have received large amounts of investments due to their consistency of cash flows, and established market structures (Liang & Punzi, 2025). The rational market forces may therefore favour such brown industries at the expense of green projects that are yet to be developed. Such a dynamic has the potential to generate a financial trap financial institutions in the initial stages of development heavily invest in the mining and energy industries to achieve the short-term profitability of the sector and consequently increase the CO₂ emissions (Saygin et al., 2025). Also, this bias is commonly strengthened by financial intermediaries. As an example, X. Zhang & Wilson (2022) discovered that analysts are more likely to make optimistic recommendations on the fuel stocks of fossil fuel companies than renewable energy firms.

2.1.3 Financial Development Theory (FDT)

The Financial Development Theory states that a strong financial system is fundamental to economic growth, improving resource allocation and investment for key sectors. A strong financial system manages to make economies more efficient by evolving to reduce information and transaction cost (Levine et al., 2004). As the renewable energy sector is rising as a new focus across economies, sound financial systems will be able to efficiently allocate adequate resources towards these sustainable projects (Awosusi et al., 2022; Xu et al., 2023a).

Between countries, the resources and financial systems are varied, which would result in different stages of economic growth for all countries. FinTech is a new stage of financial development known for its ability to raise financial inclusion and resource allocation (Alofaysan et al., 2024; Yang et al., 2021). By aligning with the FDT, FinTech development would stimulate economic growth. For developing countries, where a large population remains underbanked, FinTech creates access with digitalized finance to bridge the gap where traditional infrastructure is missing. For developed countries, where financial development is relatively strong, FinTech optimizes financial systems bringing efficiency for the flow of funds. This divergence of FinTech's role would suggest the resources invested and results of energy transition projects would fundamentally differ between economical contexts.

2.2 FinTech and Fossil Fuel Energy Consumption

Although certain sectors within FinTech are carbon neutral, the overall sector and its impact on fossil fuel consumption is currently highly negative. Vo et al. (2023) discuss how the introduction of cryptocurrencies is drastically increasing the demand for electricity, the bulk of which is of a fossil fuel nature. Also, the energy consumption of certain blockchain technologies, particularly the mining of Bitcoin, is substantial (Lu et al., 2023; Ma et al., 2025). The fossil fuel energy consumption required to support such activities and the digital infrastructures is considerable and carbon negative. Furthermore, Khan et al. (2024a) stresses that FinTech can worsen the “Carbon Curse” if the technologies underpinning its financial innovations are dirty. The incorporation of dirty technologies carries high energy demands, and thus, can lower the cost of production for fossil fuel intensive industries. In the case of poorer countries whose grids are dirtier, the early stages of financial digitization are likely to increase fossil fuel consumption.

As a retake on the existing literature, Xu et al. (2023a) describes the phenomenon of energy transition more clearly as the ameliorating of the use of fossil fuel, and the energy efficiency. In the light of the above, FinTech assists in “de-curse” the mineral-rich but carbon curse economies in the natural resources efficiency extraction and processing. Blockchain certificates, albeit energy intensive, assist within the context of specific energy source identification (Croutzet & Dabbous, 2021). It assists in differentiating between the traceability problem of electricity produced from fossil fuels and renewables and consequently stimulates the transition from fossil sources. FinTech decreases the consumption of fossil fuels by diverting investments from highly polluting activities and directing them towards green activities.

2.3 FinTech and Renewable Energy Consumption

Within most academic research, FinTech is seen as an important facilitator of the consumption of renewable energy. First of all, the literature focuses on the ability of FinTech to eliminate certain financial barriers and improve the efficiency of resource distribution. Data analysis from Croutzet & Dabbous (2021) and Vo et al. (2023) show that FinTech has a positive statistically significant influence on the consumption of renewable energy. In Croutzet & Dabbous (2021), it was estimated that an increase in the developed FinTech of a country is likely to cause a 0.1901% increase in the consumption of renewable energy in the OECD countries. A significant reduction in information asymmetry, as well as a reduction in transaction costs, is what makes this relationship positive. FinTech products can streamline the financial services offered to green projects. This encourages what is often referred to as the technique effect, whereby the financial sector becomes so technologically advanced that it encourages the transition to green energy (Jangid et al., 2025; Sreenu, 2024). Additionally, it is noted that FinTech promotes the consumption of renewable energy directly, and, indirectly, by stimulating innovations in green technologies and in the management of the environment (Teng & Shen, 2023). All of the above help FinTech to produce a circle of sustainable growth.

A good amount of the scholarly work analyses the various ways FinTech facilitates this spending. One of the most discussed innovations that make it possible to trade energy P2P and generate renewable energy certificates in a transparent manner are the blockchain and smart contracts (Akono & Kemezang, 2024a; Dabbous et al., 2025; Delina et al., 2023; Lu et al., 2023). Furthermore, the democratization of green finance is due to crowdfunding. Through crowdfunding, retail investors are able to finance (in) tangible solar and wind projects that are often left out by institutional investors (Croutzet & Dabbous, 2021; Teng & Shen, 2023). On the micro accessibility side, the innovations Pay-As-You-Go solar loans and mobile money have been pinpointed as critical to rising renewable energy uptake (Butu et al., 2021;

Oofosu-Mensah Ababio et al., 2024). These innovations have provided means to alleviate liquidity constraints for small consumers and businesses. Overall, this body of work evidence that FinTech enhances the efficiency of green bond markets and offers the infrastructure to digitally include the economically marginalized. This enables the consumption of renewable energy to be scaled to a global level.

2.4 Fintech and Energy Transition in Regions with Different Economic Development Status

2.4.1 FinTech and Fossil Fuel Energy Consumption in Developed Economies

The literature reviewed considers only the positive potential of FinTech to improve energy efficiency and encourage the move away from the use of fossil fuels in developed economies. For example, Teng & Shen (2023) claim that in OECD countries FinTech positively and structurally alters the energy use pattern by improving energy use efficiency. Specifically, they argue that FinTech shifts the energy use pattern from the traditional fossil fuel dependency to the use of renewables by improving the financing of renewables and technology innovation. This claim is also supported by Croutzet & Dabbous (2021), who argue that in upper-middle-income countries FinTech positively affects the reduction of energy use and energy intensity. They argue that positive FinTech energy impacts are the result of improving the accessibility and affordability of energy conservation. Also, Saqib et al. (2023) provide evidence of the negative impacts of FinTech on the country's ecological footprint.

However, the literature also points to growing concerns about the “Carbon Curse” and the risks that come from the use of digital infrastructures in developed resource-rich countries. The literature also outlines the “double-edged” nature of technology. In the U.S. context, and while it is generally acknowledged that FinTech promotes “green” initiatives, there is also the concern that the underlying ICT infrastructure (such as data centres) which is also energy-hungry will, in the long term, have a negative impact on global CO₂ emissions (Saqib et al., 2023). Khan et al. (2024a) analysed developed resource-rich countries such as Canada, Australia and the USA. They cite the concerns of FinTech worsening the “Carbon Curse” as a result of cheaper fossil fuel production, which leads to lower energy prices and a higher demand for energy consumption. However, the findings suggest that FinTech facilitates “de-cursing” these economies by weakening the natural resource dependency and carbon emission relationship. The studies find that in developed economies, the potential efficiency gains and availability of green financing due to FinTech outweigh the negative impact of fossil fuel consumption from its physical infrastructure.

2.4.2 FinTech and Fossil Fuel Consumption in Developing Economies

FinTech suffers from a widespread assumption of contributing to increasing fossil fuel consumption in emerging market economies. FinTech is energy intensive in the digital infrastructure of the economies it facilitates industrialisation in. In the case of the Asian developing economies, the effect of Fintech and the rents from natural resources is devastating to the sustainable environment (Chien et al., 2024). The constructs in question are the major contributors to the non-renewable energy reliant economic growth, leading to higher carbon emissions. In the BRICS countries, while Fintech improves the prospects of a green economic recovery, it also worsens the state of the environment (Wei et al., 2024). The findings indicate that in these developing economies, Fintech is a major driver of fossil fuel energy demand, which in turn is higher due to the rapid financial growth. This scenario is in line with the scale effect since economic activities on a national level are known to increase energy consumption (Xu et al., 2023a). In developing economies where energy consumption is heavily fossil fuel based, such energy consumption increases fossil fuel consumption significantly.

As it is in advanced economies, Fintech performs the essential function of “de-cursing” in resource rich developing countries too. Khan et al. (2024a) examined the applicability of Fintech’s moderating effect on the resource dependence-carbon emissions relationship to developing resource rich countries as well. Fintech in China decreases the poverty of carbon emissions by advancing green finance and aiding the shift from coal dependent energy frameworks (Deng et al., 2024). Atofaysan et al. (2024) also affirmed that in the case of developing economies, financial technologies positively and significantly impact the uptake of renewable energy.

2.4.3 FinTech and Renewable Energy Consumption in Developed Economies

The developed financial markets, particularly in FinTech, as in Europe and the US, are focusing more and more on the FinTech Green Energy Transition. Some of the changes occurring in the market include increased market interconnectedness and easier decentralised investments. Ahmad et al. (2024) studied 25 countries in the European Union and confirmed that FinTech positively impacts the green energy transition. The authors argued that digital platforms facilitate investments and transactions in finance. This is illustrated by the ease of democratising investments in renewable projects and, thus, the reduced dependence on energy sources that are harmful to the environment. This was also evidenced by Shah et al. (2025), who studied the European real estate market and found significant volatility connectedness of FinTech indices and the Renewable Energy market. Digital funds, as they say, are reshaping green energy integration in the new and old real estate markets. Ma et al. (2025) demonstrated on US indices, KBW Nasdaq Technology Index, the dynamic spillover effect of FinTech on clean energy stocks. The evidence shows that more investments in sustainable energy assets are flowing into matured financial markets. FinTech advances in driving the investments.

The existing literature is concerned with specific digital business models as well as certain non-linear relationships. As mentioned in Ashta (2023a), “Green Fintechs” based in developed countries use blockchain technologies and proprietary algorithms to facilitate and track peer-to-peer trade in renewable energy and measure various environmental footprints. Such technology directly promotes decentralised consumption of renewables. Examples of “Green FinTechs” are Doconomy from Sweden and Powerledger from Australia. However, evidence of this relationship is complex. Saqib et

al. (2023) used Quantile Autoregressive Distributed Lag (QARDL) technique to investigate this relationship concerning the United States. Although FinTech, in general, enhances environmental sustainability primarily, it exerts asymmetric impacts (predicted negative in certain quantiles). Furthermore, the authors explained that the more FinTech and renewable energy coexist, the more reduction to be expected in the ecological footprint, but only beyond a certain penetration (higher quantiles). Hence, it shows that in developed countries a critical mass of digital financial maturity is needed to significantly alter conventional energy consumption behaviour.

2.4.4 FinTech and Renewable Energy Consumption in Developing Economies

There is a consensus in the literature on the role of FinTech in developing economies as the only way of mitigating financial exclusion, which is a major hindrance to the adoption of renewable energy. Whereas in developed markets FinTech increases the efficiency of processes, in developing markets particularly in Sub-Saharan Africa and India, it increases the accessibility of the services. Ofosu-Mensah Ababio et al. (2024) cite the introduction of mobile money and solar loans under the PAYGo model as an innovation that has benefited India and Uganda most because it allows millions of unbanked individuals to buy solar home systems through digital instalment payments. FinTech integrated with Community Based Organisations (CBO) offers another example that allows for alternative credit scoring, as is the case of FarmDrive in Kenya (Butu et al., 2021). This liberates the financing possibilities for rural low-income farming families to adopt small renewable energy technology that formal financial institutions fail to consider. Sreenu (2024) highlights one of the Indian cases where financial technology enables

the use of peer-to-peer lending and crowdfunding. A case that certainly broadens the availability of green finance to serve the purpose of alleviating the financing bottleneck for clean energy.

The evidence from the data collated from the wider economic blocs indicates that the impact of FinTech as it relates to the consumption of renewable energy is positive. From the study by Tan et al. (2023), H. H. Lin et al. (2024), it is acknowledged that the development of FinTech in the BRI (Belt and Road Initiative) countries is an important factor in the positive advancement of the management of natural resources and the promotion of green ecological living as it pertains to green growth resource mobilization and green growth. It is posited that in the E-7 (Economy Seven or Emerging Economies) countries, FinTech is significant in the reduction of carbon emissions and movement from non-renewable energy sources. For the BRICS economies (Brazil, Russia, India, China, and South Africa), the authors Wei et al. (2024) have posited that there is positive advancement of FinTech in the streamlining of finances for green projects and that for positive results to be achieved on environmental sustainability, green growth strategies in conjunction with FinTech for sustainable green projects have to be adopted. There is a consensus on the “fin-tech-driven energy transition” (the incorporation of financing technologies to promote energy transition) that is predominant in developing countries: FinTech is viewed as not only an operational financial technology, but rather, a pivotal element for socio-economic development provision in the energy transition.

2.5 Hypothesis Development

From referring to the literature above brings the development of the following hypothesis:

H1: The magnitude of FinTech's impact on fossil fuel energy consumption differs across quantiles of the consumption distribution.

H2: The magnitude of FinTech's impact on renewable energy consumption differs across quantiles of the consumption distribution.

H3: The effect of FinTech on fossil fuel energy consumption differs between developed and developing economies.

H4: The effect of FinTech on renewable energy consumption differs between developed and developing economies.

2.6 Research Gap

It is evident that there has been an increasing number of studies investigating the relationship between FinTech and Energy Transition, on how it contributes or worsens such initiatives. Nonetheless, many studies also mention gaps they were not able to fill when explaining the relationship.

From a geographical point of view, studies have chosen samples of specific categories of countries, such as OECD, BRICS and SSA, which usually groups countries into more developed or less developed countries (Butu et al., 2021; Croutzet & Dabbous, 2021). Other studies investigated the relationship focusing on singular countries at firm level (Sreenu, 2024; Taghizadeh-Hesary et al., 2023). Studying the effects of FinTech adoption on Energy Transition in singular geographical groups neglect the differences between developed and developing economies, leaving a gap of lack in comparison (Ha, 2024). This study captures the variation in development status between economies with a heterogeneity analysis between developed and developing economies. The interaction between FinTech and country development status has been added to directly examine the impact FinTech has on energy transition from two different economical contexts.

The majority of available studies dive into this relationship between FinTech and Energy Transition with mean-based estimation techniques (Croutzet & Dabbous, 2021; Ofosu-Mensah Ababio et al., 2024; Vo et al., 2023; Y. Zhang et al., 2024). Models such as OLS, fixed effect, ARDL and GMM produce estimates that suggest FinTech has the same effect, positive or negative, on all economies, which is incorrect. Such models ignore distributional heterogeneity and so the effect of FinTech on economies with different levels of energy usage is hidden. As Vo et al. (2023) state, traditional models ignore that the effect of factors such as FinTech and income inequality may vary greatly across different conditional distributions of renewable energy consumption. Recent studies like Sun et al. (2025) and Sun et al. (2025)

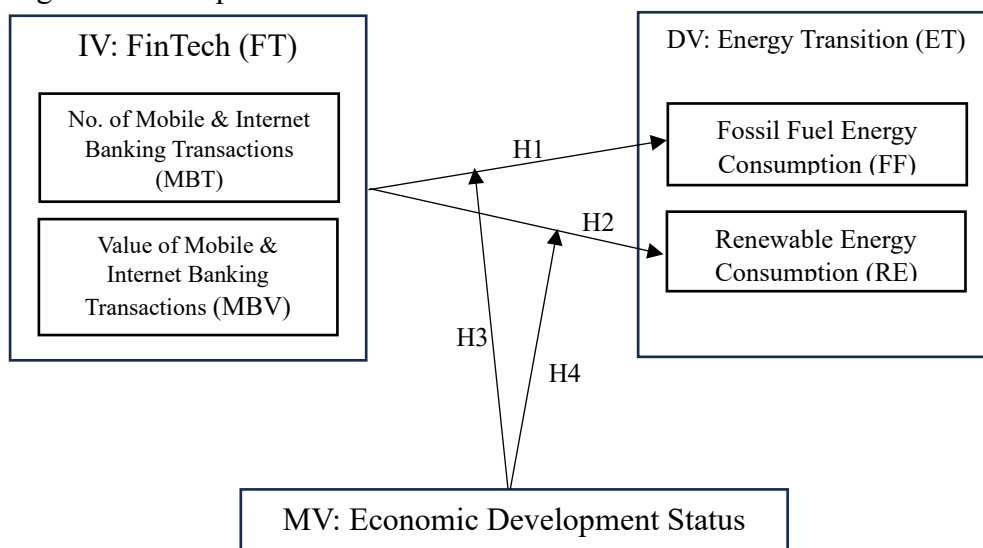
utilized Method of Moments Quantile Regression (MMQR) to demonstrate that the impact of variables often fluctuates from lower to higher quantiles, revealing structural differences that mean-based regressions miss. By adopting a panel quantile regression approach, my study addresses this critical gap, allowing for a nuanced comparison of how FinTech drives energy transition differently in countries with varying energy mixes. Combined with a heterogeneity analysis, this study gives a comprehensive analysis on FinTech towards different energy and economic development levels.

Until this point, the variation in FinTech development across the globe where many countries are still at the early stages of introducing the use of FinTech, has caused a lack of precise proxy for FinTech usage and development. Thus, many studies have used different ways of representing FinTech variables in their studies. The vast using Principal Component Analysis (PCA) by aggregating available data, usually Fixed broadband subscriptions (per 100 people), Individuals using the Internet (% of the population) and Mobile cellular subscriptions (per 100 people), to proxy Fintech (Korkut Pata et al., 2025; Y. Li et al., 2024; Okere et al., 2025; Tan et al., 2023). Studies have argued the incompetence of this proxy to relate to FinTech, expressing need to use better measurements in the future to study the relationship (Croutzet & Dabbous, 2021; Lu et al., 2023; Tan et al., 2023). This study uses a new approach, consisting of the number of mobile and internet banking transactions and the value of mobile and internet banking transactions, to proxy FinTech as it better captures FinTech's function of digitalizing finance.

2.7 Conceptual Framework

Figure 3 illustrates the conceptual framework of this study drawing from theories discussed in the theoretical framework, namely the Ecological Modernization Theory, Sustainable Finance Theory and Financial Development Theory. The framework visualizes the causal paths, and interaction effects this study aims to answer.

Figure 3: Conceptual Framework



Source: Constructed by Author

The framework is made up of 3 main components, the Independent Variable (IV): FinTech; the Dependent Variable (DV): Energy Transition; the Moderating Variable (MV): Economic Development Status. FinTech (FT) is proxied by the number of mobile and internet banking transactions (MBT) and the value of mobile and internet banking transactions (MBV). Energy Transition (ET) is proxied by fossil fuel energy consumption (FF) and renewable energy consumption (RE).

The first arrow (H1) linking FT to FF represents the relationship investigated between FinTech development with fossil fuels energy consumption. This

path reflects the Ecological Modernization Theory where financial development's effect on environmental degradation is not linear but heterogeneous. Thus, this relationship is analysed with panel quantile regression to capture the effects across different levels of FF. Path H2 links FT to RE reflecting the sustainable finance theory where financial development can contribute to sustainable practices. In this case, the relationship will be studied across different quantiles of RE as well.

Path H3 and H4 originate from the moderating variable economic development status and intersect with the causal paths (H1 and H2), representing the moderating effect of different countries level of development. H3 illustrates the analysis of whether FT's influence on FF differs between developed and developed countries while H4 shows the impact between developing and developed countries of FT on RE. These 2 paths align with the Financial Development Theory by separating the optimization and creation objectives of FT in both economic development levels.

2.8 Summary of the Chapter

Table 2.0 Summary of Chapter 2

Research Gaps	Theories	Hypothesis
<p>Although most prior research has grouped countries into clusters, this study focuses specifically on developed vs developing countries to fill in the comparative research gap by adding interaction terms to analyse heterogeneous outcomes.</p> <p>To mitigate the restrictions of the predominant mean-based estimates, from which much of the pattern of the distributions is lost, this study deploys panel quantile regression to unveil how varying levels of energy consumption furnish distinct neutral impacts.</p> <p>This study closes the reliance on imprecise proxies, such as PCA of general internet usage, by measuring the volume and value of mobile and internet banking transactions to ascertain the results on the adoption of FinTech.</p>	<p>Ecological Modernization Theory (EMT)</p> <hr/> <p>Sustainable Finance Theory (SFT)</p> <hr/> <p>Financial Development Theory (FDT)</p>	<p>H1: The magnitude of FinTech's impact on fossil fuel energy consumption differs across quantiles of the consumption distribution.</p> <hr/> <p>H2: The magnitude of FinTech's impact on renewable energy consumption differs across quantiles of the consumption distribution.</p> <hr/> <p>H3: The effect of FinTech on fossil fuel energy consumption differs between developed and developing economies.</p> <hr/> <p>H4: The effect of FinTech on renewable energy consumption differs between developed and developing economies.</p>

Source: Constructed by author

CHAPTER 3 METHODOLOGY

3.0 Introduction

This section discussed the sample and methods used in this study. The sample selection of 56 countries with data across 10 years from 2015 to 2024 are explained in this section. The variables selected and source for these data are also listed along with model specification constructed with the selected variables.

3.1 Data Description

3.1.1 Sample Selection

For this research a sample of 56 countries, consisting of 16 developed countries and 40 developing countries, were selected. Other from data availability for these economies, the sample spans across multiple regions, including Europe, Asia, Latin America and Africa, giving this study more significance in capturing regional contexts, infrastructure and policies and how they affect FinTech's ability to influence Energy Transition. The sample also reflects on the different stages of FinTech adoption around the world from economies with advanced ecosystems, with rapidly emerging hubs and to economies that are early-stage adopters. Different economies also have variation in the energy generation side of things, where there are economies that are highly fossil fuel dependent to countries that have transitioned to renewable adoption.

The time frame of 2015 to 2024 was chosen as it was the year where the Paris Agreement and UN Sustainable Development Goals (SDGs) were adopted, therefore these years are highly important to see the

initiatives of different economies in integrating sustainable practices along with financial development.

The table below shows the variable description of all the variables used in this study:

Table 3.1: List of Variables

Variable	Variable Description	Source
RE	Renewable energy consumption (% of total final energy consumption)	World Bank Database
FF	Fossil fuel energy consumption (% of total)	World Bank Database
MBV	Value of mobile and internet banking transactions (during the reference year), Percent of GDP	IMF Data
MBT	Number of mobile and internet banking transactions (during the reference year), Per 1000 Adults	IMF Data
CO2	Carbon dioxide (CO2) emissions (total) excluding LULUCF (Mt CO2e)	World Bank Database
FDI	Foreign direct investment, net inflows (% of GDP)	World Bank Database

GDPc	GDP per capita (current US\$)	World Bank Database
GE	Government Effectiveness: Index Score	World Bank Database
INF	Inflation, consumer prices (annual %)	World Bank Database
DEVS	Economic development status (0=developed; 1=developing)	
MBV_DEV	MBV * DEVS	
MBT_DEV	MBT * DEVS	

Source: World Bank. (2025). World Development Indicators | DataBank.

Worldbank.org; The World Bank.

<https://databank.worldbank.org/source/world-development-indicators#> ;

International Monetary Fund. (2025). *Financial Access Survey(FAS)*. Imf.org.

<https://data.imf.org/en/datasets/IMF.STA:FAS>

3.1.2 Dependent Variables

Energy Transition (ET) refers to the process of shifting fossil fuel-based energy generation to renewables and more sustainable alternatives. Previous studies proxied this variable with renewable energy consumption, renewable energy generation and fossil fuel energy consumption, where an increase in renewables and reduce in fossil fuel usage would suggest successful energy transition (Akono & Kemezang, 2024a; Rahman et al., 2025c; Xu et al., 2023a). This study will study from both sides of energy transition by representing it with renewable energy consumption (% of total final energy consumption) and fossil fuel energy consumption (% of total) from the World Development Indicators (World Bank). This measure

directly reflects the shift in energy mix towards renewables, proving relevancy and comprehensiveness for indicating energy transition.

3.1.3 Independent Variables

The primary independent variable for this study is FinTech (FT), which captures the adoption of financial technologies. As there lacks a clear universal indicator, the FT variable is proxied by the value of mobile and internet banking transactions and the number of mobile and internet banking transactions from the Financial Access Survey (FAS) from IMF Data. Previous studies have used different ways to represent FinTech, with a majority using PCA combining digital infrastructure, specifically fixed broadband subscriptions, internet penetration and mobile subscriptions (Akono & Kemezang, 2024a; Korkut Pata et al., 2025; Okere et al., 2025; Tan et al., 2023). The PCA method despite showing relevance to FinTech as such services need internet to function, however it is not a directly related to FinTech usage, thus is not the best way to proxy FinTech. Other studies used traded market indices that track the performance of FinTech companies, which are not as relevant for this study because FinTech companies are yet to be common worldwide, especially for developing economies (Liu & Wang, 2024; Shah et al., 2025). This study follows Frost (2020), by using both the count and value of mobile and internet banking transactions to represent FinTech adoption. This approach not only directly captures the usage of FinTech services but also distinguishes between the frequency of digital finance usage (MBT) and the economic scale of capital moving through digital channels (MBV).

3.1.4 Control Variables

To ensure the robustness of the estimated results, this study included a set of control variables following existing literature. The controls include GDP per Capita (GDPC), Foreign Direct Investment (FDI), Inflation (INF), CO2 emissions (CO2) and Government Effectiveness (GE).

GDPC is included to control for the effects economic development has on energy demand and emissions, known as the scale effect (Vo et al., 2023; Xu et al., 2023a). FDI is added to account for the possibility where foreign capital flows would also bring superior technology that affects energy use and emissions (Croutzet & Dabbous, 2021; Guo & Yin, 2024). The inclusion of INF is to account for volatility in cost of capital which could impact renewable energy investments.

CO2 is included to capture the environmental deterioration from emission that trigger reactional policy shifts, to transition into low-carbon energy sources (Vo et al., 2023). GE accounts for the capacity of a government to formulate and successfully implement environmental and economic policies (Tan et al., 2023; Xu et al., 2023a).

3.1.5 Interaction Variables

To empirically test the heterogeneity of FinTech's impact on RE and FF, this study employs Economic Development Status (DEVS) as a moderating variable. This binary indicator reflects the developed economies as 0 and developing economies as 1. The moderating variable is used to construct the interaction variables (MBV_DEV, MBT_DEV) by multiplying the FinTech proxies with DEVS. The interaction variables are constructed based on the Financial Development Theory, where financial systems are interrelated with economic maturity. Between developed and developing economies, their financial infrastructures, policies and goals differ greatly, causing FinTech adoption to have varying impacts (Alofaysan et al., 2024; Korkut Pata et al., 2025; M. Li et al., 2025). For instance, in developing countries, FinTech drives energy transition with financial inclusion and decentralised solutions whereas in developed nation, it may be driven through their strong and mature markets using green bonds. The interaction variable would help test the fundamental heterogeneity of these two development stages.

3.2 Model Specification

This study employs panel quantile regression (PQR) to investigate the relationships with the dependent variable across different quantiles. This method reveals the distributional heterogeneity that standard mean-based regression methods fail to capture. For instance, coefficients at various points of the conditional distribution, such as the 10th, 50th, and 90th quantiles, can be analysed using PQR. PQR is inherently robust towards outliers and non-normal data distributions, outliers are common in global and financial datasets, because PQR minimizes the sum of absolute deviations rather than squared errors (Koenker & Hallock, 2001).

This research uses Powell's Quantile Regression for Panel Data estimators (Powell, 2022). Standard quantile methods have the "incidental parameters problem" when estimating fixed effects, while the Powell estimator includes non-additive fixed effects. This balance between flexibility and rigidity ensures that the model is robust to the effects of bias, and that the estimates of the coefficients are neither altered nor distorted. This allows for time-invariance of the individual characteristics. This is how consistency and robustness of results from the panel data are obtained.

This study constructs the following econometric models

$$Q_{FF_{it}}(\tau) = \alpha_i + \beta_1(\tau)MBT_{it} + \beta_2(\tau)MBV_{it} + \beta_3(\tau)CO2_{it} + \beta_4(\tau)FDI_{it} + \beta_5(\tau)GDPc_{it} + \beta_6(\tau)INF_{it} + \beta_7(\tau)GE_{it} + \epsilon_{it} \quad (1)$$

In equation (1), $Q_{FF_{it}}(\tau)$ is the dependent variable, representing the conditional quantile of fossil fuel energy consumption for country i at time t . MBT and MBV are the independent variables showing the number and value of mobile and internet banking transactions respectively, which serve as proxies for FinTech. CO2, FDI, GDPc, INF and GE are the control variables representing carbon dioxide emissions, foreign direct investment, GDP per capita, inflation and government effectiveness. The subscript t denotes the time (year), i signifies the nation, ϵ denotes the error term α_i represents the constant term and $\beta_n(\tau)$ ($n = 1,2,3,\dots,7$) signifies the coefficients of the independent and control variables at the τ^{th} quantile. This study examines the impact of FinTech across different quantiles ($\tau = 0.10, \dots, 0.90$) to capture the heterogeneous effects on fossil fuel energy consumption.

$$Q_{RE_{it}}(\tau) = \alpha_i + \delta_1(\tau)MBT_{it} + \delta_2(\tau)MBV_{it} + \delta_3(\tau)CO2_{it} + \delta_4(\tau)FDI_{it} + \delta_5(\tau)GDPc_{it} + \delta_6(\tau)INF_{it} + \delta_7(\tau)GE_{it} + \mu_{it} \quad (2)$$

Equation (2) changes the dependent variable from $Q_{FF_{it}}(\tau)$ to $Q_{RE_{it}}(\tau)$, which represents the conditional quantile of renewable energy consumption for country i at time t , to examine the impact on renewable energy consumption.

$$Q_{FF_{it}}(\tau) = \alpha_i + \gamma_1(\tau)MBT_{it} + \gamma_2(\tau)MBV_{it} + \gamma_3(\tau)devs_i + \gamma_4(\tau)(MBT_{it} \times devs_i) + \gamma_5(\tau)(MBV_{it} \times devs_i) + \gamma_6(\tau)CO2_{it} + \gamma_7(\tau)FDI_{it} + \gamma_8(\tau)GDPc_{it} + \gamma_9(\tau)INF_{it} + \gamma_{10}(\tau)GE_{it} + v_{it} \quad (3)$$

To capture the heterogeneous effects from economic development status, equation (3) is constructed from equation (1) adding $(MBT_{it} \times devs_i)$ and $(MBV_{it} \times devs_i)$, the interaction terms between the independent variables and the moderating variable.

$$Q_{RE_{it}}(\tau) = \alpha_i + \lambda_1(\tau)MBT_{it} + \lambda_2(\tau)MBV_{it} + \lambda_3(\tau)devs_i + \lambda_4(\tau)(MBT_{it} \times devs_i) + \lambda_5(\tau)(MBV_{it} \times devs_i) + \lambda_6(\tau)CO2_{it} + \lambda_7(\tau)FDI_{it} + \lambda_8(\tau)GDPc_{it} + \lambda_9(\tau)INF_{it} + \lambda_{10}(\tau)GE_{it} + \omega_{it} \quad (4)$$

Equation (4), having the same idea as equation (3), was modified beyond equation (2) to further examine the effects economic development status has on renewable energy consumption.

3.3 Summary of the Chapter

To analyse the influence of FinTech on the Energy Transition across a cross-section of 56 developed and developing countries within the period of 2015-2024, the current research applies a panel data-based approach of empirical analysis. While using indirect proxies, this study measures the value and the volume of the transactions of mobile and internet banking (MBV and MBT) to directly examine the use of digital finance and its consumption of Renewable Energy (RE) versus Fossil Fuel (FF). Given the limitations of the standard mean-based estimation, this research uses Powell's panel quantile regression (PQR), a method of estimation that is robust to the influence of outliers and allows for the demonstration of the distributional heterogeneity across quantiles of the dependent variable, which in this analysis is the consumption of energy. The model also includes control variables including Government Effectiveness, Inflation, the GDP per capita, FDI, and CO2 emissions. To evaluate the differential impacts on the environment of FinTech on the developed versus developing economies, interaction variables are added to the models.

CHAPTER 4: DATA ANALYSIS

4.0 Introduction

This section shows the results and interpretations for my regression analysis for FinTech's impact on Energy Transition. In this part of the paper are the descriptive statistics, correlation matrix, VIF table and also the quantile regression results for this study, depicted in tables and graphs.

4.1 Descriptive Statistics

Table 4.1, 4.2 and 4.3 show the descriptive statistics for the sample of this study. Table 4.1 presents the descriptive statistics for developing countries, Table 4.2 for developed countries while Table 4.3 for all countries from the sample of 56 countries.

The mean values of GDPc of the developing and developed nations are USD 11,115 and USD 40,038 respectively, and the overall mean of USD 17,380 shows a higher proportion of developing countries in the dataset. The developing nations also have a higher inflation rate (INF), which is 5.25%, whereas the developed countries have a mean INF of 2.92%. The sample is indeed capturing the countries at different levels of economic development.

The situation of energy transition variables shows the overall high reliance on fossil fuels in all the countries. The average consumption of fossil fuels in developing countries is 55.75% while in developed countries, it is 61.67%. The overall sample mean of 57.13% shows that the high consumption of fossil fuels is a global rather than a targeted country issue. The consumption of renewable energy is also low with a mean of 17.30%, and this is the same for both the developing and developed countries. The variables on energy

transition efforts indicate the different levels of energy transition development across different economies.

For the FinTech indicators, the MBT average is 71,136 for developing economies and 81,959 for developed economies, while the overall average is 73,648. A small number of highly digitalised economies greatly influence world FinTech activity, and that is reflected in the entire sample having a concerning large standard deviation of 120,987. MBV has a mean of 336.47% of GDP for developing countries and 475.44% for developed countries, which is quite a difference. This dispersion is influenced not only by income level but also by variations in digital infrastructure, regulatory frameworks, and financial inclusion policies on a country basis. The variety of the FinTech, energy transition, and macroeconomic variables strengthens the need for a paired analysis in order to examine the effects that FinTech promotes on the energy transition for different levels of economic development.

Table 4.1: Descriptive Statistics for Developing Countries

Variables	Unit of Measurement	N	Mean	Std. dev	Median	Min	Max
CO2	Millions of metric tonnes of Carbon Dioxide Equivalent	430	173.30	454.19	10.70	0	2955.18
FDI	% of GDP	430	5.22	31.70	2.77	-296.01	431.79
GDPc	Current US\$	430	11115.96	10322.46	7757.00	729.52	68218.73
GE	Index Score	430	.07	0.60	0	-1.14	1.83
INF	Annual %	430	5.25	8.12	3.44	-2.10	72.31
FF	% of Total Energy Use	430	55.75	35.68	70.02	0	100.00
RE	% of Total Final Energy Consumption	430	18.15	20.73	11.10	0	86.30
MBT	Per 1,000 Adults	430	71135.57	125442.16	22105.38	0	965919.00
MBV	% of GDP	430	336.47	474.99	236.87	0	3655.50

Source: Constructed by Author

Table 4.2: Descriptive Statistics for Developed Countries

Variables	Unit of Measurement	N	Mean	Std. dev	Median	Min	Max
CO2	Millions of metric tonnes of Carbon Dioxide Equivalent	130	45.11	60.56	34.77	0	281.70
FDI	% of GDP	130	16.00	83.18	2.78	-444.71	452.22
GDPc	Current US\$	130	40038.02	31986.52	26607.34	3880.69	137516.59
GE	Index Score	130	.92	0.66	.97	-.26	2.14
INF	Annual %	130	2.92	3.80	1.74	-1.74	19.71
FF	% of Total Energy Use	130	61.67	25.43	65.68	0	100.00
RE	% of Total Final Energy Consumption	130	14.47	12.73	15.30	0	39.50
MBT	Per 1,000 Adults	130	81958.96	104928.82	78938.43	0	884602.00
MBV	% of GDP	130	475.44	787.73	298.30	0	5618.00

Source: Constructed by Author

Table 1.3: Descriptive Statistics for All Countries

Variable s	Unit of Measurement	N	Mean	Std. dev	Median	Min	Max
CO2	Millions of metric tonnes of Carbon Dioxide Equivalent	560	143.54	402.61	15.18	0	2955.18
FDI	% of GDP	560	7.72	48.88	2.77	-444.71	452.22
GDPc	Current US\$	560	17830.01	21616.07	10228.23	729.52	137516.59
GE	Index Score	560	.27	0.71	.12	-1.14	2.14
INF	Annual %	560	4.71	7.41	2.96	-2.10	72.31
FF	% of Total Energy Use	560	57.13	33.66	68.28	0	100.00
RE	% of Total Final Energy Consumption	560	17.30	19.23	12.15	0	86.30
MBT	Per 1,000 Adults	560	73648.14	120987.46	30256.99	0	965919.00
MBV	% of GDP	560	368.73	565.51	241.67	0	5618.00

Source: Constructed by Author

4.2 Correlation/VIF

Table 4.4 displays a Pearson correlation matrix; that matrix serves as a point of departure, explaining a preliminary investigation of the linear relationships of the variables under study. The preliminary investigation for multicollinearity indicates that all correlation coefficients among the independent variables are less than the threshold value of 0.80, indicating that multicollinearity likely will not contaminate the regression estimators. With respect to the dependent variables, both Fossil Fuel Energy Consumption (FF) and Renewable Energy Consumption (RE) are significantly correlated with a number of the economic variables, although the relationships are of different signs. For example, FinTech adoption (MBT) is significantly negatively correlated with RE (-19.7%***) and is also negatively correlated with FF (-16.8%***). Hence, it is likely that countries with a greater number of transactions are, on average, less energy consumptive with respect to other potential energy structural factors. Interestingly, FinTech deepening (MBV) is positively correlated with MBT (31.5%***), although there is no significant univariate linear relationship to the energy variables in the current bivariate configuration. Furthermore, Economic Development (GDPc) is highly and positively correlated with Government Effectiveness (GE) (68%***), pointing in the direction of the necessity to control for institutional quality as a variable in the line of the argument in the economic analysis.

To explore potential multicollinearity issues among the independent variables, a Variance Inflation Factor (VIF) test was also administered. The data in Table 4.5 is now concluding as all VIF values are low; they range from 1.019 to 1.944 with a mean VIF of 1.342. The level of VIF values is well lower than 10, which suggests that there is no troubling presence of multicollinearity in the model. More importantly, the FinTech proxies MBT (1.137) and MBV (1.248) had extremely low VIFs, which strengthens the case that they measure separate and unique facets of the development of FinTech.

Table 4.4: Correlation Table

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) CO2	1.000								
(2) FDI	-0.041	1.000							
(3) GDPc	-0.096**	-0.009	1.000						
(4) GE	-0.060	0.055	0.680***	1.000					
(5) INF	0.020	-0.055	-0.136***	-0.214***	1.000				
(6) FF	0.179***	0.071*	0.043	0.184***	0.015	1.000			
(7) RE	-0.052	-0.034	-0.145***	-0.056	-0.145***	0.011	1.000		
(8) MBT	0.070*	-0.049	0.131***	0.079*	0.056	-0.168***	-0.197***	1.000	
(9) MBV	0.016	0.173***	0.270***	0.256***	0.002	0.033	-0.195***	0.315***	1.000

*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$, Source: Constructed by Author

Table 4.5: VIF Table

	VIF	1/VIF
GE	1.944	.514
GDPc	1.931	.518
MBV	1.248	.801
MBT	1.137	.88
INF	1.058	.945
FDI	1.055	.948
CO2	1.019	.981
Mean VIF	1.342	.

Source: Constructed by Author

4.3 Regression Results

4.3.1 Baseline Regression Results (FF)

The outcomes derived from panel quantile regression for model 1 (Table 4.6) demonstrate a clear heterogeneity in the ways FinTech indicators impact the consumption of fossil fuel energy (FF). Heterogeneity across the quantile distribution is illustrated in Figure 4.1. The most notable difference is the frequency of adoption (MBT) versus the amount of capital (MBV) streamed through digital channels. The amount of mobile and internet banking transactions (MBT) has an increasingly strong negative relationship with fossil fuel consumption across the quantiles from the 20th to the 90th. For MBT, the visual trend indicates that the mitigating effect is most substantial in the lower to middle quantiles (20th to 40th), implying efficiency gains from digital adoption are predominant in economies with lower dependence on fossil fuels. At the median, a 1,000 increase in adult transactions corresponds with a 0.0000725 decline in fossil fuel dependency.

The value of these transactions (MBV) also shows a robust positive correlation, especially in the 30th to 80th quantiles, with the consumption of fossil fuels in the middle to upper distribution. At the median, MBV has a coefficient of 0.00638, suggesting that an increase in digital financial flows is associated with an increase in fossil fuels consumption. Although the FinTech system is productive, it is suggestive that the cash flow actively supports very high emissions sectors.

For other control variables, Government Effectiveness (GE) has a non-linear effect. GE in Figure 4.3 is sharply negatively sloped, starting with a strong positive 21.59 coefficient at the 10th quantile,

and crossing the zero line approximately at the 60th quantile. This indicates early stage energy economies with positive infrastructure development where fossil fuels use is high and then ceases to be the driver.

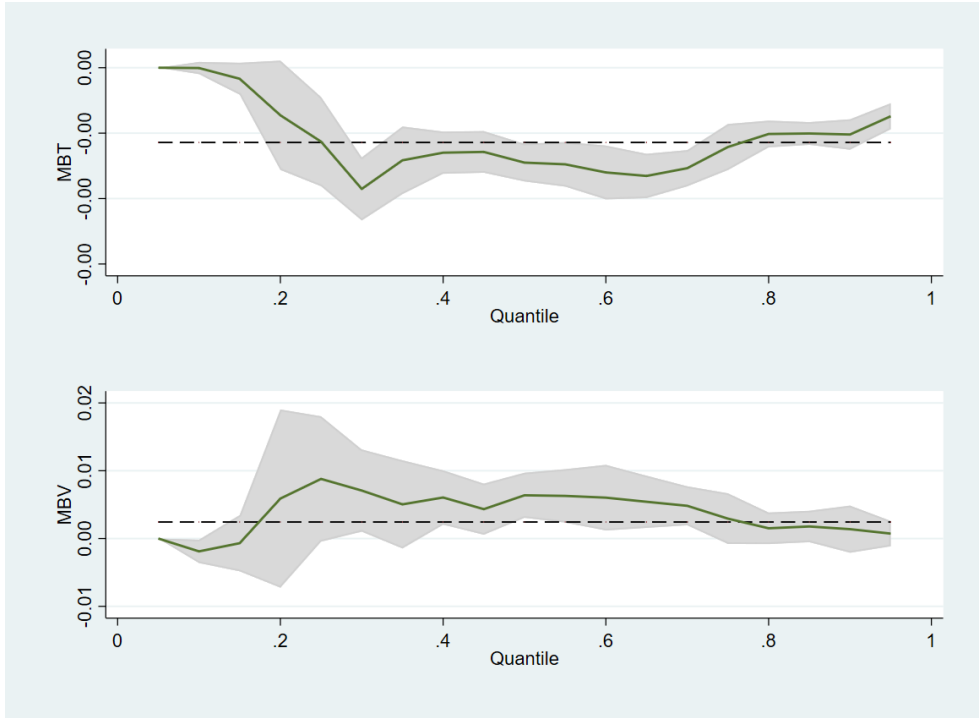
These differences the empirical support for **H1**. The fact that MBV and GE have significant coefficients in these quantiles and are otherwise silent in other quantiles illustrates that the impact of FinTech is not homogeneous, it is conditional on the level of fossil fuels consumption in the economy.

Table 4.6: Panel Quantile Regression of MBT, MBV and control variables on FF

Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Dependent	FF	FF	FF	FF	FF	FF	FF	FF	FF
MBT	-0.00000220 (0.0000162)	-0.0000363*** (0.0000134)	-0.0000926*** (0.0000178)	-0.0000649*** (0.0000193)	-0.0000725*** (0.0000730)	-0.0000800*** (0.0000104)	-0.0000768*** (0.0000172)	-0.0000506*** (0.0000126)	-0.0000510*** (0.0000675)
MBV	-0.00189 (0.00525)	0.00589 (0.00818)	0.00708** (0.00309)	0.00605*** (0.00151)	0.00638*** (0.00165)	0.00603*** (0.00145)	0.00483*** (0.000988)	0.00151** (0.000713)	0.00138 (0.00109)
CO2	0.0245* (0.0139)	0.0208*** (0.00333)	0.0102 (0.00991)	0.0192*** (0.00711)	0.0181*** (0.00155)	0.0166*** (0.00240)	0.0150*** (0.00287)	0.00901*** (0.00318)	0.0164*** (0.00427)
FDI	0.147 (0.227)	0.0866 (0.110)	0.0307 (0.0287)	0.0566** (0.0265)	0.0480** (0.0202)	0.0307*** (0.00627)	0.0219* (0.0122)	0.00594 (0.0110)	-0.00141 (0.0186)
GDPc	0.00000930 (0.0000454)	-0.000280 (0.000197)	-0.000516*** (0.000108)	-0.000430*** (0.0000557)	-0.000427*** (0.000104)	0.00000388 (0.000117)	-0.0000220 (0.0000431)	-0.000138*** (0.0000336)	-0.000149*** (0.0000455)
GE	21.59*** (7.041)	30.93*** (6.683)	26.75*** (5.203)	18.31*** (2.533)	15.38*** (2.824)	-0.386 (2.807)	-0.306 (1.892)	4.529*** (1.455)	2.446 (1.946)
INF	0.00446 (0.0724)	0.325 (0.676)	0.622 (0.575)	0.456** (0.231)	0.515*** (0.167)	0.277*** (0.0865)	0.197* (0.108)	0.109*** (0.0286)	0.0231 (0.0955)
_CONS	0.278 (1.934)	13.37* (6.846)	48.88*** (5.890)	58.21*** (2.554)	64.67*** (2.271)	73.07*** (2.185)	78.81*** (1.689)	87.09*** (1.315)	93.02*** (1.866)
Observations	560	560	560	560	560	560	560	560	560

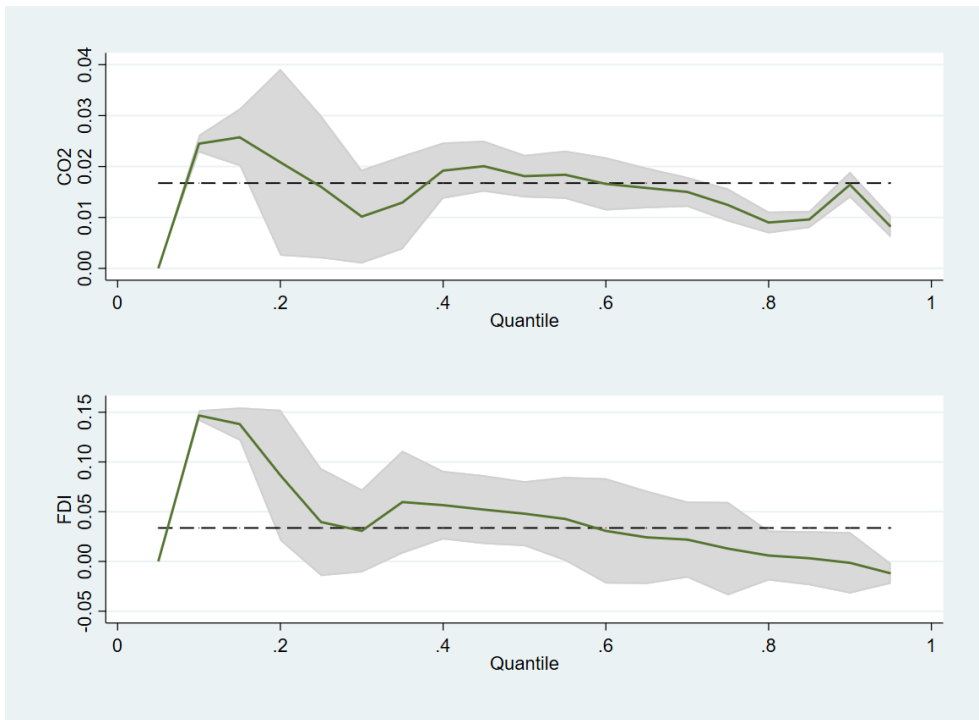
Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Own Construction

Figure 4.1: Quantile Regression Graph for MBT and MBV (DV=FF)



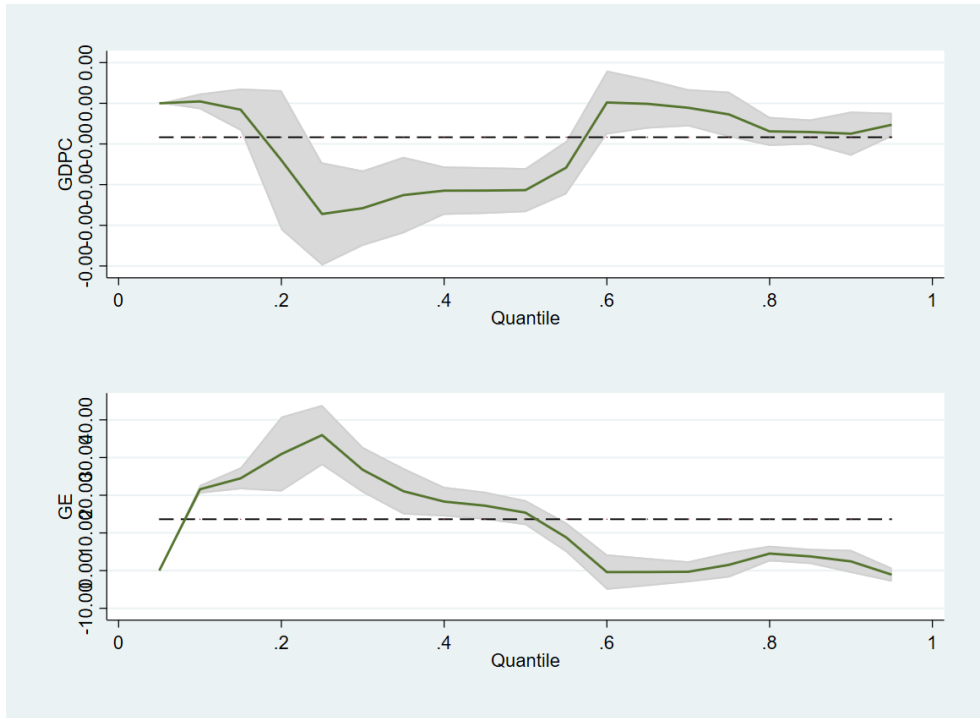
Source: Constructed by Author

Figure 4.2: Quantile Regression Graph for CO2 and FDI (DV=FF)



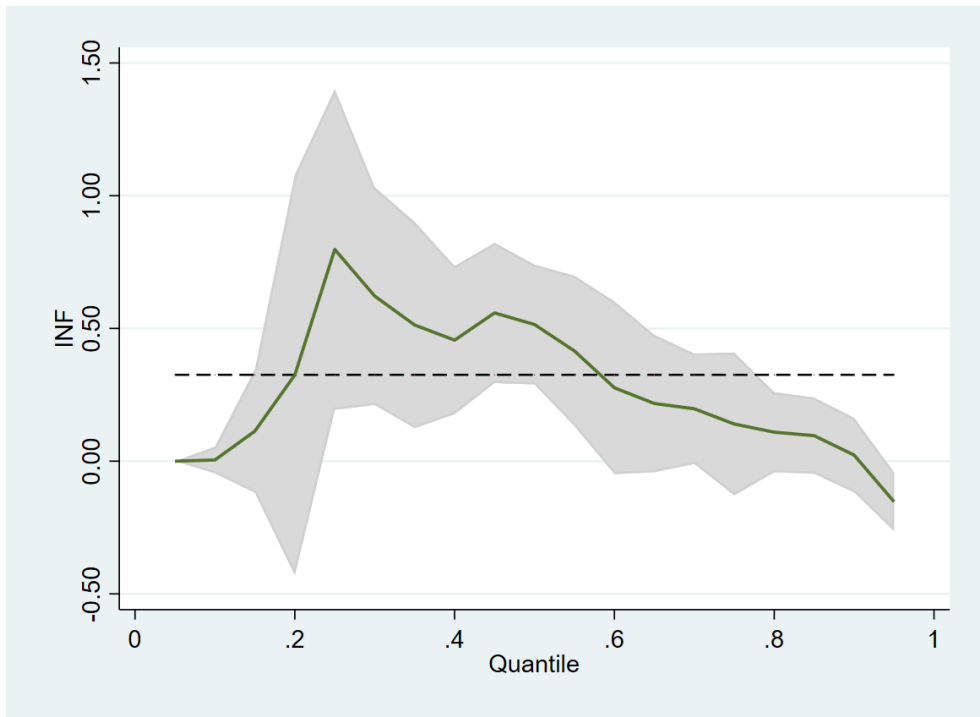
Source: Constructed by Author

Figure 4.3: Quantile Regression Graph for GDPC and GE (DV=FF)



Source: Constructed by Author

Figure 4.4: Quantile Regression Graph for INF (DV=FF)



Source: Constructed by Author

4.3.2 Baseline Regression Results (RE)

The findings regarding the impact that FinTech has on the consumption of Renewable Energy (RE) are displayed in Table 4.7 and the quantile process showcased in Figures 4.5 to 4.8. The findings suggest that the hypothesis regarding digital finance enabling the green energy transition is unfounded, as the results demonstrate that the development of FinTech is currently impeding the growth of energy renewables. The coefficients for both the number (MBT) and dollar value (MBV) of transactions are largely negative. For example, while the impact of MBT on the 30th to 70th quantile is negative, around -0.0000178 at the median, and highly statistically significant, this quantitatively negative impact is largely stable, as the MBT quantile plot displays, in the midst of the lower to mid quantiles while there is a sharp positive deviation in the 90th quantile. That is, the hindering effect of the number of transactions on the rate of renewables adoption is absent in countries with a sufficiently high level of consumption of renewables.

The volume of transactions (MBV) shows an even more dire trend. It is very negative from the median and upwards, where the negative impact increases with the greater consumption of renewable energy (-0.0027 at the median until -0.0080 at the 90th quantile). The MBV graph in figure 4.5 illustrates the extent of this negative trend, showing that in the more proactive economies on renewable energy there are also large negative MBVs that are likely to be directed to more traditional industries, meaning that even more capital is pulling to the non-green.

Of the control variables, GE is the strongest and primary factor behind the adoption of renewable energy; however, it is non-linearly

impactful. The impact also is positive and very significant from the 30th to the 70th quantiles, where the peak at the median is 7.221. The empirical evidence in the GE graph from figure 4.7 shows a clear case of the “inverted-U” phenomenon. In the middle quantiles, there is a sharp positive increase of governance effectiveness on the renewable share, but that positive effect is lost and overshoot into the negative at the highest quantile, illustrating the concept of diminishing policy returns where governance effectiveness flattens. In addition, there is a negative impact on the share of renewables from Inflation (INF), indicating that investments in the green infrastructure are very susceptible to macroeconomic volatility.

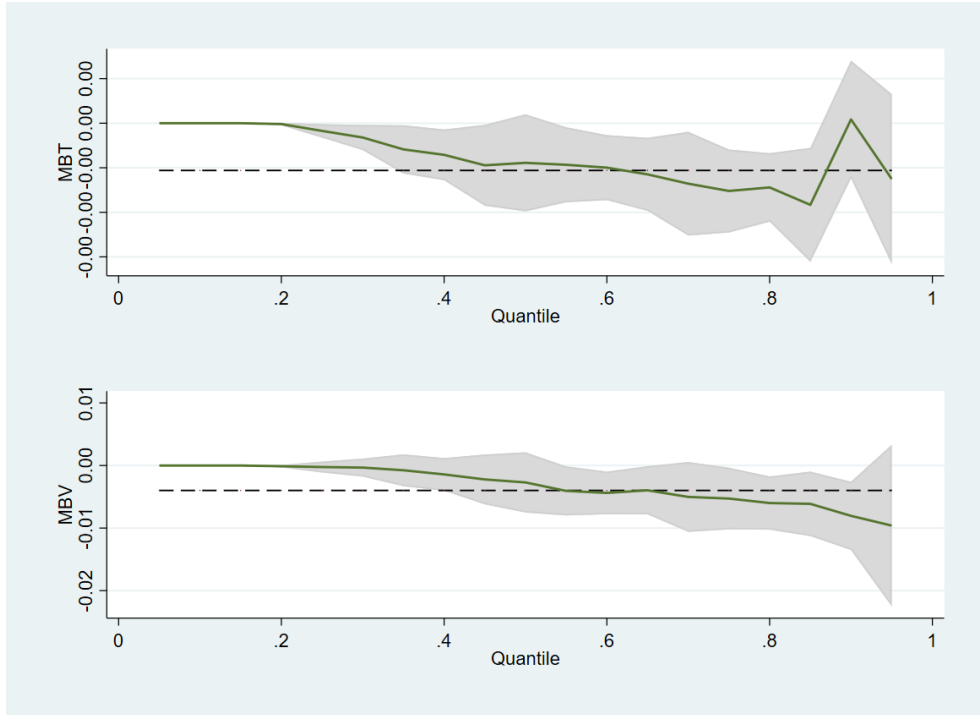
This heterogeneity affirms **H2**. The specific downward trend in the MBV coefficient, which becomes more strongly negative with each increment of renewable consumption, shows that FinTech's impact on renewable energy is asymmetric and differs greatly over the range of the consumption distribution.

Table 4.7: Panel Quantile Regression of MBT, MBV and control variables on RE

Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Dependent	RE	RE	RE	RE	RE	RE	RE	RE	RE
MBT	0 (.)	-0.00000380 (0.0000139)	-0.00000642*** (0.0000221)	-0.0000142** (0.00000602)	-0.0000178*** (0.0000267)	-0.0000199*** (0.0000545)	-0.0000271*** (0.0000626)	-0.0000288 (0.0000200)	0.00000170 (0.0000159)
MBV	0 (.)	-0.000117 (0.000514)	-0.000333 (0.000789)	-0.00142 (0.00120)	-0.00270** (0.00108)	-0.00438*** (0.000928)	-0.00502*** (0.000801)	-0.00600*** (0.00191)	-0.00804*** (0.00125)
CO2	0 (.)	0.0000812 (0.000668)	0.000615 (0.000824)	-0.000464 (0.00158)	-0.00173** (0.000876)	-0.00363 (0.00377)	0.000837 (0.00425)	-0.00176 (0.00211)	-0.00462*** (0.00125)
FDI	0 (.)	0.0160 (0.0114)	0.00602 (0.0124)	-0.00436 (0.0146)	-0.0180 (0.0212)	-0.0289* (0.0167)	-0.000669 (0.0222)	-0.0000366 (0.0173)	-0.00643 (0.0235)
GDPc	0 (.)	-0.00000562 (0.0000194)	-0.0000716 (0.0000461)	-0.000151*** (0.0000556)	-0.000199*** (0.0000564)	-0.000163*** (0.0000622)	-0.000172*** (0.0000642)	-0.000106 (0.0000755)	-0.000139** (0.0000649)
GE	0 (.)	0.261 (0.648)	3.320*** (1.239)	5.976*** (2.102)	7.221*** (1.699)	6.098*** (1.996)	5.053** (2.248)	-0.746 (2.706)	-4.322 (2.857)
INF	0 (.)	-0.0234 (0.0732)	-0.237* (0.139)	-0.536*** (0.136)	-0.446** (0.204)	-0.294 (0.202)	-0.366*** (0.0747)	-0.450*** (0.132)	-0.664 (0.920)
_CONS	0 (.)	0.328 (0.735)	4.770*** (1.777)	13.12*** (1.905)	19.47*** (1.826)	24.42*** (1.935)	31.29*** (1.879)	39.71*** (2.453)	53.15*** (3.551)
Observations	560	560	560	560	560	560	560	560	560

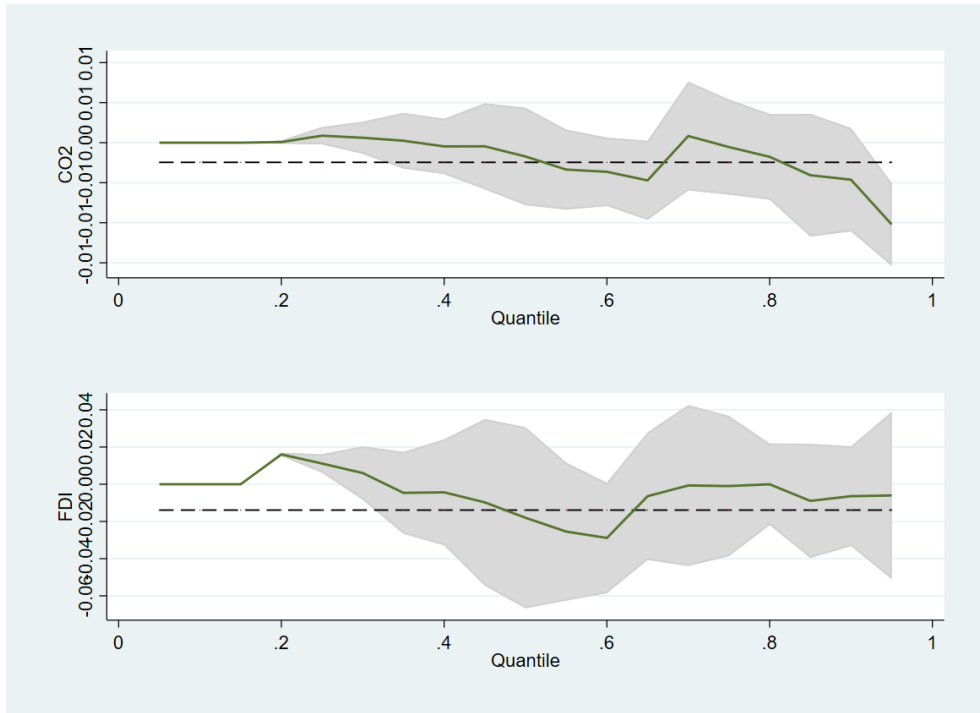
Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The 10th quantile results are omitted due to the prevalence of zero or near-zero values in the dependent variable at this distribution level, which prevented model convergence. Source: Own Construction

Figure 4.5: Quantile Regression Graph for MBT and MBV (DV=RE)



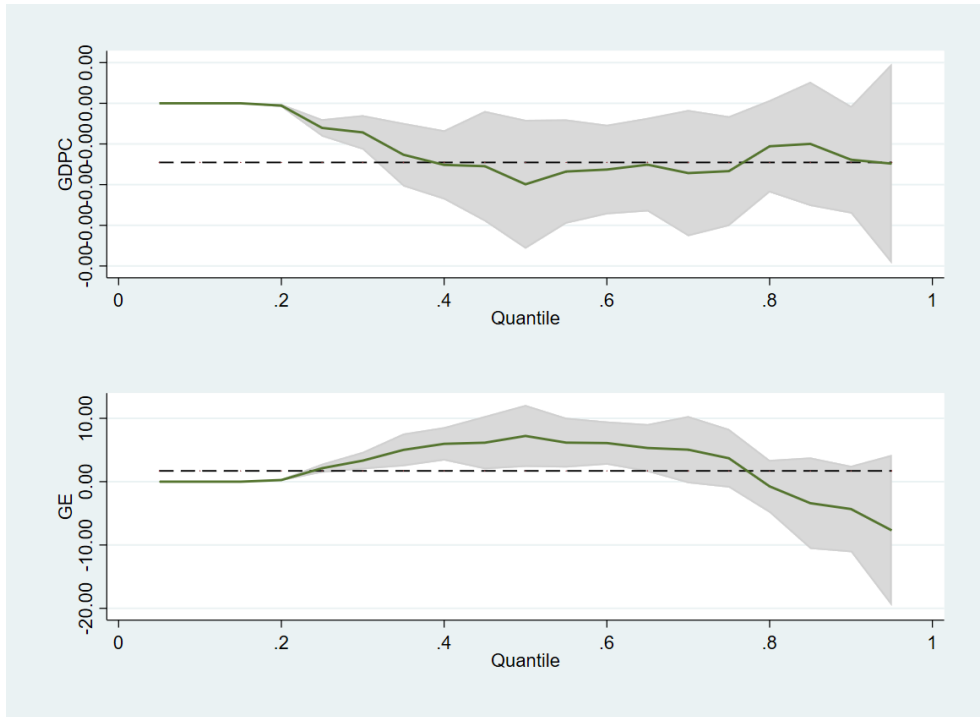
Source: Constructed by Author

Figure 4.6: Quantile Regression Graph for CO2 and FDI (DV=RE)



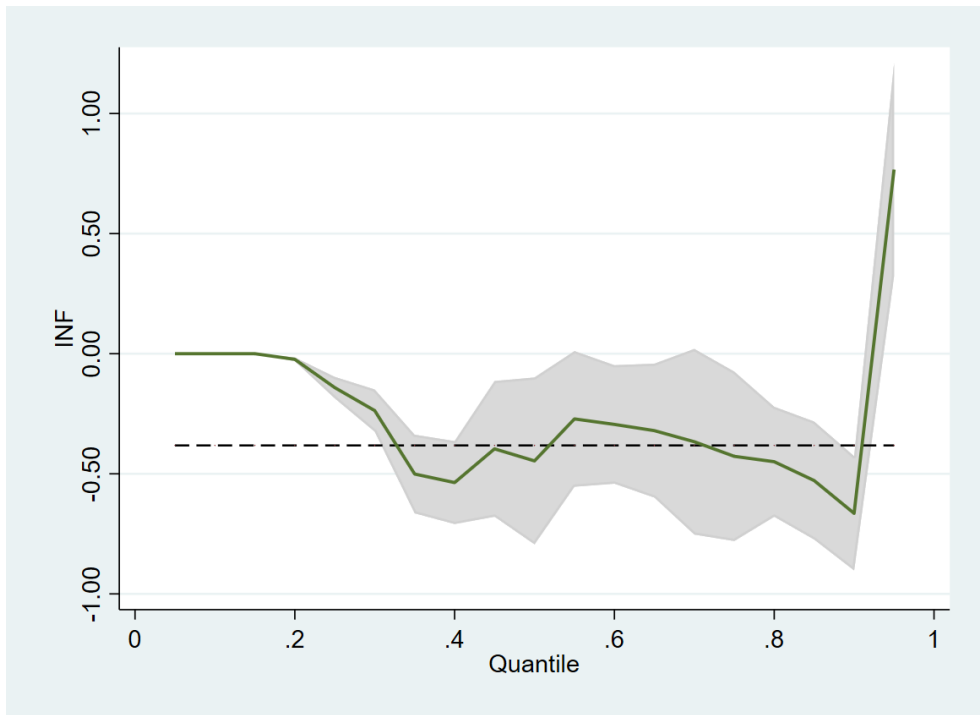
Source: Constructed by Author

Figure 4.7: Quantile Regression Graph for GDPC and GE (DV=RE)



Source: Constructed by Author

Figure 4.8: Quantile Regression Graph for INF (DV=RE)



Source: Constructed by Author

4.3.3 Heterogeneity Analysis (FF)

Table 4.8 uses the interaction terms (MBT_DEV and MBV_DEV) to explore the effect of FinTech on FF in the case of developed and developing countries. For developed countries, the number of transactions is statistically significantly negatively related to the consumption of fossil fuel, especially in certain upper and middle quantiles (30-40th, 60-80th). For instance, the value of MBT is -0.0000915 in the 60th quantile and -0.0000957 in the 80th quantile, both of which are statistically significant at the 99% confidence level. This means that in developed countries, the actual use of FinTech diminishes the dependence on fossil fuel because less fossil fuel is used to meet digital services as it is done in many processes in a digitally efficient way and the processes are energy intensive. However, the value of the transactions in developed countries (MBV) is, across the majority of the distribution, statistically insignificant in its effect on consumption of fossil fuel as shown in its coefficients such as 0.00152 in the median which is statistically insignificant.

The interaction (MBT_DEV) is, across the majority of the distribution, statistically significantly insignificant with the one exception of the 80th quantile where it does exhibit a positive coefficient of 0.0000472 at the 99% confidence level. This means that the energy savings from the adoption of FinTech are uniformly across all economies with no regard to their wealth.

In lower to middle quantiles, however, the coefficient for the interaction of development status and transaction value (MBV_DEV) shifts to positive, statistically and otherwise. At the lower bound quantile (20th), the model estimates the coefficient at 0.0315, which is considerable, and offering even more statistically at the 30th

quantile where the point estimate is 0.0289, at 95, and 99 percent, respectively. In contrast to developed countries where the scale of financed activities literally does not matter to the environment, in less developed, transiting, or otherwise emerging countries, the poured in finances fuel the environmental degradation through a heightened consumption of fossil fuels. This predilection is more pronounced in countries with a lower economic status and lower consumption of fossil fuels. There is adequate support for the conclusion derived from the quantile plots that show the countries are on different development levels. In quantiles that are relatively lower, the countries are for the most part developing and the positive spike is from the transactions to volumes on fuel developed in the economy, at stability upon zero for the upper quantiles.

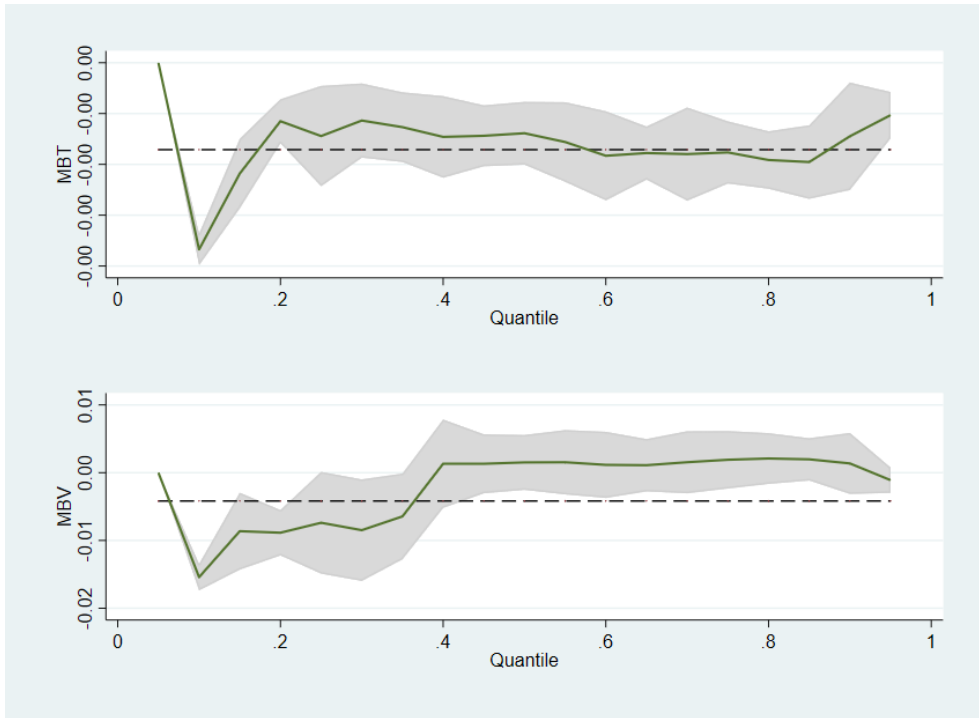
These results support hypothesis **H3**. The statistically significant interaction of the MBV_DEV at the 10th, 20th, and the 30th, or associated with the 60th quantiles, and the MBT_DEV at the 80th quantile run supports the interpretation that the phenomenon of FinTech stream is not uniformly global in all countries, thus it is also environmentally consumptive, not in the so much of a unified way.

Table 4.8: Panel Quantile Regression of MBT, MBV, moderating variable, interaction variable and control variables on FF

Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Dependent	FF	FF	FF	FF	FF	FF	FF	FF	FF
MBT	-0.000184 (0.000299)	-0.0000575 (0.0000901)	-0.0000569*** (0.0000125)	-0.0000730*** (0.0000159)	-0.0000693 (0.0000887)	-0.0000915*** (0.0000341)	-0.0000899*** (0.0000141)	-0.0000957*** (0.00000574)	-0.0000723 (0.0000700)
MBV	-0.0154* (0.00790)	-0.00886 (0.00620)	-0.00848 (0.00552)	0.00132 (0.00636)	0.00152 (0.00697)	0.00115 (0.00316)	0.00154 (0.00256)	0.00209 (0.00186)	0.00137 (0.00557)
DEVS	-57.93* (30.24)	-57.15*** (5.572)	-26.35*** (6.596)	-5.440 (3.737)	-2.365 (4.278)	0.988 (3.518)	4.576 (3.151)	5.611* (3.241)	3.938 (5.703)
MBT_DEV	0.000177 (0.000298)	0.0000239 (0.0000915)	-0.0000239 (0.0000241)	0.00000543 (0.0000329)	-0.00000429 (0.0000890)	0.0000165 (0.0000396)	0.0000319 (0.0000252)	0.0000472*** (0.0000106)	0.0000295 (0.0000755)
MBV_DEV	0.0182** (0.00868)	0.0315** (0.0152)	0.0289*** (0.00682)	0.00948 (0.00725)	0.00858 (0.00780)	0.00679* (0.00389)	0.00423 (0.00381)	-0.000262 (0.00221)	-0.000724 (0.00613)
CO2	0.0259* (0.0143)	0.0261*** (0.00371)	0.0145** (0.00634)	0.0186*** (0.00591)	0.0164*** (0.00103)	0.0141** (0.00596)	0.0108*** (0.00407)	0.00590*** (0.000368)	0.0155*** (0.00548)
FDI	0.0533 (0.129)	0.0531 (0.0325)	0.0594*** (0.0225)	0.0620* (0.0346)	0.0530** (0.0223)	0.0382 (0.0239)	0.0279*** (0.00562)	0.00893 (0.0125)	0.00267 (0.00720)
GDPc	-0.0000917 (0.000139)	-0.000464* (0.000243)	-0.000474*** (0.0000233)	-0.000439*** (0.0000701)	-0.000400*** (0.000136)	-0.00000989 (0.000117)	0.0000396 (0.0000471)	-0.0000313 (0.0000268)	-0.0000949* (0.0000552)
GE	8.643** (3.477)	14.62*** (5.090)	16.10*** (1.407)	16.86*** (2.553)	13.54*** (3.199)	0.963 (3.037)	-0.0501 (1.905)	2.132** (0.985)	2.089 (2.207)
INF	0.0261 (0.123)	0.00634 (0.694)	0.669 (0.439)	0.403** (0.180)	0.483** (0.207)	0.322** (0.128)	0.169 (0.162)	0.0766 (0.0555)	0.0288 (0.0402)
_CONS	57.89* (30.78)	64.89*** (3.660)	64.75*** (2.327)	62.62*** (1.783)	66.74*** (4.033)	71.89*** (3.422)	74.26*** (2.953)	81.69*** (3.323)	88.20*** (5.977)
Observations	560	560	560	560	560	560	560	560	560

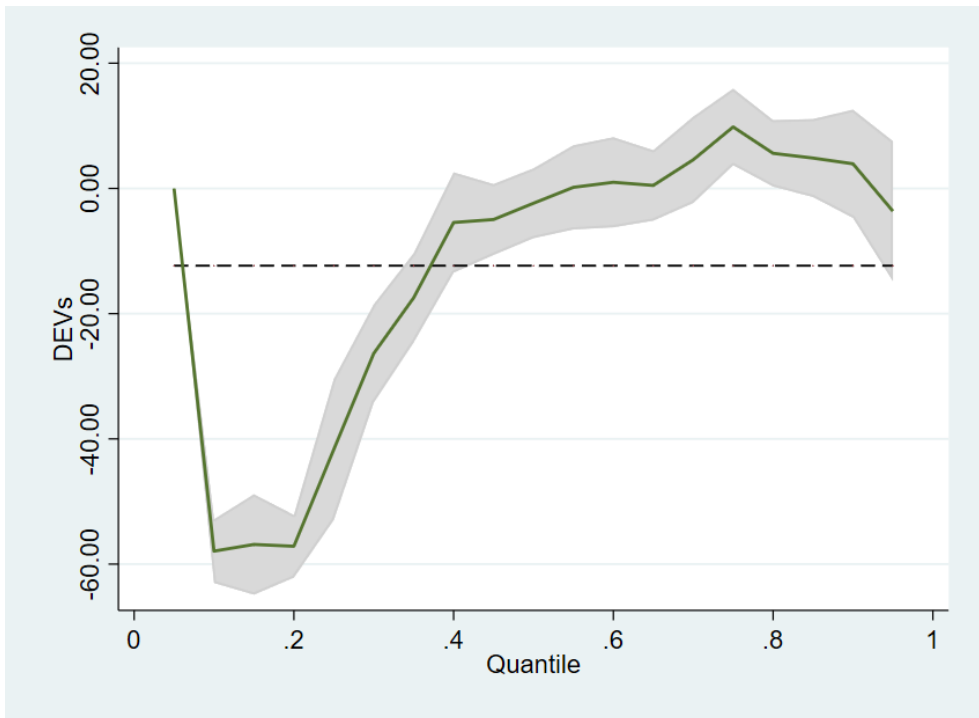
Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Source: Own Construction

Figure 4.9: Quantile Regression Graph for MBT and MBV (DV=FF, with DEVS)



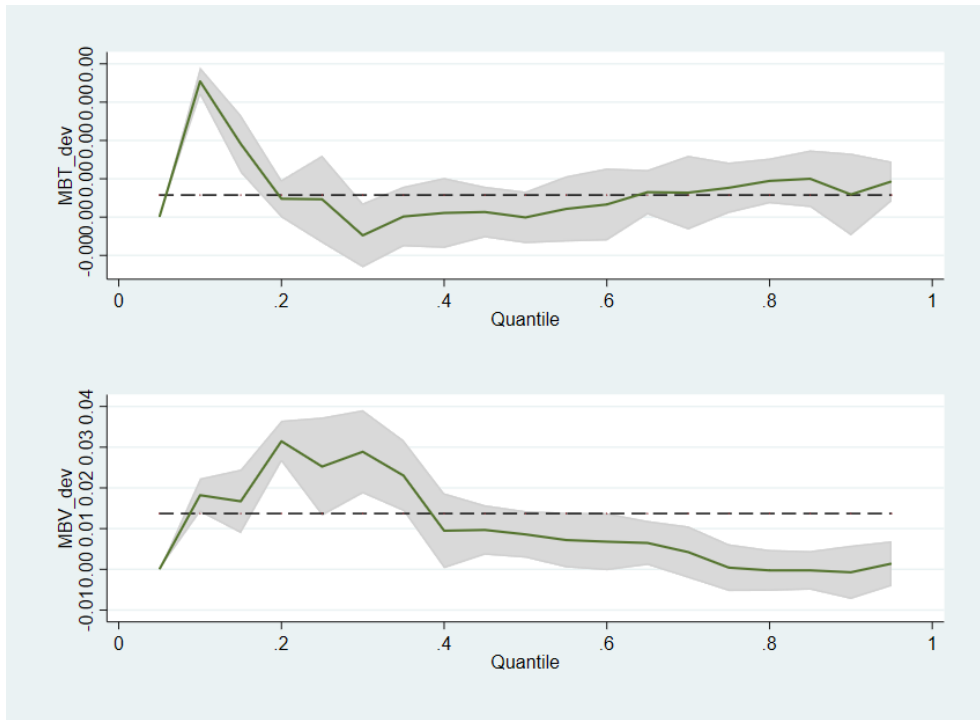
Source: Constructed by Author

Figure 4.10: Quantile Regression Graph for DEVS (DV=FF, with DEVS)



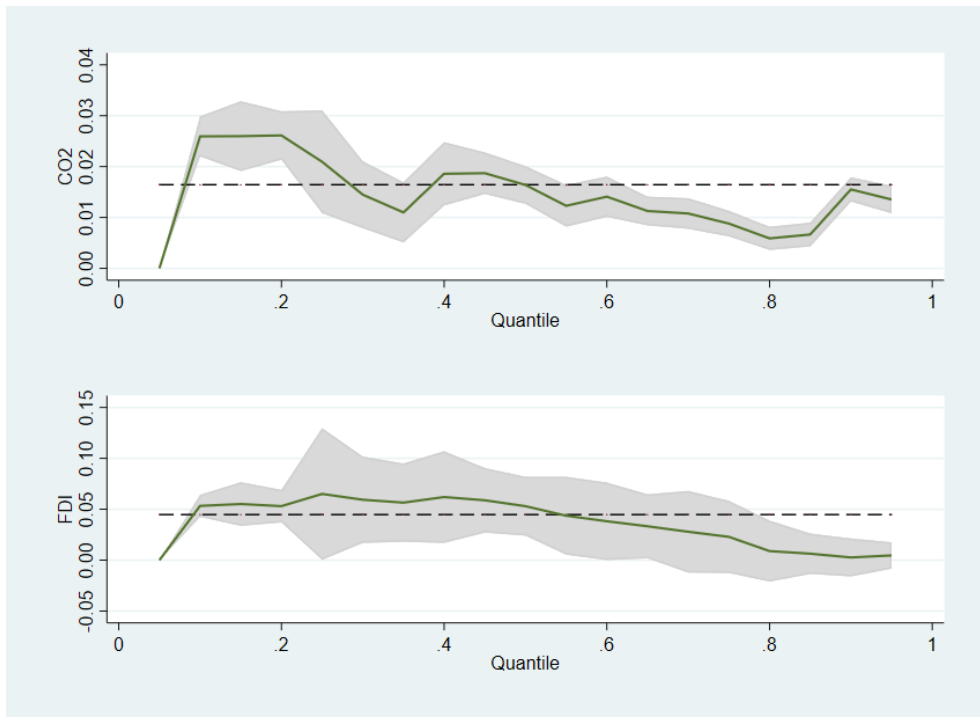
Source: Constructed by Author

Figure 4.11: Quantile Regression Graph for MBT_DEV and MBV_DEV (DV=FF, with DEVS)



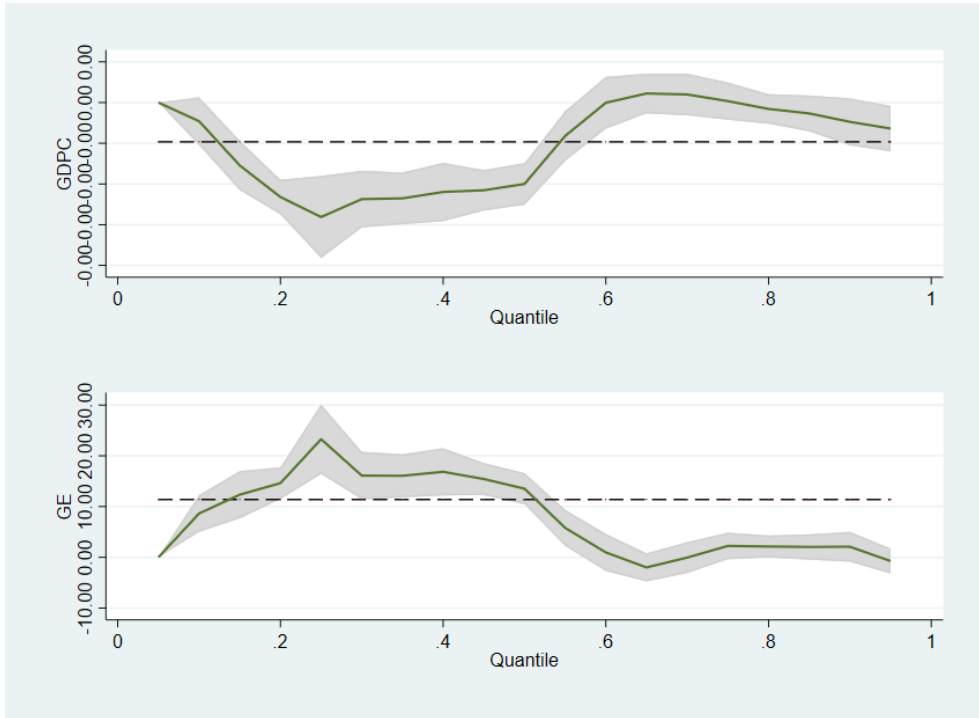
Source: Constructed by Author

Figure 4.12: Quantile Regression Graph for CO2 and FDI (DV=FF, with DEVS)



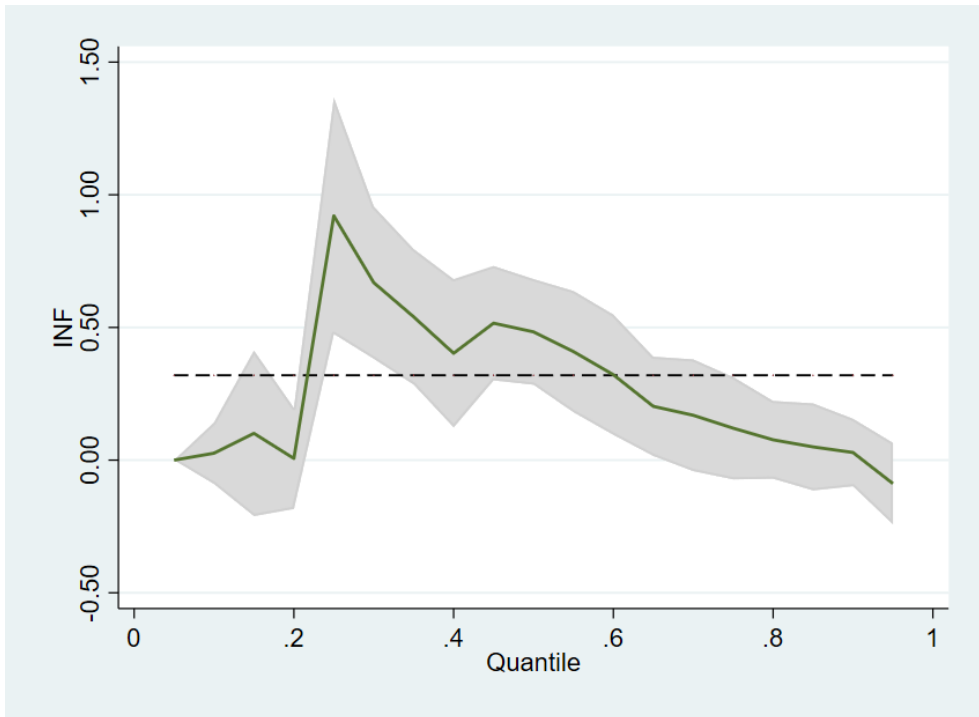
Source: Constructed by Author

Figure 4.13: Quantile Regression Graph for GDPC and GE (DV=FF, with DEVS)



Source: Constructed by Author

Figure 4.14: Quantile Regression Graph for INF (DV=FF, with DEVS)



Source: Constructed by Author

4.3.4 Heterogeneity Analysis (RE)

Table 4.9 shows the interactions terms for the impact FinTech has on renewable energy consumption (RE). The findings reveal that on the whole, for the developed world, FinTech has no statistically relevant effect on the consumption of renewable energy. Both MBT and MBV across the entire distribution (10th to 90th quantiles) show statistically irrelevant coefficients. This indicates that of the advanced economies, neither the rate at which digital platforms are utilized, nor the dollars flowing through these systems, are substantial predictors of the rate at which renewable energy is consumed.

More nuanced effects emerge when looking at each of these countries individually. The statistical insignificance of transaction frequency (MBT_DEV) interactions in all quantiles indicates there are no differences in the impacts of FinTech in advanced and developing countries. In contrast, the interactions pertaining to transaction value (MBV_DEV) are quite significantly and negatively valued for upper half of the distribution. In particular, the coefficients between the median and the 90th quantile are statistically significantly valued at the 99th confidence level, ranging from -0.00715 to -0.0121. As seen in Figure 4.17, the trajectory of the coefficient sharply decreases and becomes significantly negative with greater consumption of renewable energy. This means that there is a reduction in the proportion of renewables in the energy mix, with greater volumes of financial transactions in developing countries with a moderate to high level of renewable energy.

Concerning the control variables, GE is positively influencing renewable energy, especially at the centre of the distribution (30th to 70th quantiles) where it hits the peak value of 8.857 at the 99% confidence benchmark at the median. Meanwhile, Foreign Direct

Investment (FDI) displays a considerable negative association with renewable energy on the upper quantiles, indicating that greater foreign inflows at these particular quantiles co-exist with diminished renewable energy consumption. The development status variable (DEVS) last exhibits a positive and significant main effect on the upper quantiles. Ceteris paribus, under the upper quantiles, developing countries tend to depend on a larger share of renewables while the advanced countries tend to depend on a small share.

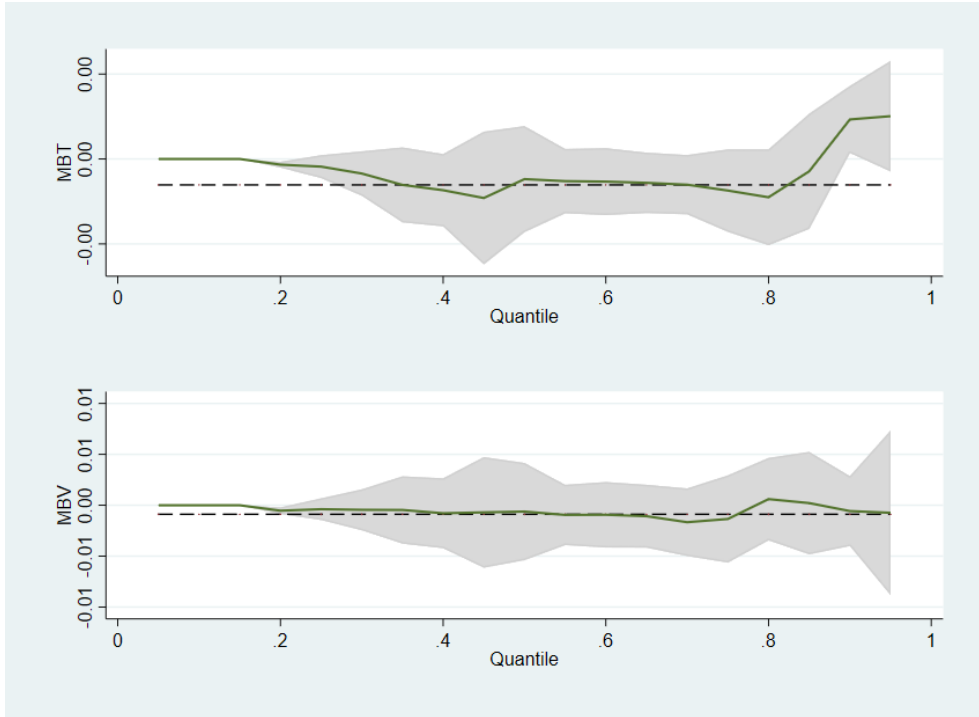
These results corroborate **H4**. The interaction term MBV_DEV attains statistical significance in the upper quantiles, suggesting that the effect of FinTech, particular in the capital, on the consumption of renewable energy is heterogenous for developed and developing countries. The effect is negative in developing countries while in developed countries, it is of no effect.

Table 4.9: Panel Quantile Regression of MBT, MBV, moderating variable, interaction variables and control variables on RE

Quantile	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
Dependent	RE	RE	RE	RE	RE	RE	RE	RE	RE
MBT	0 (.)	-0.0000333 (0.0000191)	-0.0000856 (0.0000102)	-0.0000184 (0.0000113)	-0.0000118 (0.0000148)	-0.0000133 (0.00000890)	-0.0000151 (0.0000387)	-0.0000225 (0.0000635)	0.0000233 (0.0000333)
MBV	0 (.)	-0.000535 (0.00163)	-0.000447 (0.00305)	-0.000784 (0.00356)	-0.000617 (0.000733)	-0.000933 (0.00205)	-0.00166 (0.00274)	0.000604 (0.00371)	-0.000571 (0.00166)
DEVS	0 (.)	-1.076 (2.045)	-2.420 (3.411)	-2.699 (3.844)	5.062* (2.720)	8.767*** (2.405)	14.55*** (3.268)	14.40*** (4.934)	18.25*** (3.855)
MBT_DEV	0 (.)	0.0000258 (0.0000195)	0.0000209 (0.0000103)	0.0000292 (0.0000121)	-0.0000271 (0.0000164)	-0.0000644 (0.0000106)	-0.0000101 (0.0000395)	-0.0000131 (0.0000666)	-0.0000274 (0.0000470)
MBV_DEV	0 (.)	0.000608 (0.00187)	0.000282 (0.00313)	-0.00106 (0.00383)	-0.00715*** (0.00218)	-0.00880*** (0.00231)	-0.0104*** (0.00385)	-0.0108* (0.00578)	-0.0121*** (0.00344)
CO2	0 (.)	0.0000911 (0.000566)	0.000631 (0.00128)	0.0000223 (0.00234)	-0.00113 (0.00156)	-0.00204 (0.00307)	-0.000249 (0.00291)	-0.00283 (0.00198)	-0.00487* (0.00279)
FDI	0 (.)	0.0136 (0.0155)	0.00140 (0.00958)	-0.00924 (0.0269)	-0.0277 (0.0195)	-0.0300*** (0.00735)	-0.0259* (0.0155)	-0.0448** (0.0190)	-0.0586*** (0.0192)
GDPc	0 (.)	-0.0000153 (0.0000376)	-0.0000924* (0.0000538)	-0.000170*** (0.0000240)	-0.000150** (0.0000698)	-0.000133*** (0.0000467)	-0.0000754 (0.0000537)	-0.0000616 (0.000123)	0.000101 (0.0000836)
GE	0 (.)	0.418 (0.832)	3.257** (1.368)	5.443*** (1.844)	8.857*** (1.975)	8.850*** (1.584)	7.168*** (2.017)	2.790 (3.719)	-4.488 (2.930)
INF	0 (.)	-0.0420 (0.107)	-0.265* (0.155)	-0.463** (0.198)	-0.483** (0.207)	-0.285 (0.193)	-0.387*** (0.0978)	-0.520*** (0.158)	-0.679 (0.477)
_CONS	0 (.)	1.617 (2.131)	7.326** (3.598)	15.48*** (3.378)	16.45*** (2.154)	17.68*** (1.760)	18.96*** (2.852)	27.94*** (4.796)	35.70*** (3.025)
Observations	560	560	560	560	560	560	560	560	560

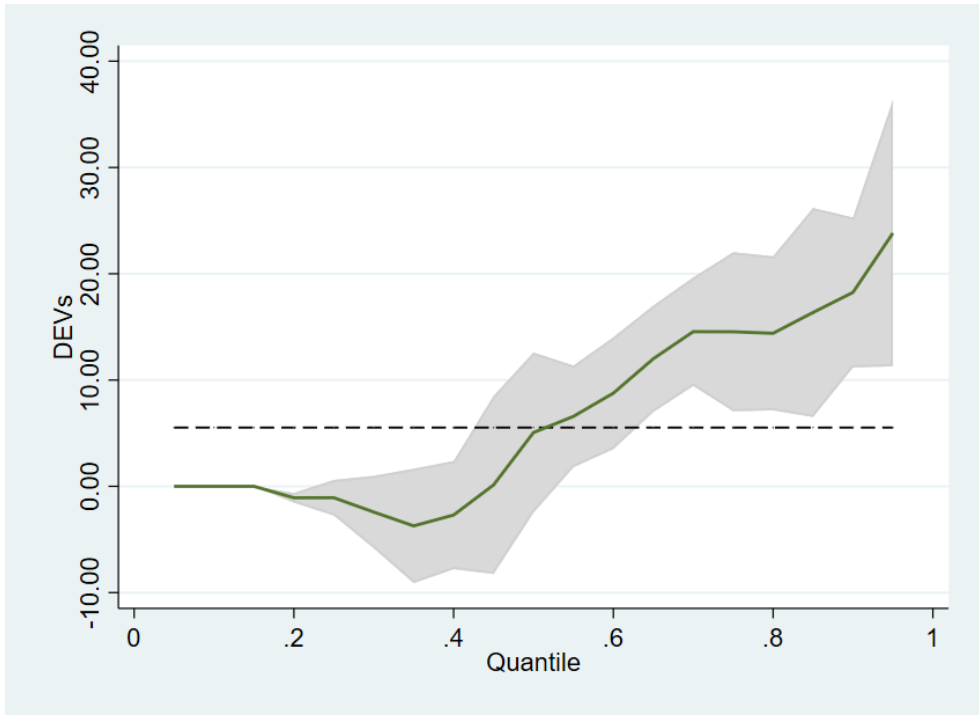
Note: Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. The 10th quantile results are omitted due to the prevalence of zero or near-zero values in the dependent variable at this distribution level, which prevented model convergence. Source: Own Construction

Figure 4.15: Quantile Regression Graph for MBT and MBV (DV=RE, with DEVS)



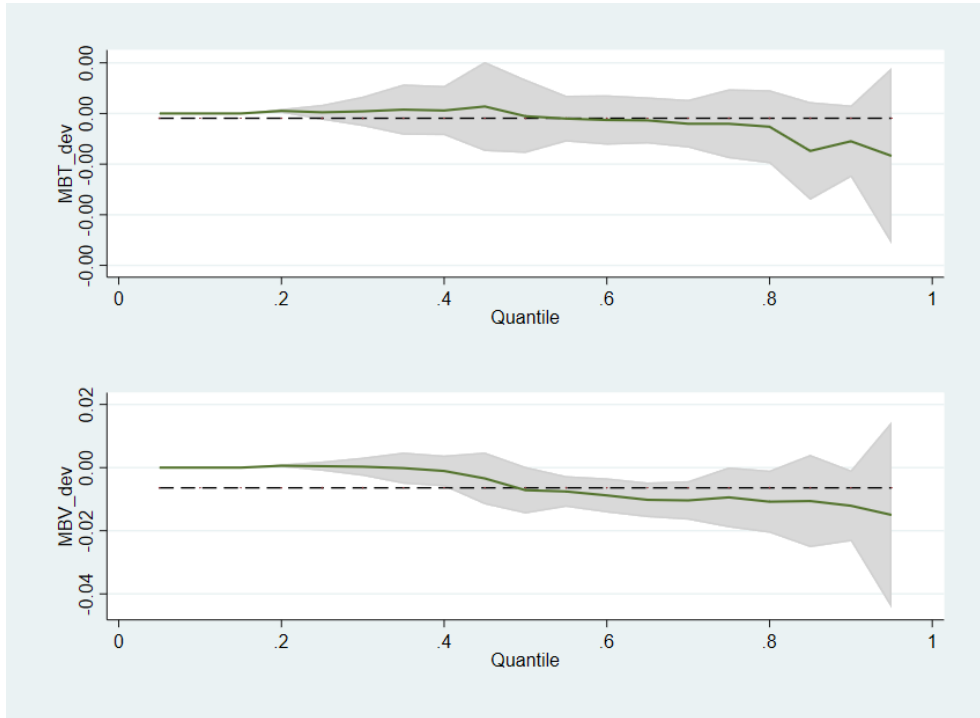
Source: Constructed by Author

Figure 4.16: Quantile Regression Graph for DEVS (DV=RE, with DEVS)



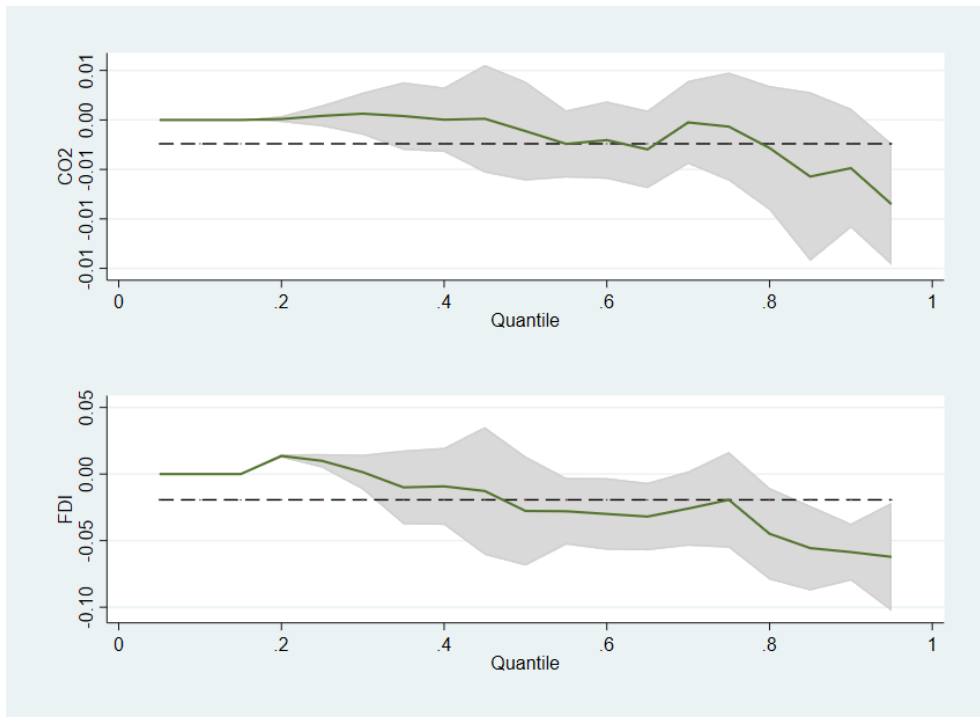
Source: Constructed by Author

Figure 4.17: Quantile Regression Graph for MBT_DEV and MBV_DEV (DV=RE, with DEVS)



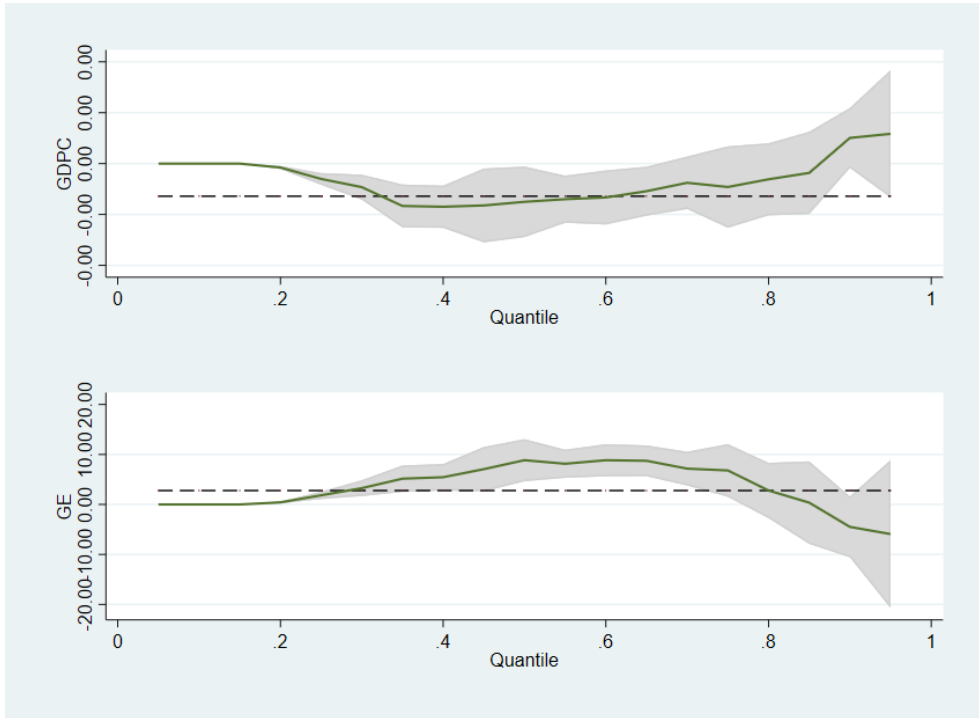
Source: Constructed by Author

Figure 4.18: Quantile Regression Graph for CO2 and FDI (DV=RE, with DEVS)



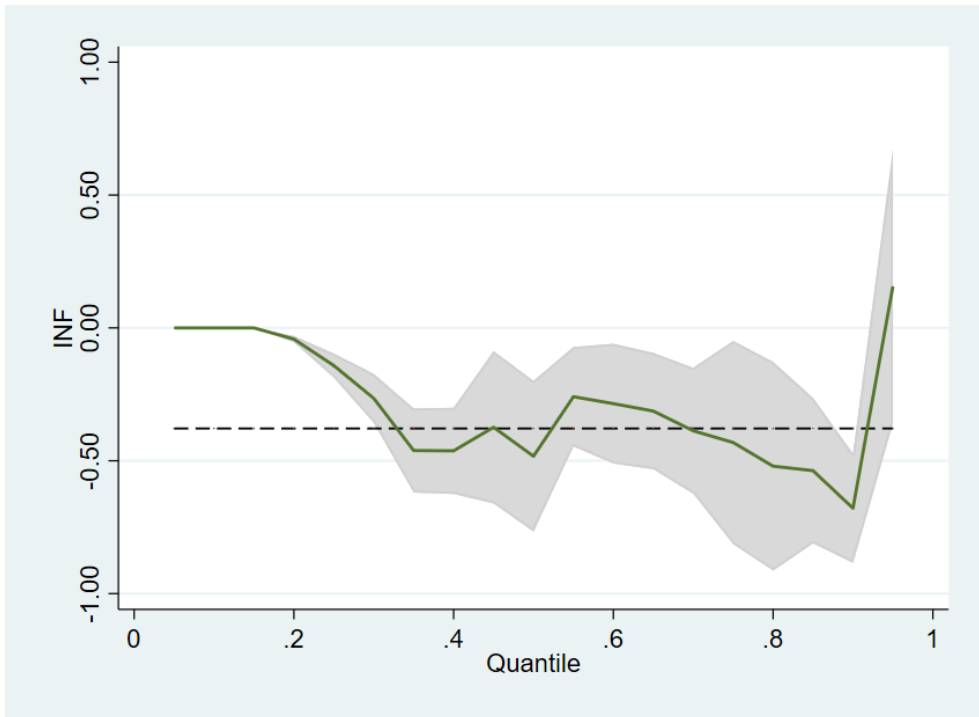
Source: Constructed by Author

Figure 4.19: Quantile Regression Graph for GDPC and GE (DV=RE, with DEVS)



Source: Constructed by Author

Figure 4.20: Quantile Regression Graph for INF (DV=RE, with DEVS)



Source: Constructed by Author

4.4 Summary of the Chapter

Table 4.10 Summary of Chapter 4

Hypothesis	Supported by Results?
H1: The magnitude of FinTech's impact on fossil fuel energy consumption differs across quantiles of the consumption distribution.	Yes
H2: The magnitude of FinTech's impact on renewable energy consumption differs across quantiles of the consumption distribution.	Yes
H3: The effect of FinTech on fossil fuel energy consumption differs between developed and developing economies.	Yes
H4: The effect of FinTech on renewable energy consumption differs between developed and developing economies.	Yes

Source: Constructed by author

CHAPTER 5: CONCLUSION

5.0 Introduction

This section is the conclusion of the study. It encompasses the discussion of results, the implications and novelty of the study. This chapter ends with the limitations and recommendations for the study.

5.1 Discussion of Results

5.1.1 Baseline Results on FF (Results for Research Question 1)

The first observations about the consumption of fossil fuels point out that the two FinTech proxies are affected quite differently. Digital transactions (MBT) assist in mitigating dependence on fossil fuels. On the other hand, the amount of money being transacted (MBV) fuels the dependence. This discrepancy can be understood considering Ecological Modernization Theory, especially in the relation to the tension between “dematerialization” and “rebound effect”.

The adverse effect of MBT on fossil fuel consumption implies that the “dematerialization” effect is a direct result of FinTech in Retail being widely adopted (as stated in numerous publications). Digital banking, for instance, diminishes the need for customers to travel to bank branches and thus, reduces the need to physically travel to a banking branch (Ashta, 2023a; M. Li et al., 2025). It also removes the necessity for paper and cash to circulate within a system due to the absence of manual paper processes. FinTech, by reducing physical activities, which should be supplemented by operational efficiencies, creates unplanned efficiencies in a system (Lu et al., 2023; Udeagha &

Muchapondwa, 2023). This is in line with the expected efficiencies FinTech is supposed to create. A transacted physical banking activity, once shifted to a digital medium, translates to reduced carbon-intensive activities. This explains the observed negative coefficient across quantiles.

Conversely, the relationship between MBV and fossil fuel consumption illustrates the “rebound effect”. FinTech innovation has enhanced efficiency and ease in the movement of capital and increases in industrial consumption and activity. As of now, the fossil fuel sector still substantially dominates the global energy mix (Vo et al., 2023). Thus, the movement of more capital increases financing of the fossil fuel economy. In this regard, FinTech is an “economic growth accelerator”. It minimizes the friction involved in capital mobilization, providing a quicker channelling of capital to fuel oil, gas, and coal-dependent industries (Chien et al., 2024; Khan et al., 2024a). This validates the “carbon curse” phenomenon described in the literature. It argues the availability of finance provides a greater incentive to utilize fossil fuels, which are cheaper, at the expense of the more expensive and greener alternatives. The results satisfactorily answer the first research objective (RO1) regarding the influence of FinTech on fossil fuel consumption at varying energy consumption quantiles, although the relationship between the quantiles did demonstrate minor, yet noticeable, changes.

5.1.2 Baseline Results on RE (Results for Research Question 2)

The baseline results for renewable energy are quite troubling. Rather than spurring developments of renewable energy shares, it seems that the FinTech advancements are more of a barrier. Both MBT and MBV variables demonstrate a negative correlation with the consumption of renewable energies. This is contrary to the Sustainable Finance Theory (SFT). The SFT argues that the investments with the aid of financial innovations are expected to support and promote long term sustainability. The negative coefficients, however, suggest that the digital financial sphere has "brown bias" meaning that it is more oriented towards the brown sectors of the economy which are carbon extensive and more stable than the green (Papoutsi et al., 2021).

There are two possible explanations as to why FinTech may impact on shares of renewable energies negatively. The first of these is the rebound effect of consumption generated by zero friction transactions. FinTech facilitates the ease of spending which lowers the costs and hurdles associated with it (Majeed et al., 2023). For example, financing the purchase of energy-consuming consumer durables becomes more accessible with instalment plans offered on digital finance platforms. This increases overall demand for the associated energy and other goods and services. The ease and accessibility of spending, fuels this effect rather than promoting saving and the associated investment (Lange et al., 2020). The lack of a green national power grid exacerbates the digital consumption of services as it increases the output of coal fired power plants. Furthermore, the energy required to sustain the digital infrastructure for dispersed online activities is significant and will likely increase the associated CO₂. This results in a more significant consumption of energy and thus reduces the proportion of renewables in the overall energy mix (Ahmad et al., 2024; Okere et al., 2025)

The second mechanism posited here concerns the environmental costs associated with the construction of the digital infrastructure itself. The growth of the digital economy needs an exponential amount of energy (Guo & Yin, 2024; Y. Zhang et al., 2024). Data centres, servers and entire blockchain networks operate with voracious appetites for electricity. The expansion of the sector incurs a quintessential trade-off when the electricity powering these FinTech networks is of fossil fuel origin. This is consistent with the findings by Okere et al. (2025). They pointed out that the quality of the environment and the compromises made in the context of FinTech stem from the excessive consumption of digital infrastructure. This also corroborates the critique made by Dabbous et al. (2025) concerning the enormous energy demand of cryptocurrencies severely restricting the potential for an energy transition. The findings address the second research objective (RO2) focusing on assessing the effects of FinTech on the consumption of renewable energy. The negative coefficient on transaction volume becomes more pronounced with an increase in consumption of renewables. Hence, the quantum of impact FinTech is able to exert is not uniform and is more amplified in certain quantiles within the distribution of consumption.

The characteristics regarding governing capacity show the chronological specifics around the energy transition more thoroughly. The findings suggest that responsible and effective governance encourages the consumption of fossil fuels in the early stages, lower quantiles. However, as consumption peaks, it becomes insignificant and/or negative. Considering that in the early stages of development, effective governments focus on the construction of economic growth stimulating infrastructure such as roads, bridges, and power grids, which are highly carbon intensive (Korkut Pata et al., 2025). The baseline results indicate that for many economies, there are still heavy

lacking Governance in the infrastructure sphere. The more effective the Governance, the more fossil fuel is consumed. Only after reaching the saturation point does governance shift focus to regulation, doing more with less (Hayaloglu et al., 2025; Wen et al., 2022).

5.1.3 Heterogeneity Analysis on FF (Results for Research Question 3)

The results from the heterogeneity model for fossil fuel energy consumption reveals an important similarity between the developed and developing economies. The transaction frequency interaction term (MBT_DEV) proves to be statistically non-significant in most quantiles. This confirms that dematerialization discussed in the baseline model discussion is not specific to a certain economic context. Instead, it is a universal phenomenon.

As mentioned in the baseline discussion, the transformation of transactions into a digital environment saves mechanical power due to dematerialization. The insignificant interaction term proves that this substitution of physical activity occurs in developing nations just as it does in developed ones. This proves optimization role of retail FinTech to be consistent globally. It reduces the energy consumption level of the daily financial operations regardless of the global economic set-up. The decrease in the consumption of fossil fuel energy is universal and is anticipated and does not contradict the previous research(Ashta, 2023b; M. Li et al., 2025).

In contrast to transaction frequency, the volume of transactions (MBV) shows the structural divergence hypothesized in the “Rebound Effect” discussion from the baseline discussion. For developed economies, the impact of transaction volume on fossil fuel energy consumption is

statistically insignificant. This might suggest that these economies have achieved decoupling, where financial growth has detached from environmental degradation. In developed economies, financial growth is likely to expand towards service sectors which are less reliant on fossil fuel usage (Croutzet & Dabbous, 2021; Teng & Shen, 2023). Such industries do not require huge energy requirements to add value (Awosusi et al., 2022).

However, for developing economies the interaction term (MBV_DEV) is significant and positive at the lower quantiles. It implies that these nations are the main contributors to the rebound effect that is evident in the outcomes of the base case. FinTech is utilized in developing nations to raise money to industrialize and develop infrastructure (Rahman et al., 2025b; Udeagha & Muchapondwa, 2023). These are carbon-intensive activities. Consequently, FinTech accelerates the expansion of the carbon-heavy industrial base in developing nations rather than optimizing a mature service economy.

These findings successfully address the third Research Objective (RO3). They confirm that the influence of FinTech on fossil fuel consumption differs significantly between developed and developing economies. Furthermore, the results validate **H3**. The statistical significance of the interaction term proves that while developed nations have decoupled financial volume from pollution, developing nations have not.

5.1.4 Heterogeneity Analysis on RE (Results for Research Question 4)

The heterogeneity results of renewable energy (Table 4.9) explain the Brown Bias that we discussed in the introductory discussions. The interaction term (MBV_DEV) has a strong negative correlation with renewable energy shares in developing economies indicating that the brown bias toward renewable is not a universal vice of FinTech, but rather a particular quality of developing countries. This finding aligns with Chien et al. (2024) and Khan et al. (2024a) who also discovered FinTech driving the carbon curse in developing regions.

In the last section, it was argued that digital capital prefers established sectors. The heterogeneity analysis confirms this crowding out effect on renewables is specific to the developing context. In these economies, the demand for cheap and reliable energy to fuel rapid growth is high (Okere et al., 2025). Fossil fuels currently meet this demand more easily than renewables. FinTech increases the efficiency of capital allocation. Unfortunately, market forces in developing regions currently allocate this capital toward the most profitable and readily available energy sources (Khan et al., 2024b). This often means more fossil fuels energy consumption. The growth is imbalanced as the financial volume increases, concentrating on the fossil fuel industry and reducing the national mix of renewables.

This evaluation addresses the fourth research objectives (RO4) concerning the relative effects of FinTech on the consumption of renewables. It strongly substantiates **H4**. The findings indicated the impact of FinTech is neutral on renewables in the developed world and in the developing the impact is rather evidently negative. It underlines the need for targeted policy measures to redirect digital capital in the developing countries.

5.2 Implications

5.2.1 Theoretical Implications

This empirical study may provide evidence that contradicts the Sustainable Finance Theory (SFT) which suggests that financial innovation goes hand in hand with environmental sustainability. Contrary to the narrative of “win-win” situations, the empirical evidence shows that increasing the volume of digital transactions also increases the proportion of non-renewable energy in developing countries. This underlines the existence of the FinTech ecosystem's “Brown Bias” and therefore, SFT should be revised in that financial digitalization should not be assumed to be automatically green. SFT should incorporate the need for regulation to address the market inefficiencies that are spilling or “shadow” public finance and need to direct investments in public finance to renewable energy.

The findings also contradict the validity of “one-size-fits-all” theoretical models in analysing the relationship of FinTech with sustainability. This study shows that the impacts FinTech on the environment are strikingly different between advanced and developing countries. Developed countries are in what may be termed an “optimization” stage of development in that there is an effective decoupling of financial from the volume of pollution. Developing countries on the other hand are in an “accumulation” stage where FinTech is sustaining carbon-industrialized and thus, the needed dynamic for further research is the application of heterogeneity-robust approaches such as panel quantile regression.

5.2.2 Policy Implications

The “Brown Bias” present in most developing economies necessitates the creation of specialized Green Taxonomies pertinent to digital lending frameworks (H. Zhang et al., 2024), Regulation of “Digital Lending” is a peculiar, yet necessary, function of Central Banks and Financial Authorities. FinTech providers ought to be compelled to reveal the environmental costs of the projects that are funded (M. Li et al., 2025; Yang et al., 2021). From this perspective, accountability and transparency in the offered funds will be guaranteed. Furthermore, Digital Loans intended for Renewable Energy projects will be made accessible, as the Market Participants will be encouraged by the Government through Tax and Interest Incentives (Dabbous et al., 2025; Khan et al., 2024a). These regulations are designed to FinTech “Grants” and thus, “correct” the use of FinTech to promote the carbon intensive industrialization in the name of climate change.

At the same time, global development organizations ought to streamline the transfer of “Green FinTech” from the Global North. Some of these entities have demonstrated successful financial decoupling. Through the transfer of technical skills, these organizations can help developing countries bypass the carbon-accumulating stage of development. The focus of the strategies should be on the application of particular green innovations as opposed to the use of FinTech to finance traditional industry growth. For instance, P2P energy trading with FinTech and renewable energy (Delina et al., 2023). This way, developing countries can use the efficiency of FinTech to streamline the management of their energy grids (Sreenu, 2024). Nevertheless, these developing countries should be mindful of the potential negative impact such a technology transfer could have.

5.3 Novelty of the Study

The current paper examines a novel approach to calculating the digital finance when dividing FinTech into two components, which are: Transaction Frequency (MBT) and Transaction Volume (MBV). Instead of observing large and single numbers or proxies in general such as internet penetration, the study employs two distinct measures to very distinctly differentiate other environmental impacts. The difference between the efficiency of digital adoption and the scale of money flows are distinguished. The findings show more frequent transactions appear to reduce the use of fossil fuel, whereas larger amounts actually increase it. That difference simply does not just come out when you apply the single variable model.

The study equally extends the methodology by involving Panel Quantile Regression (PQR) and combining the interaction terms with the economic development. Majority of the past research works tends to adhere to mean-based methods such as OLS or fixed effects where all cases are influenced equally. In this case, the study represents the variation in the impact in various regions of the distribution. It demonstrates that the FinTech has a varying impact on the environment at varying levels of consumption. FinTech also maximizes the economy in developed economies and concentrates it in poorer ones.

5.4 Limitations and Recommendations

While this study improves upon previous research by differentiating between transaction frequency (MBT) and volume (MBV), it still relies on a proxy that captures only the transactional aspect of FinTech. FinTech ecosystem is very large and includes crowdfunding, peer-to-peer (P2P) lending, green bonds, artificial intelligence and blockchain. The study might not comprehensively investigate the effect of niche innovation in the Green FinTech that are explicitly focused on sustainability by limiting the measure to mobile and internet banking. As a result, the outcomes indicate the effect of overall digital finance and not specific sustainable financial technologies.

To overcome this drawback, the future studies ought to focus on the representation of the entire range of the FinTech ecosystem through multidimensional indices that go beyond the transactional metrics to encompass the crowdfunding, P2P lending, and adoption of blockchain. In particular, it would be possible to introduce individual categories of Green FinTech innovations into the equation, like green bond issuance or AI-driven ESG systems, to be able to evaluate the technologies that are specifically aimed at sustainability

5.5 Summary of the Chapter

Table 5.0 Summary of Chapter 5

Conclusion

Research Objective 1: FT's impact on FF does differ across different levels of the FF consumption. Where usage of FT reduces FF while capital flow drives FF.

Research Objective 2: FT's impact on RE varies across the quantiles. As RE adoption increases, FT reduces RE at an increasing scale.

Research Objective 3: There is a difference in the impact of FT on FF between developed and developing economies, specifically for capital flows through FT. In developed economies, FT has decoupled from FF, while FT boosts FF in developing economies from country development.

Research Objective 4: There are differences in the impact of FT on RE among developed and developing economies, where capital flows negatively impact RE at the higher quantiles in developing economies. In developed countries FT and RE are not significantly related, while the capital flow from FT drives development in carbon-intensive sectors than renewables, showing "Brown Bias"

Implications

Theoretical Implication

1. Challenged Sustainable Finance Theory
2. Discovered the need for heterogeneity analysis between country groups and distributional heterogeneity of energy consumption

Political/Practical Implications

1. Addressing "Brown Bias"
 2. Emphasize importance of Green FinTech transfer from developed to developing economies
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Novelty

1. Dual-dimension proxy: capturing volume and value from FT
 2. Panel Quantile Regression
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Limitations

- The proxy of FinTech only captured the transactional side of FT, fail to account for technological advancements like Blockchain and AI side of FT.
 - Recommendations: future studies can utilize multidimensional measures for a more complete proxy for FT
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Source: Constructed by author

REFERENCES

- Adua, L., Clark, B., & York, R. (2021). The ineffectiveness of efficiency: The paradoxical effects of state policy on energy consumption in the United States. *Energy Research & Social Science*, 71, 101806. <https://doi.org/10.1016/J.ERSS.2020.101806>
- Ahmad, M., Pata, U. K., Ahmed, Z., & Zhao, R. (2024). Fintech, natural resources management, green energy transition, and ecological footprint: Empirical insights from EU countries. *Resources Policy*, 92, 104972. <https://doi.org/10.1016/J.RESOURPOL.2024.104972>
- Akono, E. B., & Kemezang, V. C. (2024a). How energy transition and fintech influence income inequality in Sub-Saharan Africa: Evidence from a panel-corrected standard error approach. *Next Energy*, 5, 100174. <https://doi.org/10.1016/J.NXENER.2024.100174>
- Akono, E. B., & Kemezang, V. C. (2024b). How energy transition and fintech influence income inequality in Sub-Saharan Africa: Evidence from a panel-corrected standard error approach. *Next Energy*, 5, 100174. <https://doi.org/10.1016/J.NXENER.2024.100174>
- Albaker, Y. (2024). DETERMINANTS OF FINANCIAL PERFORMANCE OF FINTECHS IN ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT COUNTRIES. *Corporate & Business Strategy Review*, 5(4), 8–19. <https://doi.org/10.22495/cbsrv5i3siart1>
- Alofaysan, H., Radulescu, M., Balsalobre-Lorente, D., & Si Mohammed, K. (2024). The effect of eco-friendly and financial technologies on renewable energy growth in emerging economies. *Heliyon*, 10(17), e36641. <https://doi.org/10.1016/j.heliyon.2024.e36641>
- Ashta, A. (2023a). How Can Fintech Companies Get Involved in the Environment? *Sustainability 2023, Vol. 15, Page 10675*, 15(13), 10675. <https://doi.org/10.3390/SU151310675>
- Ashta, A. (2023b). How Can Fintech Companies Get Involved in the Environment? *Sustainability 2023, Vol. 15, Page 10675*, 15(13), 10675. <https://doi.org/10.3390/SU151310675>
- Awosusi, A. A., Adebayo, T. S., Rjoub, H., & Wong, W.-K. (2022). How Do Financial Development and Renewable Energy Affect Consumption-Based Carbon Emissions? *Mathematical and Computational Applications 2022, Vol. 27, Page 73*, 27(4), 73. <https://doi.org/10.3390/MCA27040073>
- Buttel, F. H. (2000). Ecological modernization as social theory. *Geoforum*, 31(1), 57–65. [https://doi.org/10.1016/S0016-7185\(99\)00044-5](https://doi.org/10.1016/S0016-7185(99)00044-5)

- Butu, H. M., Nsafon, B. E. K., Park, S. W., & Huh, J. S. (2021). Leveraging community based organizations and fintech to improve small-scale renewable energy financing in sub-Saharan Africa. *Energy Research & Social Science*, 73, 101949. <https://doi.org/10.1016/J.ERSS.2021.101949>
- Carolan, M. S. (2004a). Ecological modernization theory:What about consumption? *Society and Natural Resources*, 17(3), 247–260. <https://doi.org/10.1080/0894120490270294>;JOURNAL:JOURNAL:US NR20;PAGE:STRING:ARTICLE/CHAPTER
- Carolan, M. S. (2004b). Ecological modernization theory:What about consumption? *Society and Natural Resources*, 17(3), 247–260. <https://doi.org/10.1080/0894120490270294>;JOURNAL:JOURNAL:US NR20;PAGE:STRING:ARTICLE/CHAPTER
- Central Bank, E., Piazzesi, M., Nber, S. &, & Schneider, M. (2022). *How unconventional is green monetary policy? * Melina Papoutsis*.
- Chien, F. S., Zhang, Y. Q., Lin, Z. Q., Lin, Y. C., & Sadiq, M. (2024). An integrated perspective on fintech, green innovation and natural resource rent: Evidence from Asia. *Resources Policy*, 92, 104945. <https://doi.org/10.1016/J.RESOURPOL.2024.104945>
- Croutzet, A., & Dabbous, A. (2021). Do FinTech trigger renewable energy use? Evidence from OECD countries. *Renewable Energy*, 179, 1608–1617. <https://doi.org/10.1016/J.RENENE.2021.07.144>
- Dabbous, A., Aoun Barakat, K., Ben Arfi, W., & Nammouri, H. (2025). The impact of environmental policy stringency and economic complexity on nations' energy transitions: The mediating role of fintech financing. *Energy Economics*, 147, 108540. <https://doi.org/10.1016/J.ENERCO.2025.108540>
- Delina, L. L., Lam, R. Y. H., Tang, W. S., & Wong, K. Y. (2023). Mapping the actor landscape of a future fintech-funded renewable energy ecosystem in Hong Kong. *Journal of Environmental Studies and Sciences*, 13(3), 419–427. <https://doi.org/10.1007/S13412-023-00839-4>
- Deng, Y., Cao, Z., & Yang, N. (2024). Understanding the nexus between fintech, natural resources, green investment, and environmental sustainability in China: A DYNARDL approach. *Resources Policy*, 91, 104900. <https://doi.org/10.1016/J.RESOURPOL.2024.104900>
- Dorfleitner, G., Hornuf, L., Schmitt, M., & Weber, M. (2017). FinTech in Germany. *FinTech in Germany*, 1–121. <https://doi.org/10.1007/978-3-319-54666-7>
- Erdem, M. (2025). An evaluation of incentive policy effects on solar power plant cost analysis: a comparative case study approach. *Energy*, 330, 136901. <https://doi.org/10.1016/J.ENERGY.2025.136901>

- FinTech and market structure in financial services: Market developments and potential financial stability implications - Financial Stability Board.* (n.d.). Retrieved November 14, 2025, from <https://www.fsb.org/2019/02/fintech-and-market-structure-in-financial-services-market-developments-and-potential-financial-stability-implications/>
- Frost, J. (2020a). *The economic forces driving fintech adoption across countries.* <https://www.bis.org/publ/work838.htm>
- Frost, J. (2020b). *The Economic Forces Driving Fintech Adoption Across Countries.* <https://papers.ssrn.com/abstract=3535904>
- Guo, Q., & Yin, C. (2024). Fintech, green imports, technology, and FDI inflow: their role in CO2 emissions reduction and the path to COP26: a comparative analysis of China. *Environmental Science and Pollution Research* 2024 31:7, 31(7), 10508–10520. <https://doi.org/10.1007/S11356-023-31732-W>
- Ha, L. T. (2024). Dynamic spill-over influences of FinTech innovation development on renewable energy volatility during the time of war in pandemic: A novel insight from a wavelet model. *Economic Analysis and Policy*, 82, 515–529. <https://doi.org/10.1016/J.EAP.2024.03.018>
- Hayaloglu, P., Recepoglu, M., & Cakir, M. A. (2025). Institutional Structure and Environmental Pollution: An Application within the Framework of the Environmental Kuznets Curve Hypothesis. *International Journal of Energy Economics and Policy*, 15(3), 230–238. <https://doi.org/10.32479/IJEEP.19337>
- Jangid, H., Bal, D. P., & Rao, N. V. M. (2025). Role of FinTech and technological innovation towards energy, growth, and environment nexus in G20 economies. *Scientific Reports* 2025 15:1, 15(1), 1–14. <https://doi.org/10.1038/s41598-025-02794-2>
- Karmaker, A. K., Rahman, M. M., Hossain, M. A., & Ahmed, M. R. (2020). Exploration and corrective measures of greenhouse gas emission from fossil fuel power stations for Bangladesh. *Journal of Cleaner Production*, 244, 118645. <https://doi.org/10.1016/J.JCLEPRO.2019.118645>
- Kashif, M., Pinglu, C., Ullah, A., & Qian, N. (2025). The impact of green finance and FinTech mechanisms on financial stability: evidence from advanced and emerging economies. *China Finance Review International*. <https://doi.org/10.1108/CFRI-07-2024-0393/1249151>
- Khan, S., Rahman, A. K. M. A., Saha, T., Alam, M. M., & Mahmood, H. (2024a). The role of Fintech in containing the carbon curse of natural resources: Evidence from resource-rich countries. *Resources Policy*, 90, 104733. <https://doi.org/10.1016/J.RESOURPOL.2024.104733>

- Khan, S., Rahman, A. K. M. A., Saha, T., Alam, M. M., & Mahmood, H. (2024b). The role of Fintech in containing the carbon curse of natural resources: Evidence from resource-rich countries. *Resources Policy*, *90*, 104733. <https://doi.org/10.1016/J.RESOURPOL.2024.104733>
- Koenker, R., & Hallock, K. F. (2001). Quantile regression. *Journal of Economic Perspectives*, *15*(4), 143–156. <https://doi.org/10.1257/JEP.15.4.143>
- Korkut Pata, U., Mohammed, K. S., Omeyr, C., Karlilar Pata, S., Aloffaysan, H., & Kartal, M. T. (2025). Scrutinizing the load capacity curve for a global perspective: The role of Fintech, government effectiveness and renewable energy. *Gondwana Research*, *138*, 104–117. <https://doi.org/10.1016/J.GR.2024.10.014>
- Lam, P. T. I., & Law, A. O. K. (2016). Crowdfunding for renewable and sustainable energy projects: An exploratory case study approach. *Renewable and Sustainable Energy Reviews*, *60*, 11–20. <https://doi.org/10.1016/J.RSER.2016.01.046>
- Lange, S., Pohl, J., & Santarius, T. (2020). Digitalization and energy consumption. Does ICT reduce energy demand? *Ecological Economics*, *176*, 106760. <https://doi.org/10.1016/J.ECOLECON.2020.106760>
- Lau, H. C., & Tsai, S. C. (2024). A Longitudinal Study on the History of Energy Transition and Its Implications on Global Decarbonization. *Energy and Fuels*, *38*(14), 13115–13130. https://doi.org/10.1021/ACS.ENERGYFUELS.4C01587/ASSET/IMAGES/LARGE/EF4C01587_0017.JPEG
- Levine, R., Aghion, P., Beck, T., Boyd, J., Carkovic, M., Demirguc-Kunt, A., Kareken, J., Laeven, L., Rajan, R., Smith, B., & Zingales, L. (2004). *Finance and Growth: Theory and Evidence*. <https://doi.org/10.3386/W10766>
- Li, M., Ahmed, M. U., Perera, S. C., & Wang, Y. (2025). Can Fintech Development Contribute to Mitigating the Greenhouse Effect? A Global Perspective. *IEEE Transactions on Engineering Management*, *72*, 1831–1842. <https://doi.org/10.1109/TEM.2025.3564950>
- Li, X., Jiang, Y., Xin, X., Nassani, A. A., & Yang, C. (2024). The asymmetric role of natural resources, fintech and green innovations in the Chinese economy. Evidence from QARDL approach. *Resources Policy*, *90*, 104731. <https://doi.org/10.1016/J.RESOURPOL.2024.104731>
- Li, Y., Liu, C. Y. N., Lao, U., & Dang, J. (2024). Navigating the path to environmental sustainability: Exploring the role of fintech, natural resources and green energy in Belt and Road countries. *Resources*

Policy, 88, 104485.

<https://doi.org/10.1016/J.RESOURPOL.2023.104485>

- Liang, H., & Punzi, M. T. (2025). The Effects of Financing Green and Brown Sectors: What Do Theories and Evidence Say? *Asian Economic Policy Review*.
<https://doi.org/10.1111/AEPR.70004;PAGE:STRING:ARTICLE/CHAPTER>
- Lin, H. H., Hsu, C. C., Wu, P. H., Shen, C. C., & Chen, G. H. (2024). Demystifying the interconnections among natural resources, fintech, green technologies, and sustainable environment in E-7 nations. *Resources Policy*, 90, 104698.
<https://doi.org/10.1016/J.RESOURPOL.2024.104698>
- Lin, H.-H., & Lee, Y.-K. (2025). The paradox of inclusive FinTech and the reality of exploitation: A case study of African countries. *African Journal of Political Science and International Relations*, 19(1), 1–13.
<https://doi.org/10.5897/AJPSIR2025.1524>
- Liu, Y., & Wang, K. (2024). Asymmetric impacts of coal prices, fintech, and financial stress on clean energy stocks. *Resources Policy*, 92, 104954.
<https://doi.org/10.1016/J.RESOURPOL.2024.104954>
- Lu, Y., Tian, T., & Ge, C. (2023). Asymmetric effects of renewable energy, fintech development, natural resources, and environmental regulations on the climate change in the post-covid era. *Resources Policy*, 85, 103902. <https://doi.org/10.1016/J.RESOURPOL.2023.103902>
- Ma, C. Q., Liu, X., Klein, T., & Ren, Y. S. (2025). Decoding the nexus: How fintech and AI stocks drive the future of sustainable finance. *International Review of Economics & Finance*, 98, 103877.
<https://doi.org/10.1016/J.IREF.2025.103877>
- Majeed, M. T., Mazhar, M., & Hussain, Z. (2023). Environmental Impact of Digital Financial Inclusion and Green Growth: Insights from Global Panel Data Analysis. *Pakistan Journal of Commerce and Social Sciences*, 17(3), 558–587.
<https://doi.org/10.64534/COMMER.2023.072>
- Oforu-Mensah Ababio, J., Yiadom, E. B., Mawutor, J. K. M., Tuffour, J. K., & Attah-Botchwey, E. (2024). Sustainable energy for all: the link between financial inclusion, renewable energy and environmental sustainability in developing economies. *International Journal of Energy Sector Management*, 18(5), 1088–1108.
<https://doi.org/10.1108/IJESM-07-2023-0012>
- Okere, K. I., Fasanya, I. O., & Dimnwobi, S. K. (2025). Environmental Impacts of Natural Resource and FinTech in Oil-Rich Economies: The Role of FinTech in Mitigating the Carbon Curse. *Natural Resources Forum*, 0, 1–20. <https://doi.org/10.1111/1477-8947.70021>

-
- Ozili, P. K. (2018). Impact of digital finance on financial inclusion and stability. *Borsa Istanbul Review*, 18(4), 329–340.
<https://doi.org/10.1016/J.BIR.2017.12.003>
- Papoutsis, M., Piazzesi, M., Nber, & May. (2021). *How Unconventional is Green Monetary Policy?*
- Powell, D. (2022). Quantile regression with nonadditive fixed effects. *Empirical Economics* 2022 63:5, 63(5), 2675–2691.
<https://doi.org/10.1007/S00181-022-02216-6>
- Rahman, M. M., Ahmed, T. T., Prova, N. B. F., & Ahmed, S. (2025a). Synergy of energy alternatives, FinTech, and natural resources on SDG13: results from panel QCA and econometric models. *Discover Sustainability* 2024 6:1, 6(1), 1–21. <https://doi.org/10.1007/S43621-024-00718-0>
- Rahman, M. M., Ahmed, T. T., Prova, N. B. F., & Ahmed, S. (2025b). Synergy of energy alternatives, FinTech, and natural resources on SDG13: results from panel QCA and econometric models. *Discover Sustainability*, 6(1), 1–21. <https://doi.org/10.1007/S43621-024-00718-0/TABLES/11>
- Saqib, N., Duran, I. A., & Ozturk, I. (2023). Unraveling the Interrelationship of Digitalization, Renewable Energy, and Ecological Footprints within the EKC Framework: Empirical Insights from the United States. *Sustainability* 2023, Vol. 15, Page 10663, 15(13), 10663.
<https://doi.org/10.3390/SU151310663>
- Saygın, E., Gök, A., & Yamak, T. (2025). The Effect of Financial Development on CO2 Emissions: A Nonlinear Dynamic Panel Data Analysis. *Open Environmental Research Journal*, 18.
<https://doi.org/10.2174/0118742130356943250225042742>
- Shah, W. U., Younis, I., Missaoui, I., & Liu, X. (2025). Environmental transitions effect of renewable energy and fintech markets on Europe's real estate stock market. *Renewable Energy*, 243, 122603.
<https://doi.org/10.1016/J.RENENE.2025.122603>
- Shahbakhsh, H., & Osanloo, M. (2025). Greenhouse Gas Emissions Reduction through Integration of Renewable and Non-renewable Energy Sources: A Model for Sangan Iron Ore Mine Complex of Iran. *International Journal of Engineering*, 38(11), 2547–2563.
<https://doi.org/10.5829/IJE.2025.38.11B.07>
- Sreenu, N. (2024). The impact of Fintech and green bonds on the Indian renewable energy production. *Renewable Energy*, 237, 121807.
<https://doi.org/10.1016/J.RENENE.2024.121807>
- Su, X., & Tan, J. (2023). Regional energy transition path and the role of government support and resource endowment in China. *Renewable and*

Sustainable Energy Reviews, 174, 113150.
<https://doi.org/10.1016/J.RSER.2023.113150>

- Sun, Y., Li, T., & Mehmood, U. (2025). Balancing acts: Assessing the roles of renewable energy, economic complexity, Fintech, green finance, green growth, and economic performance in G-20 countries amidst sustainability efforts. *Applied Energy*, 378, 124846.
<https://doi.org/10.1016/J.APENERGY.2024.124846>
- Taghizadeh-Hesary, F., Dong, K., Zhao, C., & Phoumin, H. (2023). Can financial and economic means accelerate renewable energy growth in the climate change era? The case of China. *Economic Analysis and Policy*, 78, 730–743. <https://doi.org/10.1016/J.EAP.2023.04.013>
- Tan, Q., Yasmeen, H., Ali, S., Ismail, H., & Zameer, H. (2023). Fintech development, renewable energy consumption, government effectiveness and management of natural resources along the belt and road countries. *Resources Policy*, 80, 103251.
<https://doi.org/10.1016/J.RESOURPOL.2022.103251>
- Teng, M., & Shen, M. (2023). Fintech and energy efficiency: Evidence from OECD countries. *Resources Policy*, 82, 103550.
<https://doi.org/10.1016/J.RESOURPOL.2023.103550>
- Udeagha, M. C., & Muchapondwa, E. (2023). Green finance, fintech, and environmental sustainability: fresh policy insights from the BRICS nations. *International Journal of Sustainable Development and World Ecology*, 30(6), 633–649.
<https://doi.org/10.1080/13504509.2023.2183526>;CTYPE:STRING:JOURNAL
- Vo, D. H., Pham, A. T., Tran, T., & Vu, N. T. (2023). Does income inequality moderate the effect of fintech development on renewable energy consumption? *PLOS ONE*, 18(11), e0293033.
<https://doi.org/10.1371/JOURNAL.PONE.0293033>
- Wei, H., Yue, G., & Khan, N. U. (2024). Uncovering the impact of Fintech, Natural Resources, Green Finance and Green Growth on Environment sustainability in BRICS: An MMQR analysis. *Resources Policy*, 89, 104515. <https://doi.org/10.1016/J.RESOURPOL.2023.104515>
- Wen, Y., Song, P., Yang, D., & Gao, C. (2022). Does governance impact on the financial development-carbon dioxide emissions nexus in G20 countries. *PLoS ONE*, 17(8 August).
<https://doi.org/10.1371/JOURNAL.PONE.0273546>
- World Energy Outlook 2024 – Analysis - IEA*. (n.d.). Retrieved November 14, 2025, from <https://www.iea.org/reports/world-energy-outlook-2024>
- Xu, S., Zhang, Y., Chen, L., Leong, L. W., Muda, I., & Ali, A. (2023a). How Fintech and effective governance derive the greener energy transition:

-
- Evidence from panel-corrected standard errors approach. *Energy Economics*, 125, 106881.
<https://doi.org/10.1016/J.ENECO.2023.106881>
- Xu, S., Zhang, Y., Chen, L., Leong, L. W., Muda, I., & Ali, A. (2023b). How Fintech and effective governance derive the greener energy transition: Evidence from panel-corrected standard errors approach. *Energy Economics*, 125. <https://doi.org/10.1016/j.eneco.2023.106881>
- Xue, C., Shahbaz, M., Ahmed, Z., Ahmad, M., & Sinha, A. (2022). Clean energy consumption, economic growth, and environmental sustainability: What is the role of economic policy uncertainty? *Renewable Energy*, 184, 899–907.
<https://doi.org/10.1016/J.RENENE.2021.12.006>
- Yang, Y., Su, X., & Yao, S. (2021). Nexus between green finance, fintech, and high-quality economic development: Empirical evidence from China. *Resources Policy*, 74, 102445.
<https://doi.org/10.1016/J.RESOURPOL.2021.102445>
- York, R., & Rosa, E. A. (2003). Key challenges to ecological modernization theory: Institutional efficacy, case study evidence, units of analysis, and the pace of eco-efficiency. *Organization and Environment*, 16(3), 273–288.
<https://doi.org/10.1177/1086026603256299;SUBPAGE:STRING:ABSTRACT;WEBSITE:WEBSITE:SAGE;REQUESTEDJOURNAL:JOURNAL:OAEC;WGROU:STRING:PUBLICATION>
- Zhang, H., Jing, Z., Ali, S., Asghar, M., & Kong, Y. (2024). Renewable energy and natural resource protection: Unveiling the nexus in developing economies. *Journal of Environmental Management*, 349, 119546. <https://doi.org/10.1016/J.JENVMAN.2023.119546>
- Zhang, X., & Wilson, C. (2022). Transition from brown to green: Analyst optimism, investor discount, and Paris Agreement. *Energy Economics*, 116, 106391. <https://doi.org/10.1016/J.ENECO.2022.106391>
- Zhang, Y., Zheng, K., Xia, F., & Cheng, Z. (2024). Fintech, natural resource rents, renewable energy consumption and environmental quality: A perspective of green economic recovery from BRICS economies. *Resources Policy*, 89, 104604.
<https://doi.org/10.1016/J.RESOURPOL.2023.104604>
- Zhu, J., Zhou, P., & Shen, Y. (2024). Exploring the individual and combined effect of natural resource rents, fin-tech, and renewable energy on sustainable development: New insights from SSA countries. *Resources Policy*, 91, 104747.
<https://doi.org/10.1016/J.RESOURPOL.2024.104747>

