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Unpacking the Financial Development, Financial Technology and Institutional Quality Nexus in Curbing Climate Change Among Middle-Income Countries

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This study examines the influence of financial development, financial technology and institutional quality on climate change in middle-income economies from 2000 to 2023. The study aims to identify the role of these factors in driving or mitigating CO2 emissions and provide policy recommendations for sustainable economic development. This study employs the method of moment quantile regression (MMQR) approach to unpack the linkage between financial development, financial technology, and institutional quality and CO2 emission across various quantiles. This approach enables a thorough evaluation of the impact of these factors on climate change across different quantiles. The outcomes illustrate the rise in CO2 emission because of financial development, urbanization and economic advancement across all quantiles. The impact of financial technology displayed mixed trends across all quantiles, minimizing emissions at a lower quantile but lowering the effect at higher quantiles Conversely, the institutional quality diminishes CO2 emission at all quantiles, denoting the role of governance in middle-income economies. These outcomes urge policymakers to approve extensive strategies that restrict the negative impacts of financial development, urbanization and economic growth while promoting institutional quality in all middle-income economies. This study is novel in exploring the drivers associated with climate change while concentrating on the financial sector and institutional quality. Besides, it also offers actionable, innovative policy recommendations to address contemporary environmental and economic challenges in middle-income economies.

1. Introduction

In recent decades, the world has undergone remarkable climate change and has substantially exacerbated global warming due to escalating anthropogenic activities and economic expansion. The escalating concentration of CO2 emission results in elevated global temperature, global warming, and erratic precipitation patterns that worsen the incidence of catastrophic events. As climate change and environmental corrosion are a widespread global phenomenon in the 21st century and have arisen as an irrefutable pain for policymakers, global organizations, such as the United Nations (UN), have arranged multiple proceedings and executed numerous ingenuities to confront environmental damage worldwide.

Hence, there is growing interest among scholars and policymakers in realizing the various factors contributing to CO2 emission. Among these factors, financial development (FNP), financial technology (FTG), and institutional quality (IQL) have emerged as key elements associated with economic expansion, which results in climate change, specifically in middle-income economies. These economies, due to their expanding economic activities, contribute significantly to carbon emissions. The gentle balance between economic progress and the environment in these countries requires innovative ways that exploit financial advancement, financial technology, and improved institutional quality to minimize the harmful effects of climate change (Das & Ghosh, 2023). One effective approach for mitigating climate change is the development of a financial system. FNP progresses the availability of financial services by encouraging investment and entrepreneurial activities. In contrast, its environmental ramifications are vague because certain researchers unveil the linkage of FNP with enhanced energy usage and CO2 emission, whereas others emphasize its capacity to foster sustainable growth. A resilient financial system supports economic growth and facilitates to embrace the sustainable practices and technology, thus lowering CO2 emissions.

Financial institutions play a critical role in promoting environmental quality as robust financial systems drive enterprises to implement cleaner technologies, cut pollution, and improve ecological performance. FNP has been identified as an essential driver for economic growth, specifically in middle-income economies, facilitating individuals and organizations in managing their finances and engaging in economic endeavors. These economies are undergoing swift escalations in energy usage, resulting in substantial CO2 emissions and ecological damage. The World Bank denotes financial development as encompassing various financial services comprising loans, credit, investments, and transactions. Rapid economic expansion in middle-income nations has culminated in environmental concerns like inadequate institutions, deforestation, and enhanced GHG emissions. Insufficient institutional support and financial services intensify these challenges, impacting over a billion individuals in these economies. Embracing green technology like solar energy might drastically curb CO2 emissions, while institutional and financial obstacles hinder advancement. However, the FNP holds the capacity to encourage the usage of green technologies, optimize energy efficiency, and lower emissions (Zhou et al., 2024).

Hence, it is imperative to concentrate on financial development mechanisms and institutional quality while managing economic growth and environmental preservation. Furthermore, financial development provides a basis for the adoption and growth of digital services in financial services, namely financial technology. Financial technology (FTG) pertains to mobile payments, blockchain, artificial intelligence, online banking, and others within the financial industry, thereby initiating a transformative impression on financial services in handling the concern of climate change (Kathuria et al., 2024). FTG are viewed as contemporary technologies that substantially mutate all economic activities and banking. Numerous preceding studies revealed that the FTG significantly affects financial progress (Singh et al., 2023; Buyya et al., 2024). FTG is considered a tool utilized by nonprofit and emerging organizations to support key sophisticated economic trends that will accelerate economic prosperity. FTG uses cloud computing, data centers, and high-speed internet, escalating energy consumption and CO2 emissions.

FTG significantly contributes to supporting green financing mechanisms such as green financing, loans for renewable energy, and carbon trading, all of which favorably influence environmental integrity. FTG can assist individuals and organizations in minimizing pollution and waste, enhancing their green energy usage (Sadiq et al., 2024). Thus, FTG is linked to the environment in multiple ways, yet it is still ambiguous the mechanism via which it influences climate change. Similarly, IQL, which indicates the stability of regulatory systems, law enforcement, and governance mechanisms, are pivotal for economic advancement without harming the environment. Countries that possess strong institutional frameworks have the potential to enhance environmental quality through direct and indirect means Nonetheless, the linkage between IQL and climate change remains questionable. In theory, resilient institutions can enact policies that advance environmental quality and curb CO2 emissions. In comparison, empirical research illustrates that institutional enhancements may, in specific settings, align with heightened economic activity and environmental damage. Mitigating climate change among middle-income economies entails financial services that cater to socioeconomically impoverished economies and bolster resilient institutional contexts.

Hence, given the aforementioned background and environmental Kuznets curve (EKC) theory, it is critical to comprehend how FNP, FTG and IQL influence climate change for advancing sustainable growth. Thus, this study offers a distinctive framework to unveil the linkage among FNP, FTG, IQL and CO2 emissions in 100 middle-income economies using second-generation advanced econometric techniques such as the method of moment quantile regression (MMQR), which generates credible estimates incorporating nonlinear and location-specific attributes across various quantiles. These economies have strong economic prosperity, growing financial infrastructure and varied institutional capabilities alongside sustainability challenges. The dual objectives of promoting economic growth and addressing climate change are specifically pertinent for these economies, where the necessity for financial expansion and enhanced governance must be reconciled with the critical need to curb CO2 emissions and alleviate climate change. Unlike prior studies, this study contributes to the literature in multiple manners: Initially, it was crucial to unpack the linkage among financial development, financial technology, and institutional quality among middle-income countries about the CO2 emissions as conferring to authors' knowledge, prior research has not yet investigated this combination. Also, this study is crucial to seek deeper insights into the divergent perspectives among researchers regarding the causes of CON and the role of other variables in alleviating the impact of CON.

Furthermore, this study accounted for a novel advanced method of moment quantile regression (MMQR) approach, which has not been applied before considering these variables. Finally, assimilating these variables into a consolidated framework will enable policymakers to formulate policies for middle-income economies, enabling them to mitigate climate change. The remaining study covers four sections. Section 2 discloses earlier literature; Section 3 exhibits data and methodology; Section 4 covers findings and discussion; Section 5 offers conclusion and policy recommendations based on findings.

2. Literature Review

2.1 Theoretical Foundation

Within the framework of environmental sustainability, the interplay between the development of financial institutions and markets, financial technologies, institutional quality, economic expansion, and urbanization holds crucial significance in figuring out the shift towards a sustainable future. This connection is consistent with each of the "Environmental Kuznets Curve (EKC) theory (Grossman & Krueger, 1995). Applying the EKC theory, which entails decoupling GDP from ecological degradation, requires the imperative development of financial systems and the quality of institutions. The EKC phenomenon was initially identified by (Kuznets, 2019), wherein an inverted U-shaped association of economic growth with the environment was observed.

Considering the EKC hypothesis, during the initial phase of growth, per capita income rises, contributing to higher emissions and exerting a negative effect on the climate. Nevertheless, once a specific point is attained, subsequent income rises result in the decline of CO2 emanations and exert a constructive outcome on the environment. Financial advancement leads to investment opportunities, and this phenomenon has been boosted by financial technologies (FTG). This technological advancement helps in allocating resources, progressing governance, and ultimately enhancing environmentally friendly processes. Several important works relating to this topic are listed in Table 1

2.2 Financial Development and Climate Change

There has been a prominent rise in the contemplation and emphasis of researchers, academics, economists, and policymakers toward financial development (FNP) over the prior few decades to scrutinize the interplay between FNP and ecological pollution, employing various variables and methodologies. (Liu et al., 2023). Financial development has several positive implications for a nation's economic framework, including the establishment of financial channels, and thus facilitates the introduction of environmentally friendly technologies and promotes research and development (R&D) endeavors. Consequently, there is a proliferation of global advertising campaigns and notable advanced technology. (N. Li et al., 2023). Therefore, financial development has the potential to positively impact environmental quality and reduce CO2 (Yu et al., 2024). Conversely, a linkage exists between financial development and increased pollution, stemming from the heightened production levels associated with economic liberalization and greater energy consumption. (Z. Liu et al., 2024). Financial institutions provide funding for environmentally beneficial initiatives mitigating CO2 emissions. (Zhou et al., 2024). There also exists a discernible negative linkage between financial advancement and the emission of CO2 in Nigeria (Ali & Malik, 2021).

Additionally, the study conducted by (Zhao & Yang (2020) centers its attention on examining the liaison between China's ecological damage and financial progress. The analyses presented in their study demonstrate that the development of economic systems has had a negative influence on CO2 emanation. Similarly, the magnitude of carbon dioxide emissions is minimally affected by the size of the stock (Fang et al., 2020). In a comprehensive analysis encompassing 124 economies worldwide, a significant correlation was observed between FNP and CON (C. Liu et al., 2023). There established a correlation between FNP and ECF in Sub-Saharan Africa (Emenekwe et al., 2022). Nevertheless, existing studies on the connection of financial development with the environment still lack definitive conclusions and require further investigation. Thus

H1: Financial development plays a significant role in determining CO2 emissions among middle-income economies

2.3 Financial Technology and Climate Change

Financial technology is used to upgrade and streamline the arrangement of financial services. Fintech is comprised of two components: Fin (Financial) and Tech (Technology), referred to as financial technology means technology-enabled financial solutions. (Rafay, 2019). The integration of financial technology (FTG) enables the digitalization of financial institutions, thereby facilitating the transition of traditional offline economic activities to online platforms. FTG has the potential to reduce the transition of offline financial activities to online platforms through the utilization of digital technology. This transition can result in a reduction of unnecessary economic activities (Li et al., 2020).

Using digital online platforms enables the efficient execution of financial transactions between capital suppliers and demanders. Consequently, the need for offline activities, which require physical travel, is substantially reduced. This reduction in travel frequency cause to curtail CO2 emanations generated by transportation (Lee & Wang, 2022). In addition, implementing an online paperless office directly lessens the utilization of physical funds within the financial services sector. Concerning the practical application of FTG in everyday consumption, using mobile payment methods enhances convenience and significantly diminishes transaction costs and resource utilization (Li et al., 2020). FTG recognizes the inherent necessity of providing financial services to marginalized populations that conventional financial institutions have overlooked (Du, 2017).

Moreover, it benefits economic development and income augmentation in underdeveloped regions. (Redondo-Rodríguez et al., 2023). Iqbal et al. (2025) emphasizes the necessity for policymakers to adopt a multi-strategy approach that integrates green finance, technological innovation, low-carbon energy, and supportive government programs. Additionally, the participation of women in economic activities has been linked to increased foreign direct investment (FDI), as empirical evidence suggests that industries with a higher concentration of female labor attract greater FDI (Shaheen et al., 2024).

Ullah and Shaheen (2024) explore the relationship between sustainable finance and technological innovation by incorporating the governance index and other economic indicators. Their study assesses the impact of these factors on sustainable development, particularly in reducing greenhouse gas emissions. Similarly, Hussain et al. (2024) find that while some economies effectively manage health-oriented outputs, such as quality of life and mortality rates, others demonstrate strong economic performance. Mahmood et al. (2024) employ regression analysis to examine the relationship between dividend yield and air pollution, seeking to identify correlations between these variables and assess air pollution’s impact on dividend yield. Furthermore, Tariq et al. (2024) investigate the social and behavioral factors influencing the adoption and usage of digital banking apps among Pakistani citizens during the COVID-19 pandemic. Norin et al. (2024) analyze the effects of advertising on children's attitudes, behaviors, and lifestyles. In response to the growing threat of global warming, scholars and policymakers have been paying closer attention to the relationship between economic growth and environmental protection (Mehroush et al., 2024).

Akbar et al. (2024) conduct an interdisciplinary study examining how institutional quality, particularly corruption levels, influences the commercialization of innovation, as measured by high-tech product exports. Bilal and Shaheen (2024) highlight that technological innovation, and natural resources contribute to the adoption of energy efficiency strategies and environmental regulations, while green financial indicators significantly promote the transition to renewable energy sources. Additionally, Shaheen et al. (2025) address a gap in the literature by analyzing how demographic trends impact the environmental consequences of international trade. Finally, Shaheen et al. (2025) investigate sustainability considerations, including environmental, social, and governance (ESG) factors, as well as governmental policies and regulations that influence capital budgeting decisions.

Financial technologies have the potential to support businesses in evaluating and mitigating their waste generation while also aiding shareholders in aligning their investments with environmentally sustainable products. This can be achieved through the utilization of advanced technologies, such as state-of-the-art cryptocurrencies, along with other innovative stages. (Jaiwant & Kureethara, 2023).The integration of fintech (financial technology) and contemporary technologies enhances innovative financial products and services (Numan et al., 2023).

H2: Financial technology plays a significant role in determining middle-income economies' CO2 emissions.

2.4 Institutional Quality and Climate Change

The endeavour to mitigate environmental deterioration is of paramount importance in contemporary society today. In the present context, the worth of institutions has emerged as a crucial aspect in shaping ecological quality. Institutional quality refers to a comprehensive framework of regulations and laws that incorporate the protection of individual rights, the provision of high-quality services, and government laws (Wu & Madni, 2021). The study introduced six distinct indicators that are associated with IQL, namely political solidity, government efficiency, regulation quality, accountability, corruption, and the rule of law (Kaufmann et al., 1999).

There exists a linkage between political support and CO2 equivalent emanations, suggesting that once a certain threshold of carbon dioxide emission is attained, political stability may contribute to the mitigation of Carbon dioxide emission. (Purcel, 2019). Robust institutions promote the adoption of clean energy sources, thereby contributing to the gradual reduction of pollution levels. Therefore, the significance of institutional quality has been emphasised as a highly effective approach to mitigating CO2e emissions and fostering sustainable development. (Wenlong et al., 2023). Corruption constitutes a vital component regarding the quality of institutions and emissions. Corruption has the consequence of diminishing the strictness of environmental regulations, leading to a rise in carbon dioxide equivalent emissions. (Arminen & Menegaki, 2019). Secondly, corruption has the potential to undermine the economic infrastructure and exert an impact on socioeconomic disparities, curtailing GHG emanations, specifically because of the scale effect (Cole, 2007).

Despite a thorough investigation into the correlation between corruption and emissions, it continues to be regarded as an academic casualty. It also examined the linkage between economic globalisation and carbon emanations in Africa from 2002-2017, with a specific focus on the influence of corruption control as an influencing factor. They discovered that the management of corruption imposed a determinantal effect on CO2 emanations in Sub-Saharan Africa. (Yameogo et al., 2021). Between the years 1987 and 2000, an extensive panel consisting of 94 countries conducted a study which revealed a direct correlation between corruption and a rise in CO2 emanations in the immediate term. Adherence to environmental legislation is also ensured through the presence of strong regulations. Rule of law also serves to guarantee observance of regulations and the adherence of firms to environmental standards. Additionally, it guarantees adherence to the accountability. Industries that exhibit a lack of environmental responsibility are subjected to appropriate measures of accountability, thereby setting a precedent for other industries to strictly adhere to regulatory guidelines. The efforts to combat corruption and maintain political stability have the effect of reducing such emissions. An analysis was conducted by utilising the QARDL estimator to inspect the linkage between institutional quality and the environment. The data span ranged from 1995 to 2018, focusing specifically on the context of Pakistan, revealing a positive link between financial development and environmental quality. However, they also found that IQN and GDP exert a negative impact on climate degradation over time (Godil et al., 2020).

The interconnections between urbanisation, institutional quality, economic growth, and ecological sustainability from 1971 to 2017 were examined, concluding that INQ exerts a notable impact concerning ecological quality. Nonetheless, it was observed that GDR growth tends to adversely affect the environment in the long run (Sarkodie & Adams, 2018). In their study conducted in 2019, it examined the relationship between trade, the worth of institutions, foreign direct investment, and ecological quality over the period 1984-2015. Their findings indicate that INQ exerts a detrimental impact on the environment, suggesting a negative linkage among variables (Zakaria & Bibi, 2019). Researchers determined that an enhanced adherence to the worth of institutions enhances ecological performance (Bekun et al., 2021).

H3: Institutional Quality plays a significant role in determining middle-income economies' CO2 emissions.

3. Research Methodology

This study utilizes annual data from middle-income economies to probe the effect of financial development, financial technology, and institutional quality on CO2 emission as a measure of climate change. The analysis flow is displayed in Fig. 1. Table 1 analytically explains the variables, measures, units and data sources.

Table No 1: Variables Description

Variables	Nature	Measurement Unit	abbreviation	Data Source
Climate Change	Dependent	CO2 Emissions Metric Tons per capita	CON	WDI
Financial Development	Independent	Financial Development Index (0-1) comprising the depth, access, and efficiency of financial markets and institutions	FNP	IMF
Financial Technology	Independent	Through PCA index in STATA by using three proxies such as ATMs per 100 thousand individuals, mobile subscriptions, and internet as per population	FTG	Self-Calculated (Tan et al., 2023)
Institutional Quality	Independent	Through an index of six governance indicators	IQL	WGI
Economic Growth	Control	GDP per capita constant (USD)	GDR	WDI
Urbanization	Control	% of population	URN	WDI

3.1 Econometric Model

The empirical model's functional form employed to probe the influence of FNP, FTG, and IQL on CO2 emission is outlined as follows:

$$CON_{it} = f\,(FNP_{it}, FTG_{it}, IQL_{it}, GDR_{it}, URN_{it}) \quad \text{(i)}$$

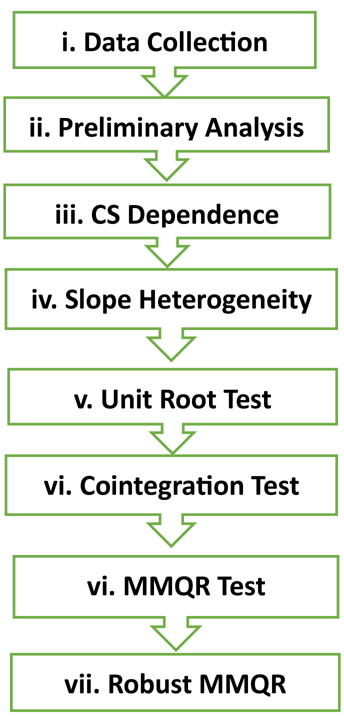
Where CON denotes carbon emissions, FNP represents financial development, FTG illustrates financial technology, GDR represents economic growth, and URN denotes urbanization. The subscripts such as *"i" and "t"* denote economies and time duration, respectively. To empirically investigate the linkage among FNP, FTG, and IQL on CON, the functional format was reformulated into subsequent econometric prescription:

$$CON_{it} = \alpha_{it} + \beta 1\ FNP_{it} + \beta 2FTG_{it,} + \beta 3IQL_{it,} + \beta 4\ GDR_{it} + \beta 5\ URN_{it} + \varepsilon_{it} \quad \text{(ii)}$$

Where α denotes the slope coefficient, while the parameters of exogenous variables are represented by $\beta 1$, $\beta 1$, and $\beta 3$, the coefficients regarding control variables are represented by $\beta 4$ *and* $\beta 5$. The combined error term is illustrated by $\varepsilon_{it.}$

3.2 Data Analysis Flow

Figure No 1: Analysis Flow



3.3 Data Analysis Methodology

This study employed the normal preliminary tests extensively described in recent investigations (Alsaleh et al., 2023). Due to countries' larger interlinkage globally concerning economic support, cross-sectional dependence (CDP) in current research has become a crucial focus, mainly on panel data assessment. So, it is significant to underscore CDP for upcoming precise statistical measures and, lastly, to guide towards inappropriate policy influences. The CDP test highlights the difficulties with panel data via reliable findings. Equation # (iii) explains the CDP test below.

$$CDP_{TM} = \left[\frac{TN(N-1)}{2}\right]^{1/2} \bar{\rho}_N \quad \text{(iii)}$$

The $\bar{\rho}_N$, N and T expose the pair-wise associates, units of cross-sections, and time, respectively. Later, for the slope heterogeneity Pesaran and Yamagata test is applied (Pesaran & Yamagata, 2008). Then, Swamy (1970) Conducted a reviewed replication valuation. This technique is shown by Equations under (iv) and (v).

$$\tilde{\Delta}_{SH} = (N)^{\frac{1}{2}}(2k)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - k\right) \ldots.\ for\ larger\ sampling \quad (iv)$$

$$\tilde{\Delta}_{SHAdj} = (N)^{\frac{1}{2}}\left(\frac{2k(T-k-1}{T+1}\right)^{-\frac{1}{2}}\left(\frac{1}{N}\tilde{S} - 2k\right) \ldots.for\ smaller\ sampling \quad (v)$$

S and N depict test statistics and cross-sectional units, respectively, about the exogenous variables k. The ensuing phase of current research contains the query of the attributes regarding the data stationarity. Whilst the CDP reveal the outcomes' reliability obtained through unit root tests. In the current study, for measuring the emphasis of key exogenous variables in the framework, the cross-sectional unit root test CIPS and CADF test have been included, like financial development, financial technology, and institutional quality. The unit root tests engaged in this inquiry, the CADF as well as CIPS, are represented by equations (v) and (vi).

CADF is represented as:

$$\Delta Y_{i,t} = \gamma_i + \gamma_i Y_{i,t-1} + \gamma_i \bar{X}_{t-1} + \sum_{l=0}^{p} \gamma_{il} \Delta\overline{Y_{t-l}} + \sum_{l=1}^{p} \gamma_{il} \Delta Y_{i,t-l} + \varepsilon_{it} \quad (vi)$$

Where: $\bar{Y}_{t-1}$ exhibits the lagged bounds at the 1st difference of $\bar{Y}_{t-1}$ exhibit $\Delta\overline{Y_{t-l}}$. Also, the mean of the CADF has been engaged for the CIPS statistics below Equation # (vi).

$$\widehat{\mathrm{CIPS}} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i=1}}^{\mathrm{n}} \mathrm{CADF_i} \quad (vii)$$

The lagged parameters are illustrated as $\bar{Y}_{t-1}$ and the first difference of $\bar{Y}_{t-1}$ suggest $\Delta\overline{Y_{t-l}}$.

Then, the cointegration test endorsed by (Persyn & Westerlund, 2008) Has been deployed.

Afterwards, the Westerlund cointegration test is documented while the terms encircled the group statistics. $\mathrm{G_a}$and $\mathrm{G_t}$, then the panel statistics are enlightened by $\mathrm{P_a}$and $\mathrm{P_t}$

$$G_t = \frac{1}{N}\sum_{i-1}^{N} \frac{\acute{\alpha}_i}{SE(\acute{\alpha}_i)} \quad (viii)$$

$$G_\alpha = \frac{1}{N}\sum_{i-1}^{N}\frac{T\acute{\alpha}_i}{\acute{\alpha}_i(1)} \qquad (ix)$$

$$P_t = \frac{\acute{\alpha}}{SE(\acute{\alpha})} \qquad (x)$$

$$P_\alpha = T\acute{\alpha} \qquad (xi)$$

Based on the endorsements, the current study exploits the FMOLS, FE-OLS, and DOLS estimation techniques (Alsaleh et al., 2023). These approaches are employed on panel data and offer extensive benefits, specifically to address endogeneity and attain exact statistical estimations. The DOLS estimator principally discourses endogenous response by enhancing the discrepancies in lead and lag variables and managing endogeneity. The study accomplishes this by employing the novel approach of the MMQR recommended by (Machado & Silva, 2019).

This MMQR approach offers multiple benefits, comprising robustness to outliers ignoring the chance of primary panel heterogeneity. Moreover, considers the provisional impact of heterogeneous covariance by varying the full distribution related to the shifting means. Besides, MMQR estimation enables assessing the main outcome variable outlines for several quantiles, like lower, medium, and higher-order quantiles. Although the employed approach of MMQR depicts certain benefits, like its capacity to manage outliers and look at the conditioned heterogeneous covariance effect (Chau et al., 2022), it contains certain limitations. For example, the predicted parameters regarding MMQR are more complex compared with general or Gaussian regression predictors. Additionally, the systematic coefficients in a closed setup in MMQR may not be employable (Khan et al., 2023).

Moreover, the proximate technique of MMQR is not proposed to succeed the other recognized approaches relying on the established purpose; rather, it pertains to an auxiliary tool to estimate regression quantiles accounting for individual impacts (Machado & Silva, 2019). Also, the provided findings through MMQR can fluctuate enormously depending on the analysis method, such as employing panel estimators relative to 1st generation. The 1st generation estimations reveal the independence of CS units, whereas the 2nd generation estimators recognize a linkage between the units of cross-sections (Menegaki, 2018). Conversely, in the investigation, utilizing the GMM (generalized method of moments) can change the empirical findings by considering sampling error and estimation (Durlauf & Blume, 2016). Moreover, utilizing the ARDL (Auto-regressive distributed lagged) model for the panel data would result in varying statistical estimates compared with MMQR. S, it is vital to reflect these limitations, as they might modify the empirical outcomes and resulting policy suggestions.

Equation (xii) below determines the computation of the conditional quantile... $Q_y\ (\delta|\hat{X}_{it})$:

$$Y_{it} = \dot{a}_i + \ddot{X}_{it}\,\Phi + (\dot{\Lambda}_i + Z'_{it}\,\Psi)\,\breve{U}_{it} \qquad (xii)$$

Where: $\text{þ}\{\dot{\Lambda}_i + Ƶ'_{it}\,\Psi > 0\}$, signifies a probability of 1, whereas the model's parameter is represented as $(\Phi, \dot{\Lambda}_i\; Ƶ'_{it}\,\Psi)$; i = 1,..., n denotes the varied fixed effects though the selected components of X's k-vector are displayed as Z restricting discrete modifications with component l illustrated by: $Ƶ_j = Ƶ_j(\ddot{X}), j = 1,2, \ldots \ldots, k$

$\ddot{X}_{it}$ It is recurrent invariant and consistently dispersed. Also, the term $\breve{U}_{it}$ is reorganized in time (t) amongst individuals I and rectangularly to X_{it}, allowing Machado and Silva's moment condition underneath:

$$Q_y\left(\dot{\delta} \middle| \hat{X}_{it}\right) = \left(\dot{a}_i + (\dot{\boldsymbol{\lambda}_i}\,\boldsymbol{\rho}_i\, q(\dot{\delta})) + \ddot{X}_{it}\,\Phi + Ƶ'_{it}\,\Psi\, q(\dot{\delta})\right) \quad (xiii)$$

Here: $\ddot{X}_{it}$ incorporates independent vector domains, whereas, $Q_y\left(\dot{\delta}\middle|\hat{X}_{it}\right)$ denotes the quantile distribution of Y_{it}. Equation # (xiv) underneath optimization links:

$$Min_q = \sum_i \sum t\,\eta_{\acute{o}}\left(Rit - [\![(\wedge\,\dot{Z}]\!]_i + Ƶ'_{it}\,\gamma)q\right) \quad (xiv)$$

Where; $\eta_{\acute{o}}\,(\ddot{R}) = (\delta \grave{-} 1)\,\ddot{R}I\left\{\ddot{R} \le 0\right\} + T\ddot{R}I\left\{R \ddot{>} 0\right\}$ represents a checked function.

3.4 Descriptive Findings

Table 2 displays descriptive findings utilizing mean trends, data boundaries, average scores dispersal, and normality supposition. The findings disclose that GDR displays the highest mean value of 3.384, followed by URN and CON. Nonetheless, FNP displays the lowest mean score during the study time. After monitoring deviation from the mean, CON discloses the most exceptional dispersion, followed by IQL and FTG, respectively. Also, maximum and minimum values specify the highest and lowest outlines in data.

Table No 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
CON	9968	1.558	1.395	0	7.672
FNP	9880	.189	.141	0	.739
FTG	9880	.514	.335	.001	3.692
IQL	9880	.289	.777	0	5.15
LGDR	9880	3.384	.48	1.799	4.745
LURN	9880	1.629	.318	0	2

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; log of gross domestic product. LURN; log of urbanization

3.5 Variance Inflation Factor (VIF) Outcomes

The VIF value of IQL is the highest among all variables which is 1.453, after FNP, and LGDR, along with the smallest value of FTG, which is 1.098, signifying that no multicollinearity occurs among exogenous variables in the model. This suggests the stability of the regression model.

Table No 3: VIF Test

	VIF	1/VIF
FNP	1.367	.732
FTG	1.098	.910
IQL	1.453	.688
LGDR	1.319	.758
LURN	1.301	.768
Mean VIF	1.308	.

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; log of gross domestic product. LURN; log of urbanization.

3.6 Cross-Sectional Dependence

Because of globalization and the interdependency of all middle-income economies, there has been a significant rise in economic advancement and links in current times. Hence, it is critical to determine that overlooking the interdependence among economies might cause imprecise estimates and recommendations for policy. Afterwards, appraising the CSDP in the data is vital before engaging in more econometric methodologies. Table 4 illustrates the CSDP findings utilizing p-values and more test statistics about the associated variables. Based on the given outcomes, it can be described that the p-values are statistically significant at the 1% level.

This suggests that the null hypothesis, which signifies the absence of CSDP in the data, has been rejected. The variables such as CON, FNP, FTG, and LGDP reveal high CS dependence, showing strong interlinkage and representing high significance relative to IQL, and LURN, having comparatively lower values, indicating some degree of dependence, while weaker compared with other variables.

Table No 4: Testing the CS Dependence (CSDP)

Variable	CD-test	p-value
CON	309.655	0.000
FNP	243.541	0.000
FTG	131.27	0.000
IQL	20.245	0.000
LGDP	235.193	0.000
LURN	37.699	0.000

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; log of gross domestic product. LURN; log of urbanization, p<0.01***, p<0.05**, p<0.1*

3.7 Slope Heterogeneity

The present study further examines slope heterogeneity using a test proposed by (Durlauf & Blume, 2016). The estimated outcomes are displayed in Table 4, which indicates both $\hat{\Delta}$ and $\hat{\hat{\Delta}}_{\text{adjusted}}$. It is significantly significant at 1%, verifying heterogeneity in the slope coefficients. As previously stated, the interconnectedness of economies is enhanced by globalization and trading, and they are also crucial for attaining diverse financial, economic, and environmental objectives. (Adebayo et al., 2022).

Table No 5: Slope Heterogeneity Testing

Description	Test Statistics	P-value
Opentilde $(\widehat{\Delta})$	173.560***	0.000
adj $(\widehat{\widehat{\Delta}}_{adjusted})$	179.305***	0.000

3.7 Unit Root Tests

Furthermore, Table 5 represents the outcomes of the panel unit root tests, namely the CIPS and CADF tests, conducted at the level and the first difference. The tests mentioned are commonly referred to as second-generation unit root tests. The results indicate that all variables except FNP are not stationary at a level while becoming stationary at 1^{st} difference. It reinforces the usage of the cointegration approach in the study while ensuring the robust estimation of long-term linkage between financial development, financial technology, institutional quality and climate change in middle-income economies.

Table No 6: Unit Root Tests

Variables	Z-bar at level	Z-bar at first difference
CON	-1.553	-35.986***
FNP	-2.490**	---
FTG	1.572	-45.103***
IQL	-1.517	-23.014***
LGDP	0.192	-9.501***
LURN	-1.624	-29.988***

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; the log of gross domestic product. LURN; log of urbanization, p<0.01***, p<0.05**, p<0.1*

3.8 Cointegration Analysis

Afterwards, the variations in slope and the stationarity of the data are analyzed, and the subsequent procedures focus on the variables' cointegration, reporting the outcomes in Table 7. It focused on long-term connections to CO2 emissions and certain explanatory and control variables. Specific outcomes having negative values with a p value=0.000 signify the rejection of the null hypothesis of no integration at a 1% level of significance (p<0.01) the null hypothesis of "no cointegration" is rejected, suggesting the association between CO2 emissions, financial development, financial technology, institutional quality, GDP, and urbanization throughout the study.

Additionally, the outcomes found from Pedroni's cointegration tests in Table verify cointegration. The following tests validate the existence of cointegration by determining if the residuals from the calculated cointegration equation exhibit stationarity. The extremely negative test statistics reveal robust evidence of stationarity in the residuals, implying the presence of a long-standing linkage. Since all findings do not accept the null hypothesis, the authors concluded that all variables in the study proceed together gradually, suggesting a long-term extended linkage.

Table No 7: Pedroni's Cointegration Outcomes

Details	Statistic	p-value
Modified Dickey-Fuller t	-7.0047	0.000
Dickey-Fuller t	-3.7327	0.000
Augmented Dickey-Fuller t	-4.005	0.000
Unadjusted modified Dickey–Fuller	-7.6647	0.000
Unadjusted Dickey-Fuller t	-4.0174	0.000

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; the log of gross domestic product. LURN; log of urbanization, p<0.01***, p<0.05, ** p<0.1 *

3.9 MMQR Estimations

This study, in its last phase, assesses the varied impact of certain exogenous and control variables concerning CO2 emissions throughout three separate quantile ranges such as 25th, 50th, 75th, and 90th quantile categorizing them into lower (25th quantile), medium (50th quantile), and higher order (75th and 90th quantiles). This analysis employs an innovative MMQR approach as illustrated in Table 8. The outcomes indicate that the effect of FNP is positive as well as significant within all quantiles which is 2.132 at the 25th quantile, 3.213 at the 50th quantile and 4.190 at both the 75th And 90th quantile suggesting that greater financial development is linked with higher CO2 emission. Moreover, FTG indicates a negative and significant effect of -0.331 and -0.131 at the 25th and 50th quantiles respectively. Nonetheless, the effect becomes insignificant at higher 75th and 90th quantiles with a p-value of 0.0473 highlighting that FTG may mitigate emissions at lower polluting levels but would not much influence larger emitters.

Furthermore, IQL imposes an adverse and highly significant effect on CON revealing that with a 1% increase in IQL, CON minimizes by 0.003 and 0.130 at the 25th quantile and 50th quantile respectively, and by 0.004 at both the middle and higher quantiles. Also, the economic growth (LGDP) illustrates a highly significant and positive association with CON. The findings describe that the effect of LGDP is positive as well as significant within all quantiles which is 0.461 at the 25th quantile, 0.296 at the 50th quantile and 0.146 at the 75th quantile and 90th quantile signifying that greater economic growth cause the CON emission to rise specifically at lower and middle quantiles comparatively. Similarly, the economic growth (LURN) demonstrates a highly significant and positive association with CON. The findings describe that the effect of LURN is positive as well as significant within all quantiles which are 0.293 at the 25th quantile, 0.394 at the 50th quantile and 0.485 at the 75th quantile and 90th quantile signifying that urbanization causes CON emission to rise gradually at lower, middle, and higher quantiles. It is pertinent that MMQR is contingent upon the moment constraints. So, there is no substantial necessity to address R^2.

Table No 8: MMQR Estimations

Explained Variable: CO2			Quantiles			
	Location	**Scale**	**25thQuantile**	**50thQuantile**	**75thQuantile**	**90thQuantile**
FNP	0.000*** (3.357)	0.000*** (1.236)	0.000*** (2.132)	0.000*** (3.213)	0.000*** (4.190)	0.000*** (4.190)
FTG	0.047** (-0.104)	0.000*** (0.229)	0.000*** (-0.331)	0.014** (-0.131)	0.473 (0.040)	0.473 (0.040)
IQL	0.019*** (-0.003)	0.001*** (-0.002)	0.017*** (-0.003)	0.018*** (-0.130)	0.020*** (-0.004)	0.019*** (-0.004)
LGDR	0.000*** (0.273)	0.000*** (0.189)	0.000*** (0.461)	0.000*** (0.296)	0.000*** (0.146)	0.000*** (0.146)
LURN	0.000*** (0.407)	0.000*** (0.115)	0.000*** (0.293)	0.000*** (0.394)	0.000*** (0.485)	0.000*** (0.485)
_cons	0.000*** (1.207)	0.041*** (-0.141)	0.000*** (1.347)	0.000*** (1.224)	0.000*** (1.112)	0.000*** (1.112)

Note: CON: Carbon dioxide emission, FNP; Financial development, FTG; Financial technology, IQL; Institutional quality, LGDR; log of gross domestic product. LURN; log of urbanization

4. Discussion

The outcomes of the method of moment quantile regression (MMQR) calculations yield essential insights into the association between financial and economic variables and CO2 emissions across various quantiles. The findings demonstrate that FNP shows a significant and positive influence on CO2 consistently through all quantiles suggesting that financial expansion amplifies economic activities contributing to enhanced emissions, specifically in the highly urbanized regions. Financial technology (FTG) exhibits mixed impacts on CO2 emission. At low and medium quantiles i.e. 25th and 50th quantiles, there exists empirically significant and negative influence highlighting that FTG contributes to emission reduction by improving efficiency and fostering sustainable financial solutions. While, at higher (75th and 90th) quantiles the effect is insignificant, indicating that the influence of FTG on lowering emissions lessens as emissions escalate.

This may result from the prevalence of energy-demanding industries at elevated contamination levels. Institutional quality (IQL) exhibits a modest yet considerable impact on emissions. It exerts a beneficial influence on emissions at 25th along with 75th quantiles, suggesting that the robust institutions may mitigate emissions under certain economic situations but may prove inadequate in high-emission contexts. This underscores the necessity of institutional reforms that amalgamate rigorous environmental rules with strong economic policies. Economic growth (LGDR) consistently exerts a negative influence on emissions throughout all quantiles, along with the effect's amplitude diminishing as emissions enhance.

This indicates that although economic growth promotes technological progress and the usage of cleaner energy, its efficacy in diminishing emissions diminishes at elevated levels of urbanization. Urbanization (URN) significantly contributes to CO2 emissions across all quantiles. It highlights the substantial environmental impacts of urban expansion and the necessity of environmentally sound urban design, green infrastructure, and the progression of green technologies.

5. Conclusion

The MMQR findings indicate that FNP substantially elevates emissions CON across all quantiles discerning measures that foster green financialization. Financial technology (FTG) demonstrates a diminishing impact on emission reduction at elevated levels, indicating that its efficacy must be bolstered by holistic environmental regulations. Institutional quality (IQL) exerts limited yet significant influence on emission patterns, underscoring the critical role of institutions in ensuring ecological sustainability. Economic growth in emission reduction, nevertheless, its effectiveness wanes in high emission contexts, necessitating policies that harmonize economic development with sustainable practices. Urbanization contributes to being a major contributor to emissions, underscoring the critical necessity for sensible urban planning regarding carbon-free infrastructure. In light of these findings, policymakers ought to adapt governments and financial payouts according to emission levels.

Middle-income economies necessitate more stringent environmental regulations and sustainable development systems. Future research ought to look at emission patterns specific to sectors and the contribution of institutional quality to curb environmental deterioration. Simultaneously, the MMQR estimation fails to consider the R^2, indicating substantial concerns regarding the model's fitness. To mitigate the potential limits and improve policy implications, future research must tackle these concerns by increasing the sample size, incorporating additional control variables, employing instrumental variables to address endogeneity, and using the CSARDL estimator to quantify the explained variation in the primary endogenous variable.

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