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Building a Greener Future: Exploring the Synergy of Sustainable Investments, Environmental Taxes, and Green Innovations in Emerging Economies

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ABSTRACT

The expansion of economic growth raises concerns about sustainable development in emerging countries, and in response, green growth has emerged as a critical policy option. Given the significance, the current study intends to explore the quantile-dependent association between green investment, green taxation, and green technologies with the green growth of emerging economies. The annual data from 2000 to 2023 has been collected to accomplish the desired goal of the study. The advanced Method of Moments Quantile regression (MMQR) was employed after examining the cross-sectional dependencies, stationarity properties, and presence of cointegration among the variables. The outcomes indicated that lower levels of green growth are not influenced by implementing environmental taxations in emerging economies. Furthermore, the empirical findings assert that encouraging investments in renewable energy and green technologies complement low, medium and high level of green growth in emerging countries. The study suggests that green policies encourage the adoption of green finance systems to embrace modern technologies in the manufacturing process in order to achieve sustainable development thereby anticipating several regional policy implications to accelerate green growth.

Keywords: Sustainability, Emerging Countries, Environmental Taxes, Renewable Energy Investment, Ecological Innovation, Green Growth
JEL Classifications: Q56, H23, F21, Q55, O44

1. INTRODUCTION

The concept of green growth is focused on achieving financial and economic development while ensuring ecological sustainability (OECD, 2021). To achieve sustainable development goals, green growth strategies must be implemented at various levels of economic development. The increasing concerns about climate change and environmental degradation necessitate the adoption of green growth strategies, particularly in emerging countries that now account for two thirds of the global carbon discharge leading to environmental pollution (IEA, 2021). Sustainability and economic growth are interconnected, as sustainable development objectives prioritize ecological quality improvements (Yikun et al., 2022) therefore, the emerging economies need to create policies that reduce environmental degradation while decreasing the levels of greenhouse emanations and ecological footprints, in order to meet sustainable development objectives (Zhao et al., 2024).

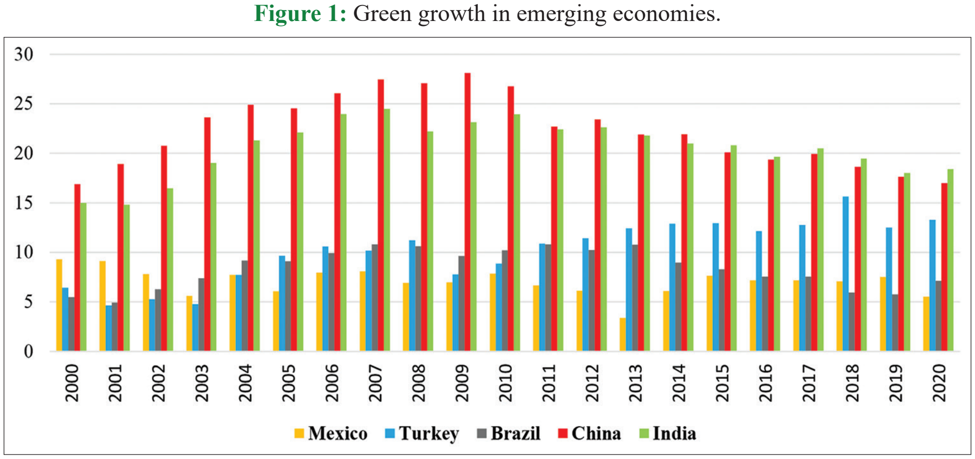
With similar aim, numerous economies around the globe have pledged to control environmental degradation without compromising economic growth through initiatives like COP-26, the Paris agreement, and the sustainable development goals for 2030 (Hussain et al., 2022). However, the achievability of these goals for every country is challenging, given their mutual exclusivity for global competitiveness. Nevertheless, high-income countries have shown promising initiatives and progress to implement environmentally friendly strategies in pursuit of sustainable development, whereas emerging countries lack sustainable economic development and are often criticized for inefficient and anti-environmental industrial practices that hinder the notion of green growth (Afshan and Yaqoob, 2022).

This can also be identified from Figure 1 depicting the level of green growth for most emerging nations for the past twenty years. Despite the growing levels of carbon emanations, resource depletion and ecological footprints in these nations, the levels of sustainable growth declines, particularly in gigantic economies of China and India in the last 10 years. In similar context, it is observed that the ecological conditions of emerging bloc with over reliance on the manufacturing sector has been criticized for ignoring green practices resulting in extensive greenhouse gas emanations. Recently, the electricity and heat production sector experienced the biggest increase in CO_2 emissions in 2021, accounting for 46% of the global emissions increase, according to the International Energy Agency. This was caused by a rise in the use of fossil fuels to meet the growing demand for industrial and domestic power consumption. The sector's global emissions reached a record high of almost 14.6 Gt, surpassing the 2019 levels by about 500 Mt. China was responsible for nearly all of the global increase in emissions in this sector between 2019 and 2021, while also experienced an increase of 5% annual carbon emanations in 2021. Although, many economic regions had witnessed an increase in CO_2 emissions in the year 2021, Brazil and India experienced the highest growth of over 10% contributing excessively in carbon discharge during the year. On the other hand, the developed economies like Japan witnessed less than a 1% emission increase, portraying the commitment towards sustainability. Furthermore, India's carbon emissions rebounded strongly in 2021, rising by 80 Mt above 2019 levels, prominently due to the over reliance on coal in power generation (IEA, 2021). Meanwhile, it is noticed that the level of green growth in Turkey (Figure 1) has shown improvements in current years, nevertheless, the country reported the largest increase in environmental pollution, with a 7.9% rise in emission levels compared to its 2019 before the pandemic levels. Hence, owing to the vulnerable ecological conditions in emerging blocks, the current study calls for the need to incorporate green growth strategies in these economies' environmental policy initiatives. In this regard, efforts can be made to mitigate the nation's environmental degradation by implementing numerous green practices such as reliance on green energy sources, improved energy efficiency, and amplified green technology innovation, all of which require an institutional emphasis on eco-friendly environmental guidelines and regulations.

With the focus on green environmental measures, Suki et al. (2022) argue that advancements in eco-friendly technologies are essential in reducing ecological degradation while emphasizing that green technologies not only aid environmental conditions but also benefit the growth of emerging nations. Such innovation relies on the vision of eco-friendly practices implemented to boost green growth in the country (Wei et al., 2022) by promoting efficient resource use and optimal energy generation with the objective of reducing hazardous emissions and achieving economies of scale (Yikun et al., 2022). Moreover, innovative industries enable sustainable growth (Ullah et al., 2021) by enabling economic, environmental, and social advancements to avail that promote a sustainable industrial revolution. The advancement of technology is essential for this transformation; otherwise, addressing ecological concerns would be challenging and costly. Aside from other determinants, technological advancement is intended to be the cornerstone of environmental policy. In addition, technologies foster innovation, environmental preservation, and protection by minimizing negative ecological repercussions. Technology fusion in the energy industry, based on green technology, can help improve green growth (Su et al., 2020). The application of green technology increases the likelihood of attaining sustainable development (Wolde-Rufael and Mulat-Weldemeskel., 2021). In this regard, various studies encourage the implementation of green technology instead of the traditional carbon-releasing production process (IEA, 2019). Sustainable energy consumption and production should be the primary policy implications for emerging countries by utilizing green innovation systems.

With a significant association between economic growth and environmental degradation, it all comes down to effective measures that government can implement, like ecologically motivated laws and regulations. One such policy tool that has gained popularity in recent literature is green taxation. Green taxation can promote the shift towards net zero emissions while protecting economic growth, making it an important policy tool to achieve sustainable

Figure 1: Green growth in emerging economies.



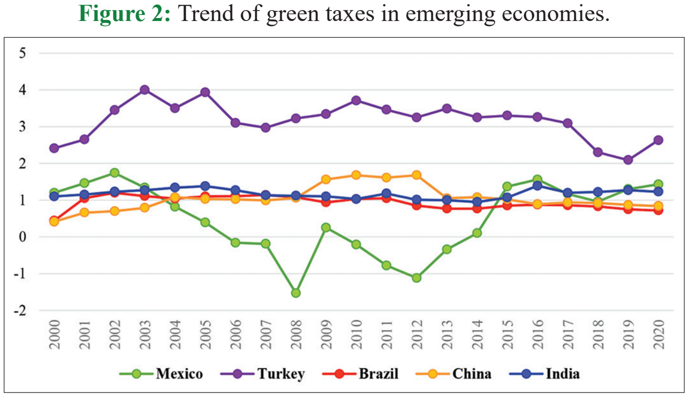
Source: World Development Indicator

development objectives (Haites, 2018; Tang et al.,2024). Emerging economies can benefit from green taxation as it offers a cost-effective way to achieve low-carbon transformation and promote inclusive and equitable growth. Figure 2 exhibited the trend of environmental taxes in emerging economies. At present, the trends of green taxes are evidently volatile giving the uncertain policy measures, however, on the plus side, the existing uncertain movement underlies the potentials to recognize transition from high and low periods of taxation trends, thereby asymmetric relationships are crucial to be identified.

On the other hand, to ensure the effectiveness of green taxes, emerging economies must focus on forming tax reforms that align with their specific environmental challenges. Imposing taxes on commercial activities has proven to be a beneficial and effective strategy for reducing fossil fuels utilization which reduces air pollution, promotes environmental awareness and may encourage taxpayers to find different ways to eliminate harmful waste, contributing to SDG3 and SDG15. Alongside it can also help to generate revenue at a lower cost for the economy compared to conventional taxes. By utilizing taxes on carbon and fuel instead of payroll taxes, the shadow economy can be lowered, promoting formal employment, which is essential for emerging economies and supports SDG8. However, the suggestion to tax industrial activities based could face resistance from state governments, as it may lead to lower revenue from the industrial sector (Saleem, 2005). Therefore, it is important to investigate the link between green taxation and sustainable economic development. However, research on this topic is currently limited, leaving room for further exploration to determine the impact of green taxation on green growth. It is also worth noting that the taxation process is influenced by the economic conditions of the country, and the relationship between green taxation and growth development may differ between developed and emerging nations (Mehrara, 2007). Manifestly, the revenue generated through taxation promotes investment at various levels. In similar vein, green investment positively influences developing nations' financial or economic sectors (Chen et al., 2022).

The financial industry has played a significant role in driving human progress for centuries, but it is essential to use global savings wisely, especially in areas where a universal financial system is in place (Nureen et al., 2022). Proper investment can enhance human lifestyles, and environmental issues can be addressed through the efficient utilization of financial reserves (Xiong et al., 2022). In the last two decades, the investments trends towards clean energy projects have witnessed rising trends and captured investors' attention, particularly in emerging blocks due to their promising growth potential. However, research in this field is limited regarding the effectiveness of green investments in the context of sustainable development. The growing inclination of financial sector towards sustainable investment (Habiba and Xinbang., 2022), which is also known as green finance, green investment, or sustainable finance (Chishti and Sinha, 2022) trails to benefit the environment, support climate change mitigation and adaptation measures, and facilitate sustainable development. Investing in clean energy projects, ecological friendly products and conservation process is crucial for mitigating environmental consequences and achieving green growth (Fu and Irfan, 2022; Irfan and Ahmed, 2022). Therefore, it can be conceived that green investments hold the potential as an innovative strategy to facilitate economic gains and environmental conservation, making it an essential aspect of green growth (Wei et al., 2022).

Figure 2: Trend of green taxes in emerging economies.



Source: World Development Indicator

In an effort to combat existing environmental vulnerabilities, the current study makes a valuable contribution to existing literature by examining the significance of sustainable environmental measures of green taxation, green investment, and green technology. Firstly, the study focuses on green growth as a dependent variable, which has received less attention in literature, and aims to explore its association with sustainable development measures. Secondly, the study analyzes the top five emerging economies, namely Brazil, China, Mexico, Turkey, and India, which have contributed significantly to global economic growth in recent years. However, their economic development has also led to ecological destruction due to excessive ecological footprints, emission discharge and resource depletions, making sustainability a critical concern. Thirdly, the study employs the novel methodology of Method of Moments Quantile Regression (MMQR) to investigate green growth behavior at several quantiles. This approach is preferred over traditional methods as it is more robust and effective in handling the non-parametric procedures than conventional statistical approaches, as economic and financial variables usually possess asymmetric natures (Khan et al., 2025).

The remaining paper is structured as follows. A literature review is discussed in the second section. The third section discusses the data/model description tracked by methodology in the fourth section. The outcomes are discussed in the fifth section, and the study concludes in the sixth section.

2. REVIEW OF LITERATURE

There has been much debate over how green growth would impact environmental quality, employment, climate variability, and sustainable development. However, the outcomes are conclusive in supporting these claims (Wang et al., 2021). Additionally, literature takes into account a variety of important factors that influence green development. This section reviews the existing literature and discusses some critical factors and their impact on economic growth.

2.1. Green/Environmental Technologies and Green Growth

Following several researchers (Hascic et al., 2008; Liu and Liang, 2013; Sohag et al., 2015), the impact of technological innovation on environmental performance and economic development is probed. However, studies confirmed that reducing carbon emissions or improving ecological performance is attainable only because of technological innovation with compelling factor productions. Technological innovations are the finest approach to enhance the quality of resources by improving environmental performance, which raises the individual's standard of life and supports social stability, as stated by Klewitz and Hansen (2014). The cross-sectional datasets of 71 countries that joined GEM 2002 have been considered. Wong et al. (2005) explored the impact of technological innovation on economic development; their analysis exposed that technological innovation has a significant positive effect on economic growth.

Moreover, the dynamic connection between technical innovation with environmental performance and economic development has been examined by Murad et al. (2019) for Denmark from 1970 to 2002. Their empirical findings revealed that technical innovation positively connects environmental performance and economic development in Denmark. Technological innovation has reduced emissions and supported environmentally friendly instruments with minimal carbon footprints. The data of 127 manufacturing firms were collected from 1989 to 2004 to examine the influence of technological innovation on environmental performance. According to Carrión-Flores et al. (2013), technological innovations have significantly reduced emissions. A similar study by Du et al. (2019) found the positive impact of technological innovation on reducing carbon emissions by using data from 71 nations from 1996 to 2012.

In the primary literature by Huang et al. (2019), Nassiry (2019), and Azhgaliyeva et al. (2019), the production-based emissions and consumption-based emissions used as an alternative to green development. In opposition, the present study took adjusted net savings, excluding particulate emission damage as a proxy of green growth. Previous studies like Lee and Chou (2018), Wang et al. (2021), Hao et al. (2021), Yang et al. (2021), Wang et al. (2021), and Fernandes et al. (2021) hold up EAMFP as a green development indicator used for examining the empirical model. Their point of view for developed and developing economies is that green development is robustly influenced by green innovation. Nosheen et al. (2021) analyzed the influence of green technology on green growth for European Union nations by using the cross-sectional dependence and Westerlund cointegration approach. The results exhibit that, to a large extent, green technology increases green development.

Further findings point out that factors like energy usage and production-based technologies hurt green growth. Similarly, for sample G7 nations, Wang et al. (2021) studied the impact of technological innovation or green patents on green development using the Bayer-Hanch Cointegration test, which shows that in the long-run GDP and technological innovation, or green patents have an incredible effect on green growth. The dependence of green development on technological innovation and GDP has also been analyzed. Sohag et al. (2021) too explored the relationship between green development, energy, and technological innovation for sample OECD countries. By employing the CS-ARDL approach, they presumed that technological innovations and green development have a long-term positive relationship.

Finally, some studies argued that the position of technical innovation in environmental performance is superficial in green development, leaving the role of innovation in green economic growth unexplored. A few studies have examined the relationship between technological innovation and green development. Ling Guo et al. (2017) utilized data from 30 regions of China during 2011-2012 and displayed the positive effect of technological innovation on green economic development. Likewise, Ulucak (2020) observed the effect of environmental-related technologies, renewable energy, and nonrenewable energy on the green economic development of BRICS economies. The results of the analysis exhibited the positive impact of environmental-related technologies and renewable energy in raising the green economic development of BRICS economies.

2.2. Green/Environmental Taxation and Green Growth

The main objective of an environmental tax is to generate revenues for the nation and to primarily bring about behavioral changes in businesses by utilizing environmentally friendly technologies and on consumers to consume fewer pollutant products so that environmental harm could be reduced (Borozan, 2019; Shahzad, 2020). Carbon taxes significantly alter the composition of production and consumption, encouraging carbon-neutral production and consumption of energy-efficient products (Shahzad, 2020; Mardones and Baeza, 2018; Tol, 2018). Environmental taxes help lessen emissions and support green innovations, low carbon, and a good environment (Shahzad, 2020). Similarly, Ligthart and Van Der Ploeg (1999) displayed that environmental taxes can accomplish multiple aims like sustainability, economic development, increased employment, and engrave labor taxes (Shahzad, 2020). Moreover, Pearce (1991) asserted that as most taxes misrepresent incentives, an environmental tax approves a misrepresentation, which is the consequence of the extreme usage of ecological services. The "double dividend" hypothesis also forecasts that environmental taxes can increase profits to approve other economic misrepresentations (Pearce, 1991). Nevertheless, environmental taxes can increase the production cost for manufacturing firms and compromise their international competitiveness (Mulatu, 2018). Moreover, manufacturing firms can transfer the increased cost of the environmental tax to their customers, thus harming low-income people and worsening income inequality (Fremstad and Paul, 2019; Oueslati et al., 2017). If the cost of the environmental tax is passed on to customers, the environmental tax may undermine the fight against environmental deprivation instead of only maximizing the state revenues (Lin and Li, 2011; Vehmas, 2005). Environmental taxes reduce emissions as presumed by the literature (Haites, 2018; Miller and Vela, 2013; Lin and Li, 2011; Morley, 2012). Apart from the above studies, Nakata and Lamont (2001) for Japan also noticed that environmental taxes reduce emissions and account for energy usage with lower emissions. Similarly, the studies by Lu et al.

(2010), Xu and Long (2014), Guo et al. (2014), and Zhang et al. (2016) also concluded environmental taxes could diminish carbon emissions in China. Furthermore, Borozan (2019) employed a quantile regression approach and analyzed that energy tax enhances energy consumption for EU countries that consumes subtle energy; however, at higher quantiles, energy tax hardly diminishes energy consumption. Thus, Hotunluoğlu and Tekel (2007) had not found that environmental taxes reduce emissions for 18 European nations. Likewise, for Malaysia and Romania, Loganathan et al. (2014) and Radulescu et al. (2017) did not observe that environmental taxes significantly reduce emissions, respectively.

Similarly, Lin and Li (2011) did not find that environmental taxes helped lessen carbon emissions. Liobikienė et al. (2019) did not discover that energy taxes affect greenhouse gas emissions in EU countries. On the other hand, Aydin and Esen (2018), for a group of 15 European countries, analyzed that environmental taxes diminish emissions and encourage technological innovation. For a group of OECD countries, a one euro increase in ecological taxes decrease carbon emissions from nonrenewable energy consumption by 0.73%, as highlighted by Sen and Vollebergh (2018).

2.3. Green/Sustainable Investments and Green Growth

Globally, research scholars experienced four phases of green finance in their literature, i.e., the evolution of green finance, high development, rolling, and expeditious growth. The concept of green finance was developed from the period 1998 to 2002. Ning et al. (2022) assert that green finance is an essential connection between economic and ecological industries and significant fiscal innovation in pursuit of environmental preservation. From 2000 to 2005, green finance went through a sturdy evolution. Ecological conservation was the base for establishing the foundations of finance, which constituted the financial services industry as a specific service sector (Jinru et al., 2021). Afterward, the period from 2006 to 2011 was challenging for green finance. In underdeveloped and developing states, financial institutions are growing green financial services. Anh Tu et al. (2021) conducted surveys, in-depth analyses, and consideration of regional green investment. In 2012, the conception of green finance was swiftly developing. In the advancement of green finance, the rights price of business enterprises, individual investors' awareness, and financial organizations' sustainability were all discovered. These investigations show that the analyses on green finance have advanced from top to bottom and from simple to composite. Globally, this progress has become possible in collaboration with the rising knowledge of environmental confronts. The target of green finance is ecological sustainability, described by Jinru et al. (2022) as the corresponding development of those beyond three.

Contrary to other countries' academic worlds, local studies on green finance theory have only recently begun in the United States. According to Zhang et al. (2021), green finance is a distinct financial approach that organizes the requirement of financial services to environmentally friendly and sparkling businesses. Furthermore, Nawaz et al. (2021) assumed that the financial industries are the basic needs of green finance in protecting the environment. Sun et al. (2022) also concluded that financial tools such as green finance were created for environmental security. Conversely, the third and last perspective is broad and has achieved well-known recognition in the USA's intellectual world. Several studies about green finance from this viewpoint are remarkable. Zhang and Vigne (2021) found the meaning of green finance, measurement, and structure. The authors employed a fixed-effect model on the dataset of China's six central provinces to examine the effect of green investment on regional economic development and propose policy recommendations.

The above-discussed literature has several gaps which need to be fulfilled in the current study. It has been evident from the reviewed literature that there is a lack of studies establishing the association of green technology, green taxation, and green investment with green growth. Several studies used economic growth as a dependent variable, but green growth is still unexplored. Moreover, the carbon tax is employed in various studies; however, green taxation is not considered. Technology and innovation have also room to explore in terms of green technology. Given that, the current study fills these gaps, especially in the context of emerging nations.

3. DATA DESCRIPTION AND THEORETICAL FRAMEWORK

Based on the existing literature, a theoretical framework has been developed to fulfill the study's objectives. The functional form of the relationship between green growth (GGR) with green taxation (GTX), green technology (GTC) and green investment (GIN) can be presented as follows.

$$GGR_{it} = f(GTX, GTC, GIN) \quad (1)$$

Green growth is referred to as natural resources that enable the provision of ecological facilities (Hussain et al., 2022). Similarly, green growth relates to the detachment of economic expansion from resource use and adverse environmental effects (Allan and Meckling, 2021). Green growth is a strategic route to diversify the economic path toward sustainability. Given the influences of green growth, green technology is an essential factor, as implementing eco-friendly technology is crucial in the industrial sector of emerging countries (Afshan and Yaqoob, 2022). For the successful execution of technology, government policies also play a significant role. In this context, green taxation can help to curb harmful emissions. Moreover, the revenue generated through green taxation can be invested in green investment projects that eventually boost green growth. Based on these theoretical channels following baseline regression model for longitudinal data is presented.

$$GGR_{jt} = \gamma_0 + \gamma_1\ GTX_{jt} + \gamma_2 GTC_{jt} + \gamma_4 GIN_{jt} + \varepsilon_{jt} \quad (2)$$

Where "j" presents the cross-sections and "t" symbolizes the time.

The present study utilizes the yearly data of green growth measured as Adjusted net savings, excluding particulate emission damage (% of GNI) and retrieved from the web source of the

World Development Indicator. Green taxation is measured as environmental taxes as the percentage of GDP and Green technology is measured as the total percentage of green-registered patents. The data for both variables is obtained from OECD. Likewise, the data on green investment is taken from IRENA and measured as an investment in green energy as a percentage of GDP. The overall data ranges from the period of 2000 to 2023. A detailed description of the variables is flourished in Table 1.

The visual characteristics of all variables are enhanced by correlation significance, regression fitted line and distributional featured presented in Figure 3. The correlation coefficients are displayed at left panel, the baseline regression model with fitted line is displayed at right panel and distribution testing is exhibited in the diagonal. The stars present the significance of correlation coefficient. For Mexico and Turkey, the moderate correlation is observed between green growth and green taxation, green investment and green innovation. On the flip side, strong and significant correlation is found for India and Brazil. Similarly, all variables deviate from normality indicates the nonlinear behavior and support the implementation of MMQR approach.

4. METHODOLOGY

There are several econometrics techniques to deal with the longitudinal data like the Fixed Effects Ordinary Least Squares (FEOLS), the Dynamic Ordinary Least Squares (DOLS), and the Fully Modified Ordinary Least Squares (FMOLS). All these methods are meant to get robust and approximate estimates. The FEOLS is developed through Driscoll and Kraay standard errors, whichever give a consistent estimate with autocorrelation up to specific lag and general forms of cross-sectional dependency. Nonetheless, Pedroni (2004) paid attention to the fact that the cross-sections are heterogeneous in terms of variation in mean and adjusting the cointegration equilibrium. Pedroni commenced the FMOLS approach to tackle these problems, which encompasses individual-specific intercept and undergoes “heterogeneous serial auto-correlation of the error processes” over every cross-sectional unit. The DOLS estimators given by Kao and Chiang (2001) are the more revised version of the panel estimation approach. The DOLS method gives more robust and precise estimates than FEOLS and FMOLS stand on Monte Carlo simulations in finite samples. To overcome the endogenous response, the DOLS approach also coped with endogeneity problems through the extension of lead and lagged differentials. The above-mentioned linear estimation techniques only concentrate on the average distribution of data rather than any other condition.

Table 1: Data and sources

Indicator	Variable	Description	Source
GGR	Green Growth	Adjusted net savings, excluding particulate emission damage	WDI
GTX	Green Taxation	Environmental taxes as a percentage of GDP.	OECD
GTC	Green Technology	Total percentage of green-registered patents	OECD
GIN	Green Investment	Investments in green energy (Million USD)	IRENA

Conversely, the panel quantile regression portrays the relationships among variables at various quantiles (Sarkodie and Strezov 2019). This approach was initially given by Koenker and Hallock (2001) to estimate the quantile (location) asymmetries or various quantiles of the endogenous variables, which depend on exogenous variables. Exclusively, the quantile estimation approach is more dynamic in detecting outliers in the estimation. This approach is suitable if the relationship between the conditional means of variables is weak (Binder and Coad 2011). Still, the non-crossing estimates are lacking in simple quantile regression, while estimators are calculated for various quantiles, resulting in invalid distribution for the response.

The present study implements a distinctive estimation approach, i.e., the Method of Moments Quantile Regression (MMQR) with a fixed-effects approach presented by Machado and Santos Silva (2019). However, the panel quantile regression is robust to outliers; it cannot examine heterogeneity across panel cross-sections. By allowing the individual effects, the MMQR consents to “conditional heterogeneous covariance effects” of the elements of carbon emissions to affect the whole distribution, as compared to panel quantile regression by Canay (2011) and Koenker (2004), which only permits shifting means. The MMQR is more suitable when the model has endogenous explanatory variables, and the panel data is described with individual-specific effects. The MMQR gives robust estimates in various conditions even though the model is nonlinear.

The MMQR is the leading approach to other nonlinear approaches as they are portrayed exogenously as the threshold is not preferred by data-driven procedure, instead set to zero (Shin, et al. 2014). Moreover, the method allows for location-based asymmetry because the parameters might be conditional on the location of the dependent variable, carbon emission, within the conditional distribution. Based on these reasons, the MMQR approach is deemed the most suitable approach that includes both asymmetric and nonlinear connections by handling heterogeneity and endogeneity altogether. The MMQR is also intuitive since it provides non-crossing estimates across structural quantiles. The conditional quantile estimations Qτ(τ| X) for the locational-scale variant model describes as;

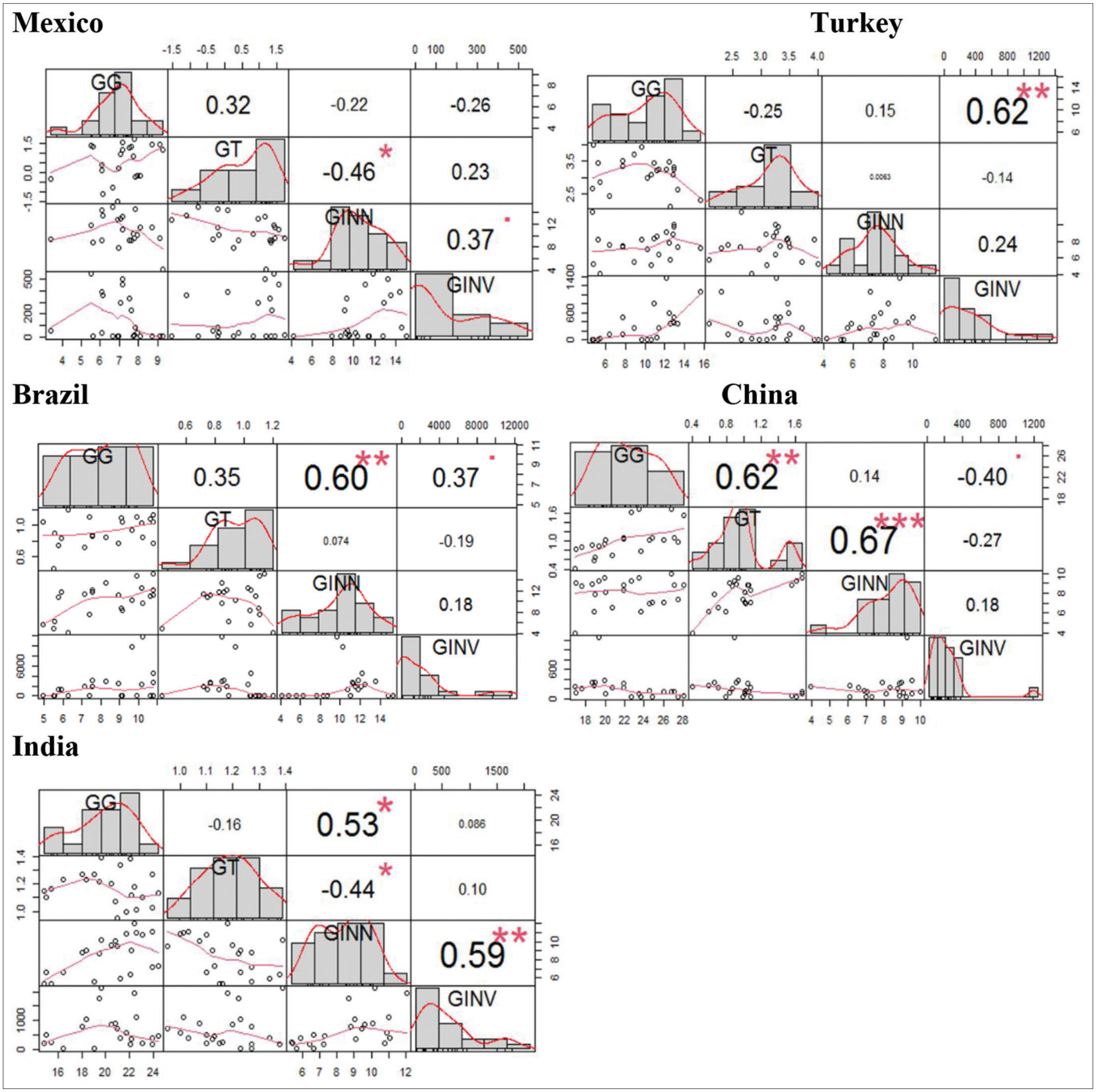
$$Y_{it} = \beta_i + X_{it}^{'}\theta + (\gamma_i + W_{it}^{'}\alpha)\varepsilon_{it} \tag{3}$$

Where the $P\{\gamma_i + W_{it}^{'}\alpha > 0\} = 1$. $(\beta,\theta',\gamma,\alpha')'$ are the estimated parameters (β_i, γ_i), i=1,……., n, expressed as individual fixed effects, and W is a k-vector of preferred components of X that have some differentiable transformations with factor 1 presented as,

$$W_p = W_p(X), p=1,\ldots\ldots k \tag{4}$$

Where X_{it} is iid for any Fixed i and independent across time (t). ε_{it} is also iid (independent and identically distributed) through time (t), across individuals (i), and orthogonal to X_{it}, which makes it possible to ensure the moment conditions of Machado and Santos Silva (2019). Equation (3) proceeds with the following:

Figure 3: Connectedness among the variables. ***, ** and * represent the significance level at 1%, 5% and 10%, respectively



$$Q_{\tau}\left(\tau/X_{it}\right) = (\beta_i + \gamma_i q(\tau)) + X_{it}^{'}\theta + W_{it}^{'}\alpha q \tag{5}$$

Here $X_{it}^{'}$ is a vector of independent variables like GTX, GTC and GIN. Q_{τ} (τ/X_{it}) denotes the dependent variables distribution $Y_{it,}$ (GGR) in structural quantiles, which is conditional on the distribution of independent variables $X_{it,}$ with individual i and quantile τ fixed effects shown by the scaler coefficient represented as b_i $(\tau) = \beta_i + \gamma_i$ $q(\tau)$. Nevertheless, the intercept shift fails to signify individual effects, contradictory to the OLS fixed effects. All the parameters are fixed over time, and their heterogeneous effects are admissible to alter across the structure quantiles of the conditional distribution of the dependent variable Y. The τ^{th} sample quantile describes the $q(\tau)$ function, which is acquired through the optimization issue as shown below,

$$min_q = \sum_i \sum_t \rho_{\tau}(U_{it} - (\gamma_i + W_{it}^{'}\alpha)q) \tag{6}$$

The check function from the above equation is defined as

$$\rho^{\tau}(V) = (\tau - 1)VI\{V \leq 0\} + \tau VI\{V > 0\} \tag{7}$$

5. RESULTS AND DISCUSSION

There are some prerequisite examinations of longitudinal data, i.e., to check cross-sectional dependence and order of integration before embarking on the formal analysis. Table 2 furnishes the outcomes of the cross-sectional dependence and CIPS unit root test. It has been evident from the CD test that all variables are significant at a 5% level of significance, indicating that green growth, green taxation, green investment, and green technology are cross-sectional dependent. Various implications are associated with the cross-sectional dependence of the variables for testing stationarity properties and cointegration. The second-generation CIPS unit root test portrays that, at a level, the variables have unit root concerns that resolve at first difference. Concludingly, green growth, taxation, investment, and technology are stationary at first difference.

Broadly, the unit root properties are also accessed through the IPS unit root test, as it examines the stationarity properties of the variables without considering the cross-section dependency. Table 3 presents the result of stationarity analysis at the level and first difference. The outcomes reveal that green growth, taxation, investment, and technology are stationary at first difference at 1% level of significance.

Moving toward the cointegration analysis, the current study employed a first-generation Engle-Granger-based cointegration test (Table 4) and a second-generation Westerlund test (Table 5). Engle-Granger-based cointegration test scrutinizes cointegration among the variables without incorporating cross-sectional dependence. Several test statistics proposed by the test indicate that green taxation, innovation, and technology are cointegrated with the green growth of the emerging bloc of countries.

The second-generation cointegration test of Westerlund (2007) has been used to test the cointegration among the variables. The test offers panel and group-based tests statistics for evaluating the cointegration level between the variables. Table 5 provides the fallouts of the test. The outcomes of the panel and group-based tests endorse the long-run association among the variables with high significant value at a 1% significance level. The results confirmed that green technology, investment, and taxation are cointegrated with green growth. It implies that green technology encourages investors toward green investment projects. Green tax will also help protect the environment and must be imposed to promote green projects. The outcomes are valuable for emerging nations where economic growth is not compromised with ecological welfare. Also, innovation and technology should be augmented with the taxation and investment process to enhance the economic benefits. The error correction term is negative and significant $\left(\frac{Pa}{T}=-0.1724\right)$, stipulating that long-run divergences are required a 17.24% speed of adjustment to restore the equilibrium relationship between green taxation, investment, and technology with green growth. It has been evident that the adjustment rate is low as the process of green development in emerging countries is less friendly to green determinants.

Cointegration among the variable motivates us to enquire about the quantile-dependent relationship between the variables. The Method of Moments Quantile Regression (MMQR) approach is employed in the current study (Table 6). Green taxation is highly significant at middle and high quantiles of green growth; however, their effect is more potent at high quantiles. The tax imposed on the carbon-releasing industries, the nonrenewable energy consumers, and petroleum emitters companies can improve the environmental quality of emerging countries. The results are in line with the work of Haites (2018). Borozan (2019) emphasizes that taxes on energy products can minimize environmental pollution and increase the financial stability of any country. It has also been noted that taxation is insignificant at all lower quantiles of green growth, showing that green economic progress cannot boost without implementing green taxes.

At various quantiles of green growth, green investment is positively significant with minor effect change from lower to higher quantiles.

Table 2: Results of cross-sectional dependence and CIPS unit root test

Variables	CD test	p-value	CIPS test	
			Level	1st difference
GGR	6.224	0.000	0.073	−8.652***
GTX	13.552	0.000	−0.210	−8.473***
GIN	20.867	0.000	−0.792	−6.949***
GTE	22.971	0.000	−0.674	−13.750***

***, ** and * represent the significance level at 1%, 5% and 10%, respectively

Table 3: Results of stationary analysis

Variables	Im, Pesaran and Shin			
	I (0)		I (1)	
	C	CandT	C	CandT
GGR	−1.504	−1.166	−6.281***	−6.210***
GTX	−0.844	−0.126	−4.995***	−4.128***
GIN	−1.523	−1.015	−3.265***	−3.002***
GTE	−1.593	−0.072	−4.904***	−4.700***

***, ** and * represent the significance level at 1%, 5% and 10%, respectively

Table 4: Results of Pedroni (Engle-Granger based) panel cointegration in the emerging bloc

Estimates	Stats.	Prob.
STD=*f* (GTX+GIN+GTE)		
Panel v-statistics	13.483	0.000
Panel rho-statistics	14.393	0.000
Panel PP-statistics	−11.229	0.000
Panel ADF-statistics	−6.262	0.000
Alternative hypothesis: Individual AR coefficient		
Group rho-statistic	16.255	0.000
Group PP-statistic	−8.923	0.000
Group ADF-statistic	−10.140	0.000

Table 5: Results of Westerlund's (2007) bootstrap panel cointegration

Statistics	Value	Z value	P-value	Robust P-value
Gt	−18.988	−9.328	0.000	0.000
Ga	−13.855	−12.868	0.000	0.000
Pt	−16.126	−23.058	0.000	0.000
Pa	−18.107	−21.369	0.000	0.000

Table 6: Results of panel quantile estimations (MMQR)

Variables	Lower quantiles			Middle quantiles			Higher quantiles		
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
GTX	0.035	0.074	0.120	0.144*	0.122**	0.079**	0.178**	0.177***	0.187***
GIN	0.038	0.176*	0.192*	0.176**	0.052**	0.116***	0.119***	0.127***	0.183***
GTE	0.115**	0.177**	0.173**	0.159**	0.161**	0.170**	0.191**	0.110***	0.175**

***, ** and * represent significant level at 1%, 5% and 10% respectively. Source: Authors' Estimation

At all middle and high quantiles, the investment coefficient is highly significant. The result has various implications in the context of emerging nations. It is worth noting that when green growth is in extreme conditions, the investment in green products also flourishes. There is a need to reconstruct the financial system of emerging countries, i.e., transform the brown growth process into a green system. Consequently, green investment enhances economic progress without compromising ecological safety. The results are consistent with Wang et al. (2021), who reveals the positive impact of green investment on the environmental sustainability of China.

Regarding the coefficients of green technology, the outcomes showed a positive and significant quantile association with green growth in the emerging bloc. These results exposed that green technology encourages environmental sustainability. It can alleviate pollution by implementing advancements in manufacturing tools. These steps toward green innovation eventually accelerate economic growth. It also helps to enhance energy efficiency in emerging nations to improve ecology. Moreover, the outcomes of MMQR flourish in that at each level of green growth, the effect of technology is positive on emerging nations' growth. These results align with the study of Ahmed et al. (2022) who examined green innovation's impact on green growth in South Asian countries. The authors conclude that green innovation positively impacts the green growth of emerging Asian countries.

6. CONCLUSIONS AND POLICY IMPLICATIONS

The post-crisis effects of environmental and economic trade-offs are now amply demonstrated to achieve sustainable development. Global economic growth is harmed by climate change, contributing to ecological instabilities and unsustainable development. All governments, organizations, and enterprises must act quickly to discover climate change solutions that support their efforts to achieve growth objectives while minimizing environmental effects. Thus, the current study intends to explore the relationship between green taxation, green investment and green technology with green growth in emerging countries. The advanced Method of Moments Quantile Regression (MMQR) approach is utilized in the study to acquire the fruitful benefits of the study. The variables' cross-sectional dependency and stationarity properties are checked through CSD, CIPS and IPS testing procedures. First and second-generation cointegration tests are utilized to explore the long-run equilibrium among the variables. After confirming the cointegration, estimates of MMQR were examined at several quantiles of green growth. The outcomes suggest green environmental taxes, investment, and technology can enhance green growth.

Based on the outcomes of the current study, the following policy implications are suggested in the context of emerging countries.

- The policymakers of emerging countries should revise their sustainable policies for introducing green technology advancement across the region. The government should promote green investment plans in industries, as emerging nations heavily depend on trade activities associated with the country's manufacturing sector. Potential developers and users of climate-friendly technologies should be encouraged to make the necessary investments through suitable policy signals, such as tax exemption for using green technology services and systems. Alternatively, the government could priorities the utilization of public research and development (RandD) funds to promote green innovation and patenting in renewable energy technology. Economic growth leads to ecological destruction; thus, limitations should be imposed by the government on trading firms. Likewise, the green energy process should be implemented to acquire efficient output from the energy sector.
- Governments should design effective environmental taxes that commensurate with the environmental damage. These would include energy taxes, motor vehicle taxes as well as taxes on carbon, waste, and plastic. By determining the appropriate tax rate to represent environmental damage, the government could ensure that the environmental cost of polluters' actions is reflected in their costs. This incentives the polluters to minimise pollution at the lowest possible cost to society. For emerging countries, economic growth is of immense importance; thus, green taxation enhances the environmental quality without compromising economic and financial gain.
- Promoting green economies and fostering green investments should be the core objective of emerging countries. Financial investment augmented with green products drives toward sustainability. In order to create a favorable investment environment, governments must implement good macroeconomic policies that promote long-term economic growth and a balanced external account. Therefore, external debts must be controlled through stringent policies. To attract private sector investment in the green economy, the government must take the lead in developing policies to support and motivate eco-friendly investment for industries in addition to investment priorities and spending in areas that promote green economic sectors.

The proposed policies may assist emerging countries in making the necessary progress toward equitable economic growth as well as environmental sustainability.

Although the current study comprehensively elaborates the quantile-dependent relationship between green growth with green taxation, green investment, and green technology; yet few limitations are there, providing room for future work. The future studies study can be done for more countries like BRICST, OECD, or BRI nations by taking the same determinants. Likewise, more variables can be incorporated into the model to enhance the study's implications. Lastly, other advanced panel data techniques can be employed in future studies.

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