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Effects of Economic Growth, Foreign Direct Investment, and Renewable Energy Consumption on Environmental Pressure in NICs

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Abstract

Despite extensive research on the growth–environment nexus, limited evidence considers the joint effects of foreign direct investment and renewable energy on ecological sustainability using both demand– and biocapacity–based measures. In this context, this study investigates the effects of economic growth (EG), foreign direct investment (FDI), and renewable energy consumption (REC) on environmental degradation in the framework of the environmental Kuznets curve (EKC) and the pollution haven and pollution halo hypotheses for newly industrialized countries (NICs), which include Brazil, China, India, Indonesia, Malaysia, Mexico, the Philippines, South Africa, Thailand, and Türkiye. This study employs the ecological footprint (EF) and, as a core innovation, the ecological footprint pressure index (EFPI), a biocapacity–adjusted indicator integrating environmental demand and supply constraints to provide a more holistic assessment of environmental degradation (ED) beyond conventional measures. The study employs the method of moments quantile regression (MMQR), a novel estimation technique that goes beyond traditional mean–based estimators by capturing distributional heterogeneity across different levels of ecological degradation. The study results are as follows: (i) The findings confirm the EKC hypothesis, implying an inverted U–shaped relationship between EG and ED. (ii) Furthermore, the study reveals a U–shaped relationship between FDI and EF. In contrast, an inverted U–shaped relationship is found between FDI and EFPI, indicating that although FDI may initially raise ED, improvements in regulatory quality and environmental governance can mitigate pressure over time when biocapacity is considered. (iii) Finally, the results show that REC reduces ED, highlighting the central role of energy transition policies.

Plain Language Summary

Economic growth and foreign investment can drive development, yet they may simultaneously intensify pressure on natural resources. This study investigates the effects of economic growth, foreign direct investment, and renewable energy consumption on environmental sustainability in newly industrialized countries. The central premise is that environmental pressure depends not only on the extent of resource use but also on the capacity of nature to regenerate. To capture this distinction, the study employs two complementary measures: one reflecting resource consumption (EF) and another adjusting for ecological carrying capacity (EFPI). The findings reveal that economic growth initially exacerbates environmental pressure but tends to mitigate it beyond a certain income threshold, whereas the effect of foreign investment differs depending on the environmental measure used. Renewable energy, by contrast, consistently alleviates

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environmental pressure. Overall, the findings stress that clean energy expansion and effective environmental governance are essential to guide economic growth and foreign investment toward sustainable outcomes.

Keywords
sustainable development, ecological footprint pressure index, pollution haven/halo hypotheses, environmental degradation, environmental Kuznets curve

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The 21st century has brought profound economic, political, social, cultural, and ecological challenges, with several planetary boundaries already transgressed and the current development trajectory becoming increasingly unsustainable. During the Anthropocene, in which human beings have caused a perilous shift in geologic time, the pursuit for substantial societal transformation akin to the Industrial Revolution and the reluctance to change in various societies are significant issues (United Nations Development Programme (UNDP), 2022). Delays in addressing these issues may also jeopardize the expansion of the world economy. These challenges include determining how global efforts can reconcile environmental quality (EQ) and economic growth (EG). Although environmental problems arise from EG, ecological concerns are also increasingly responsible for economic losses (UN Environment, 2019). Therefore, understanding how economic growth can be aligned with environmental sustainability has become a central research and policy question.

A trade–off between EQ and EG can be facilitated by certain factors but hindered by others. For instance, escalating trade relations due to economic globalization and financial integration among countries are the antecedent factors influencing this equilibrium. There is sufficient evidence that foreign direct investment (FDI) inflow has noteworthy adverse effects on EQ, specifically for developing countries (Balsalobre-Lorente et al., 2023; Baskurt et al., 2022; Esmaeili et al., 2023; Liu et al., 2022; Solarin & Al-Mulali, 2018). Similarly, the notion that FDI can promote economic growth and well–being has been reinforced by practice over time. However, researchers have raised concerns about how long such growth and well–being can last. The sustainability challenge is also positioned on the intricate and hotly contested link between economic activities and the environment (Murthy & Gambhir, 2017). To this end, the United Nations determined that Sustainable Development Goals (SDGs) such as SDG 6, SDG 7, SDG 11, SDG 12, SDG 14, and SDG 15 are the most connected to the accomplishment of EQ (Alvarado et al., 2021).

There are also increasingly vital concerns regarding global economic development, which has recently been disrupted by shocks such as the COVID–19 pandemic. For example, global EG slowed from 3.1% in 2022 to 2.2% in 2023, based on past global economic trends. However, FDI declined by 12.4% in 2022, mainly due to a steep 36.7% decline in developed countries, whereas FDI inflows increased by 4% in developing economies (United Nations Conference on Trade and Development (UNCTAD), 2023). These concerns also affect FDI and rising nations' inclination for renewable energy consumption (REC). Hence, it's urgent to reconsider economic and environmental policies regarding globalization, EG, and ecological concerns, particularly for developing nations.

Since the 1990s, the concept of ecological footprint (EF) has grown to encompass a wide range of socioeconomic and ecological issues (Matuštík & Kočí, 2021). It gained prominence with the study of Wackernagel and Rees (1996), who established the term "footprint" as a metaphor expressing the impact of humans on nature. The EF measures the proportion of the biosphere's annual potential for regeneration required to restore the natural resources used by certain people in a given year (Venetoulis & Talberth, 2010). Namely, the EF is accepted as a reference that indicates distance from planetary boundaries (Matuštík & Kočí, 2021). It stems from recognizing that everyone takes a portion of the biosphere's potential for production and assimilation (Wackernagel & Yount, 2000). The EF is also a widely used measure of how individuals utilize the environment by comparing the consumer footprint with the territory's biocapacity (BC), in which a negative balance indicates a measure of unsustainability (Syrovátka, 2020). However, although it mainly provides valuable insights into the demand side of EQ, the EF may not fully capture the BC that represents the supply side. Hence, it is important to consider both perspectives when evaluating EQ to avoid any potential inaccuracies or misunderstandings. To fill this gap, Wang et al. (2018) developed the ecological footprint pressure index (EFPI), which was derived by dividing the EF by the BC. Thus, a more comprehensive assessment of the ecological condition made it possible to evaluate the environment's supply (BC) and demand (EF) at the same time by using the EFPI (Hacıimamoğlu & Cengiz, 2024). Despite this, existing studies mainly rely on carbon-based indicators or demand-driven measures, leaving the supply-side dimension of environmental capacity largely underexplored. Moreover, we observed that empirical evidence examining the joint effects of EG, FDI, and REC on both EF and EFPI for NICs remains limited, which provides the primary motivation for the present study.

The sample countries of this study were limited to newly industrialized countries (NICs), namely Brazil, China, India, Indonesia, Malaysia, Mexico, the Philippines, South Africa, Thailand, and Türkiye. The concept of NICs, as described by World Atlas, refers to economies that have surpassed the developmental threshold of developing nations yet remain unclassified as developed economies (Sawe, 2017; Shahzad et al., 2021). The selection of these countries is justified for several reasons: (i) NICs accounted for 29.32% of the global real GDP in 2022. These nations engaged in 25.93% of global trade and have over $4 trillion in reserves. (ii) NICs accounted for 47.96% of the world's population in 2022 (World Bank, 2024). (iii) In addition to their growing economic share and significant impact on the global economy, the NICs are front–runners in the swift economic transformation of the 21st century. Environmental concerns in each of these countries are growing in tandem with their EG. This situation is critical not only for local populations but also for the integrity of global ecosystems. Finally, (iv) the NICs also consume most of the total worldwide energy production, including the countries that produce the most CO_2 emissions. Similarly, NICs use more renewable energy (RE) globally than any other group and are among the countries most capable of producing RE (Miao et al., 2022).

This research makes four significant contributions to the literature. First, this is among the first to examine the effects of EG, FDI, and REC on environmental degradation (ED) for NICs over the period 1990–2018 within the framework of the EKC and the pollution haven (PHA) and pollution halo (PHH) hypotheses. Second, two different indicators, the EF and EFPI, were used as measures of ED to compare results and are presented in two different models in the study. Third, researchers frequently concentrate solely on the demand aspect of the environment by using CO, CH_4, CO_2, SO_2, N_2O emissions, and EF as measures of ED while ignoring BC, which stands for the supply-side dimension of environment. However, as a more thorough measure of ED, this study uses the EFPI, which simultaneously considers the EF and BC. This allows for the analysis to consider the overlooked supply side of environment, leading to a more thorough and rational assessment of the environmental deterioration of these countries. Fourth, an innovative methodology, method of moments quantile regression (MMQR), was used to investigate the relations among variables instead of conventional testing methods that provide comparatively poor findings. This innovation made it possible to attain more consistent results and policy consequences.

The present study aims to add to these discussions by analyzing how EG, FDI, and REC affect ED using novel and inclusive parameters such as the EFPI to assess NICs. This study seeks to answer three basic questions: 1) How does EG influence ED in NICs based on the EKC hypothesis? 2) Is there any connection between FDI and ED based on the PHA/PHH hypotheses? 3) Does REC mitigate ED? To address these questions, this study employs panel data from NICs spanning the period 1990–2018. Specifically, the dependent variables are the EF, which reflects the demand dimension of the environment, and the EFPI, calculated as the ratio of EF to BC, thereby simultaneously capturing both the demand and supply dimensions of ED, while the explanatory variables include EG, FDI, and REC. Accordingly, the econometric strategy involves cross–sectional dependence and slope homogeneity tests, second–generation unit root tests, and bootstrap cointegration analysis, followed by the MMQR approach as the main estimation technique, along with simultaneous quantile regression (SQR) for robustness.

The structure of this study proceeds as follows. Section 2 covers the topic's theoretical synopsis and the literature review. Section 3 presents an explanation of the data and model specification. Section 4 also explains the econometric strategy, and Section 5 consists of the outcomes and discussion. The final section then tops with conclusions and suggestions for researchers and policymakers.

Theoretical Synopsis and Related Literature

Theoretical Synopsis

The EKC draws conceptually on Kuznets's original inverted U-shaped relationship between income inequality and economic development, which subsequent environmental research adapted to the income–environment nexus (Kuznets, 2019). Subsequent studies applied this framework to the relationship between GDP per capita and ED (Grossman, 1995; Grossman & Krueger, 1991; Selden & Song, 1994). According to the EKC hypothesis, when GDP per capita rises, ED indices initially rise and subsequently fall (Stern, 2018). Regarding the EKC, many researchers concur that ED increases with EG in earlier stages but decreases with EG in later stages (Dinda, 2004; Kasman & Duman, 2015). Similarly, in the first stages, EF grows because of EG, financial development, and the use of non–RE sources, which is a sign that the environment is being negatively affected (Shahbaz et al., 2023). Some scholars also demonstrate that EG has a significant positive effect on CO_2 in the long term and the importance of energy efficiency in improving EQ (Satari Yuzbashkandi et al., 2024). However, new research reveals that the EKC conclusions have a relatively weak empirical foundation when addressing developing nations' environmental issues (Stern, 2004). In high– and middle–income countries, an inverted U–shaped relationship between income and ecological footprint (EF) has been observed, which is consistent with the Environmental Kuznets Curve (EKC) hypothesis; however, this pattern does not hold for low– and lower–middle–income countries (Al-Mulali et al., 2015).

However, we observed that despite the extensive EKC literature, empirical findings remain limited for developing and newly industrialized countries, particularly when broader ecological indicators beyond carbon emissions, such as EFPI, are considered. So, from a theoretical perspective, we consider that this limitation stems from the fact that most EKC analyses primarily capture scale effects while insufficiently accounting for supply-side ecological constraints and biocapacity measures. Figure 1 illustrates the conceptual and theoretical framework of the study.

In addition, two key theoretical frameworks are used to discuss the effects of FDI on ED: the PHA hypothesis and the PHH hypothesis. Because labor is cheap and natural resources are abundant in developing nations, FDI flows from industrialized countries to these regions. The PHA hypothesis explains trade, particularly the movement or relocation of "dirty" businesses from developed to developing areas (Cole, 2004). Similarly, according to research such as Cole et al. (2011), there is a statistically significant association between EG and environmental pollution. In addition, there has been a significant increase in several pollution generated by both domestic and foreign investment. A large body of research also suggests that developing countries with relatively loose environmental laws attract foreign capital invested in pollution-intensive industries since they save money by not having to pay high costs associated with pollution management compliance at home (He, 2006). In other words, developing countries can draw in foreign investment from industrialized nations due to a combination of factors such as low–cost labor and resources and laxer environmental regulations that lead to increased ED in those nations (Solarin et al., 2017). However, a minor but crucial element of the theoretical discussion here is also worth emphasizing. PHH contends that nations with high points of ecological guard and value can produce beneficial spillover effects for FDI, contrary to the PHA hypothesis, which argues that nations with laxer environmental regulations and worse EQ are more appealing to FDI (Chiriluş & Costea, 2023). So, a boost in labor and environmental management techniques, a transfer of clean technology, and an influx of FDI will enable developing nations to meet their targets for sustainable development (Sarkodie & Strezov, 2019).

Overall, whether FDI deteriorates or improves ED remains context–dependent and suggests the need for comprehensive indicators and country–specific analyses. In addition, this context dependency operates through competing scale, technique, and regulatory effects, which may produce divergent environmental outcomes across different EG stages. Although EKC, PHA, and PHH stem from different theoretical backgrounds, they are intertwined frameworks that can explain determinants of ED for NICs. For instance, the EKC hypothesis captures the dynamic relationship between EG and ED through the effects of scale and structural transformation. In contrast, PHA and PHH focus on the role of FDI, which highlight whether it intensifies ED through pollution–intensive specialization (pollution haven) or mitigates it through technology transfer and regulatory diffusion (pollution halo). Furthermore, These theoretical mechanisms operate simultaneously, not independently, in NICs characterized by rapid industrialization, increasing FDI inflows, and increasing energy demand. Therefore, this study aims to develop a more integrative and theoretically grounded understanding of the dynamics of ED for NICs by jointly examining these three foundational theoretical perspectives.

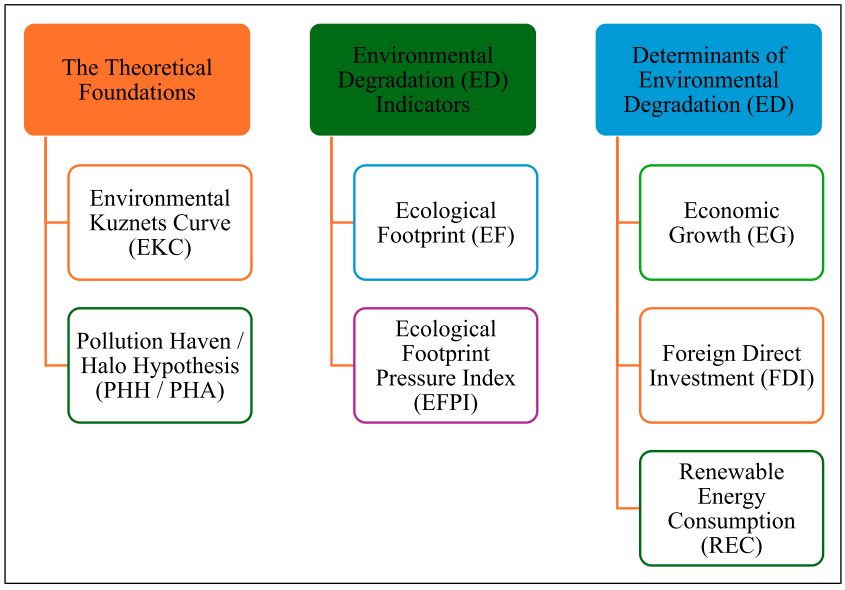

Figure 1. The conceptual and theoretical synopsis

Literature Review

Existing empirical studies on the nexus of EG–FDI–ED can be categorized into three groups: (i) studies emphasizing the PHA hypothesis, (ii) research supporting the PHH hypothesis, and (iii) analyses focusing on RE as a mitigating factor. However, most of these studies rely on single environmental measures such as carbon–based or demand–driven indicators and provide limited insight into the supply–side dimension of environmental capacity. For instance, several studies document the effects of FDI on the environment. For example, FDI has a reciprocal link with global CO_2 and exacerbates ecological deterioration (Shahbaz et al., 2015). Particularly in the long run, there is an empirical indication that FDI outcomes in more significant environmental pollution (Baskurt et al., 2022; Esmaeili et al., 2023). The EF also increases with FDI but decreases with stringent environmental regulations in APEC states (Balsalobre-Lorente et al., 2023). Some research also indicates that FDI leads to ecological deterioration in developing countries such as Türkiye; conversely, RE sources enhance EQ (Bekun et al., 2023). In addition, trade openness and energy use deteriorate EQ, and FDI exacerbates environmental deterioration and supports the PHA hypothesis (Liu et al., 2022). Xiong and Gao (2023) have also stressed that environmental regulations are very important for both environmental outcomes and the performance of green innovation, which shows how important regulatory frameworks are for determining environmental efficiency. Moreover, Gao and Wang (2023) present empirical evidence indicating that improvements in infrastructure and spatial connectivity increase carbon efficiency, underscoring that structural and policy-related factors are critical determinants of environmental performance.

The fact that industrialized nations have strict environmental laws that make it difficult for foreign firms to invest explains why FDI may exacerbate ecological deterioration in the developing world (Solarin & Al-Mulali, 2018). Similarly, Chaudhry et al. (2022) argue that the primary drivers of FDI in developing economies are technological advancements and stringent environmental regulations in industrialized nations. Furthermore, due to power dependency, multinational enterprises can exercise legal authority over governments when developing host countries rely on sophisticated resources from industrialized nations (Deng et al., 2023). Nevertheless, some studies argue that the PHA hypothesis is only valid based on several factors, such as low human capital (Lan et al., 2012). Zafar et al. (2019) demonstrate that human capital and FDI might help reduce the EF, while energy usage and EG harm the EF and natural resources. Furthermore, some studies argue that FDI from developed countries may enhance innovative technology and management techniques in developing nations, which lowers carbon emissions (Apergis et al., 2023).

Current global environmental challenges and the transition toward RE may also create opportunities for NICs to pursue more sustainable EG. For instance, some contend that RE sources such as hydropower, solar photovoltaic, wind, biomass, and geothermal have a favorable and substantial impact on the economic development of Asian economies (Jain et al., 2023). Even in the long run, energy consumption does not mitigate the acceleration of pollution; growing evidence suggests that RE has a significant role in mitigating the short– and long–term effects of ecological deterioration (Nahrin et al., 2023). Similarly, according to Li et al. (2022), RE has the potential to both improve environmental values and spur economic prosperity. Recent evidence also emphasizes that the transition to RE is essential for achieving low–carbon development and addressing global climate change challenges (Gao, Zhang, & Liu, 2025). With the increasing use of RE, the EF of a particular region is significantly reduced (Sharma et al., 2021). In this regard, recent studies highlight the growing role of artificial intelligence applications in accelerating the RE transition and enhancing system efficiency (Gao, Cai, & Wu, 2025). This mitigating role of RE reflects a reduction in fossil fuel dependency and carbon intensity by altering both demand and capacity-adjusted environmental indicators. It has also been demonstrated that using RE sources improves environmental sustainability, whereas non-renewable energy degrades EQ (Alola et al., 2019). Along the same lines, Nathaniel and Khan (2020) assert that trade, economic expansion, and non–renewable energy significantly affect environmental deterioration in ASEAN nations. Similarly, higher export quality, human capital, and better environments result from increased investment in the RE sector in developed and developing countries (Rafique et al., 2022).

According to Ozcelik et al. (2024), there is a causal connection between environmental pollution and imports and exports in China and India, foreign investment, and environmental pollution in Brazil and Russia. Similarly, high levels of FDI inflow are confirmed by the empirical data to be the cause of increased ED in the PIIGS economies, including Portugal, Italy, Ireland, Greece, and Spain. At the same time, the use of RE decreases CO_2 emissions (Balsalobre-Lorente et al., 2022). Other studies support the idea that there is a substantial and negative relation between the usage of REC and changes in EF for the MINT countries (Mexico, Indonesia, Nigeria, and Türkiye) between 1990 and 2013 (Balsalobre-Lorente et al., 2019). Additionally, using panel data from 1990 to 2017 for sub-Saharan African countries, Sarkodie et al. (2020) show that while the rising percentage of REC reduces greenhouse gas emissions, raising the joint impact of income level, governance, and REC amplifies CO_2. Moreover, climate policy uncertainty has been found to influence urban green total factor energy efficiency, underscoring the importance of regulatory dynamics in shaping environmental outcomes (Gao et al., 2024). Overall, all of these existing assessments show that empirical evidence does not adequately examine EG, FDI, and REC together using

indicators adjusted for both EF and EFPI for NICs. Furthermore, we observed that limited attention has been paid to how these variables interact within a combined theoretical framework.

Based on the theoretical framework and prior empirical evidence, the following testable hypotheses are formulated:

H_1: EG has an inverted U-shaped effect on ED in NICs, confirming the EKC hypothesis.
H_2: FDI significantly affects ED in NICs, with the direction contingent upon whether the pollution haven or pollution halo dynamic prevails.
H_3: REC significantly reduces ED in NICs.

Data and Model Specification

We evaluate the effect of EG, FDI, and REC on ED in NICs from 1990–2018, within the scope of EKC and PHA/PHH hypotheses. To this end, the study analyzes relationships among ED parameters (such as EF and EFPI) and EG, FDI, and REC. EF represents the ecological footprint per capita measured in global hectares, while the EFPI is calculated by dividing the EF per capita by the BC per capita. EG is measured by real GDP per capita, FDI represents net inflows of foreign direct investment as a percentage of GDP, and REC denotes renewable energy consumption as a percentage of total final energy consumption, as shown in Table 1. Data for EF and EFPI are obtained from the Global Footprint Network database (Global Footprint Network (GFN), 2024), while the data for EG, EG^2, FDI, FDI^2, and REC are composed from the World Development Indicators dataset (World Bank (WB), 2024).

The selection of variables is grounded in the theoretical frameworks of the EKC and PHA/PHH hypotheses. EG and EG^2 terms are incorporated to test the non-linear income–environment relationship posited by the EKC (Dinda, 2004; Grossman, 1995; Panayotou, 1993), while FDI and FDI^2 components allow for the empirical testing of the PHA and PHH by capturing the potential non-monotonic effect of foreign capital on ED (Balsalobre-Lorente et al., 2019; Cole, 2004; Cole et al., 2011; Shahbaz et al., 2015). REC is included given its widely documented role as a key factor in mitigating ED across developing economies (Xue et al., 2021). Two separate empirical models are estimated: Model 1 uses the EF, capturing the aggregate demand placed on the environment, whereas Model 2 employs the EFPI, which normalizes EF by BC. This dual-model approach enables a comparative evaluation of how the same determinants may produce divergent effects on absolute versus relative ED (Li et al., 2014; Pata et al., 2022).

Critically, EF and EFPI capture fundamentally different dimensions of ED. EF quantifies the absolute per capita ecological demand, whereas EFPI, defined as the ratio of EF to BC, measures relative environmental pressure normalized by ecological supply capacity (Zheng et al., 2020). This conceptual distinction has direct implications for the empirical findings: the same explanatory variable may exhibit different relationship patterns across the two indicators (Sun et al., 2024). Accordingly, these divergent patterns are not contradictory but rather complementary, jointly offering a more comprehensive assessment of the FDI–environment nexus in NICs (Karaduman, 2021).

The two empirical models are specified as follows:

$$\text{Model 1}: \ln EF_{it} = \alpha_0 + \alpha_1(\ln EG)_{it} + \alpha_2(\ln EG)^2_{it} + \alpha_3(FDI)_{it} + \alpha_4(FDI)^2_{it} + \alpha_5(\ln REC)_{it} + u_{it} \quad (1)$$

$$\text{Model 2}: \ln EFPI_{it} = \beta_0 + \beta_1(\ln EG)_{it} + \beta_2(\ln EG)^2_{it} + \beta_3(FDI)_{it} + \beta_4(FDI)^2_{it} + \beta_5(\ln REC)_{it} + \varepsilon_{it} \quad (2)$$

The dependent variables in Models 1 and 2 are EF and EFPI, respectively, ecological footprint and ecological footprint pressure index. The models include the following independent variables: EG, EG^2, FDI, FDI^2, and REC. Similarly, the cross-section (country–NICs), time period (1990–2018), and residual terms are denoted by i, t, and u_{it} (ε_{it}), respectively. To

Table 1. Variables, Symbol, Measure, and Source

Dependent variable	Symbol	Measure	Signs	Source
Ecological footprint pressure index	EFPI	Ratio of EF per capita to BC per capita (Global hectares)	N/A	GFN
Ecological footprint	EF	EF per capita (Global hectares)	N/A	GFN
Independent variable	**Symbol**	**Measure**	**Signs**	**Source**
Economic growth	EG	GDP per capita (constant 2015 US$)	+	WB
Foreign direct investment	FDI	FDI, net inflows (% of GDP)	+/-	WB
Renewable energy consumption	REC	REC (% of total final energy consumption)	–	WB

reduce scale differences and facilitate coefficient interpretation, all variables except FDI are transformed into natural logarithms.

Regarding the theoretical context, when FDI has a monotonically growing effect on ED, the PHA hypothesis is valid. In other words, ED rises in tandem with FDI ($\alpha 3 > 0$ and $\alpha 4 > 0$; $\beta 3 > 0$ and $\beta 4 > 0$). On the other hand, once FDI has a monotonically decreasing influence on ED, the PHH is valid. That is, FDI reduces ED ($\alpha 3 < 0$ and $\alpha 4 < 0$; $\beta 3 < 0$ and $\beta 4 < 0$). Furthermore, the U–shaped curve confirms the existence of a U–shaped non–linear link among FDI and ED. In other words, environmental deterioration declines with increasing FDI but increases after the turning point ($\alpha 3 < 0$ and $\alpha 4 > 0$; $\beta 3 < 0$ and $\beta 4 > 0$). On the contrary, in the case of an inverted U–shaped, the existence of an inverted U–shaped non–linear link between FDI and ED is confirmed. Namely, FDI leads to a rise in ED, but after the turning point, it declines ($\alpha 3 > 0$ and $\alpha 4 < 0$; $\beta 3 > 0$ and $\beta 4 < 0$).

Econometric Strategy

Cross–Section Dependence and Slope Homogeneity Tests

A shock occurring in one country might affect the others. So, cross–section dependence (CSD) must be checked to avoid biased estimates and misleading inference. In this context, the study employs the LM of Breusch and Pagan (1980), the CD_{LM} of Pesaran (2004), and the CD tests of Pesaran (2015) to determine whether CSD exists. The alternative hypothesis of CSD tests assumes the presence of CSD, while the null hypothesis claims that CSD does not exist. The study examines the presence of slope homogeneity (SH) by using Delta ($\tilde{\Delta}$) and Delta Adjusted ($\tilde{\Delta}_{adj.}$) tests proposed by Pesaran and Yamagata (2008). Neglecting slope heterogeneity can lead to misleading estimates. For the $\tilde{\Delta}$ and $\tilde{\Delta}_{adj.}$ the alternative hypothesis assumes slope heterogeneity, whereas the null hypothesis supposes slope homogeneity.

Panel Unit Root and Cointegration Tests

First–generation unit root tests ignore the potential CSD problem. Due to this fact, second-generation unit root tests should be applied in the case of CSD. In this respect, this study observes the stationarity features of the variables using two second-generation unit root tests accounting for slope heterogeneity and CSD problems: Cross–sectionally Augmented Im, Pesaran, and Shin (CIPS) (Pesaran, 2007) and Bootstrap Im, Pesaran, and Shin ($IPS_{bootstrapping}$) (Smith et al., 2004). In both tests, the null hypothesis is that a unit root exists in the panel, whereas the alternative hypothesis is that the panel is stationary.

Cointegration relationships between variables are explored using the LM established by Westerlund and Edgerton (2007) and the Durbin–Hausman (DH) cointegration tests proposed by Westerlund (2008). These cointegration tests consider slope heterogeneity and CSD issues. Furthermore, allowing the explanatory variables to be stationary at different levels, the DH cointegration test brings further flexibility to cointegration analyses. The DH cointegration test provides group ($DH_{group)}$ and panel (DH_{panel}) statistics. In heterogeneous panels, decisions are made based on group statistics, whereas panel statistics are used for homogeneous panels.

While the null hypotheses of DH_{group} and DH_{panel} statistics assume that cointegration does not exist, the alternative hypothesis of DH_{group} statistic states that cointegration exists for some cross-section units, and the alternative hypothesis of DH_{panel} statistic implies that cointegration exists for all units.

Method of Moments Quantile Regression Approach

We employ a novel and advanced practice, the MMQR, created by Machado and Silva (2019), to evaluate long–term parameters between variables. Furthermore, for robustness, the simultaneous-quantile regression technique (SQR) is applied (Koenker, 2005; Koenker & Bassett, 1978). MMQR approach has several advantages. Firstly, this method yields reliable results for non-normal distributions and non–linearity models. Secondly, MMQR considers heterogeneous and distributional differences between various quantiles of the dependent and independent variables, allowing for individual effects. Thirdly, the MMQR method successfully addresses endogeneity and multicollinearity problems. Fourthly, quantile–based tests are more powerful than traditional tests since they generate distinct coefficient estimates across quantile. In contrast, traditional tests yield estimation results based on a mean. Fifthly, MMQR is built upon a location-scale framework that endogenously models heteroscedasticity through the scale function, rather than requiring ex-post corrections. Furthermore, it employs distributional fixed effects that allow individual effects to influence the entire conditional distribution beyond conventional location shifters, thereby capturing time-invariant sources of CSD at different quantile levels. Finally, this method can deal with outliers and capture location-scale asymmetries. The MMQR equation is described in equation (3):

$$Q_Y(\tau \mid X_{it}) = (\alpha_i + \delta_i q(\tau)) + X_{it}'\beta + Z_{it}'\gamma q(\tau) \quad (3)$$

In equation (3), $Q_Y(\tau \mid X_{it})$ represents the quantile distribution of the dependent variable Y_{it} (EF and EFPI). X_{it} denotes the vector of explanatory variables that are EG, EG^2, FDI, FDI^2, and REC. Equation (3) is further reconstructed and is rendered as in equation (4). Figure 2 visualizes a summary of the empirical strategy.

$$Q_{lnEFPI(lnEF)}(\tau_k \mid \alpha_i, X_{it}) = \alpha_i + \gamma_{1\tau} lnEG_{it} + \gamma_{2\tau} lnEG_{it}^2 + \gamma_{3\tau} FDI_{it} + \gamma_{4\tau} FDI_{it}^2 + \gamma_{5\tau} lnREC_{it} \quad (4)$$

Findings and Discussion

Table 2 presents the descriptive statistics. The results revealed significant structural differences among the variables. The FDI exhibited the highest standard deviation value of 1.590. This result demonstrated that FDI levels were highly volatile among NICs. Additionally, the FDI had the minimum value of −2.757, signifying that net FDI inflows were negative in some countries. Conversely, the EG had both the highest average (8.303) and the highest maximum value (9.393). These results indicated that GDP levels were comparatively more stable among NICs, whereas FDI levels exhibited significant variability. Regarding distributional characteristics, skewness values indicated that most variables were negatively skewed, with EFPI exhibiting the strongest left-tail asymmetry (−1.546), whereas FDI was the only positively skewed variable (0.707). Kurtosis values revealed that EFPI (4.941) and FDI (4.330) displayed leptokurtic distributions with heavier tails, while EF (2.073) and EG (2.722) exhibited platykurtic distributions. The Jarque–Bera (JB) test results indicated that none of the variables had a normal distribution. Therefore, this study utilized the quantile technique instead of the conventional estimator, which provides more robust and reliable results when the assumption of normal distribution is not fulfilled. These additional statistics further justified the use of quantile-based estimation techniques in the study. Consistent with this distributional evidence, the diagnostic tests reported in the Appendix provide no evidence of multicollinearity and endogeneity but reveal the presence of heteroskedasticity, first-order serial correlation, non-normality, and functional-form misspecification (see Table A1).

It is necessary to control for the existence of CSD to obtain consistent estimates in panel data analysis. Accordingly, the study applied the LM, CD_{LM}, and CD tests. The outcomes showed that CSD existed for all test statistics, as seen in Table 3.

Then, confirming the presence of CSD, SH was checked using the $\tilde{\Delta}$ and $\tilde{\Delta}_{adj.}$ tests. Table 4 displays the $\tilde{\Delta}$ and $\tilde{\Delta}_{adj.}$ test results. The test results confirmed the presence of slope heterogeneity for Models 1 and 2.

After determining the slope heterogeneity, the stationarity properties of the variables were examined. The order of integration was determined using the CIPS and $IPS_{bootstrapping}$ unit root tests. According to the unit root test results in Table 5, all variables had unit roots at the level except the FDI and FDI^2 variables. However, in the first difference, all were stationary. As a result, the remaining variables were stationary at first difference, whereas FDI and FDI^2 variables were stationary at level.

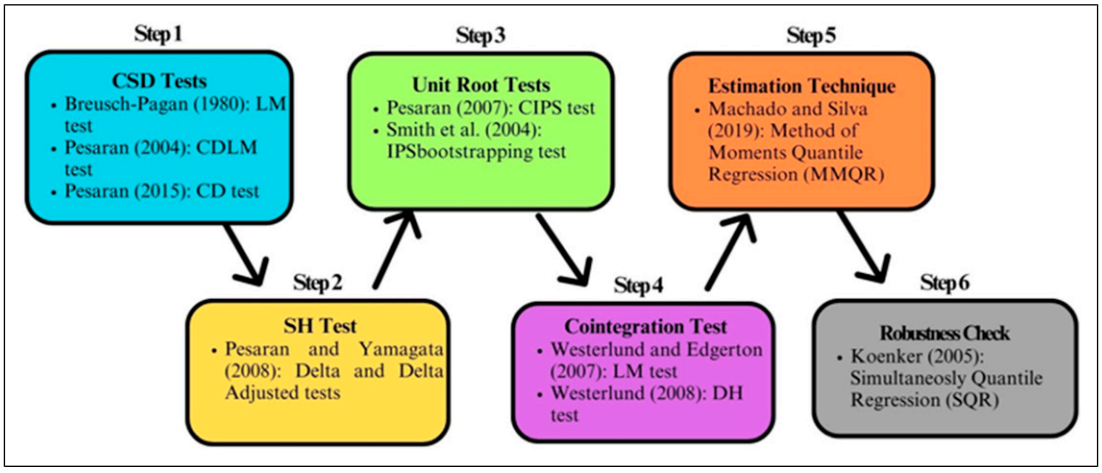

Figure 2. Summary of empirical strategy

Table 2. Results of Descriptive Statistics

Variables	Mean	Max.	Min.	Skew.	Kurt.	Std. Dev.	JB stats.
EF	0.767	1.513	−0.274	−0.544	2.073	0.471	24.730***
EFPI	0.453	1.525	−1.499	−1.546	4.941	0.671	161.002***
EG	8.303	9.393	6.268	−0.793	2.722	0.757	31.321***
FDI	2.172	8.760	−2.757	0.707	4.330	1.590	45.521***
REC	3.026	4.072	0.673	−0.851	3.411	0.749	37.006***

Source: Authors' estimation. *** divulges significance level at 1%.

Having established stationarity properties of the variables, the study investigates whether the variables are cointegrated, namely, whether they pass together in the long run. Therefore, the cointegration relationships among the variables were analyzed using the LM and DH cointegration tests. Table 6 presents the LM and DH test outcomes for Models 1 and 2 in this context. The null hypothesis asserting the existence of a cointegration relationship for Models 1 and 2 could not be rejected based on the results of the LM test, indicating the presence of a cointegration relationship. Furthermore, in the DH test, the DH_{group} test statistic was considered for heterogeneous panels and the DH_{panel} test statistic was valid for homogeneous panels. Because slope heterogeneity was verified for both models, the DH_{group} test statistic was employed to determine whether cointegration exists. According to the DH_{group} test statistic, the null hypothesis, which holds that there is no cointegration, was rejected. Thus, the variables were found to be cointegrated.

In Model 1, the EG was statistically insignificant at the 0.10th–0.30th quantiles, became significant and positive from the 0.40th quantile onward, and increased monotonically from 0.450 to 1.418 at the 0.90th quantile. EG^2 was significant and negative only at the 0.70th–0.90th quantiles, as shown in Table 7. These findings indicated that the EKC hypothesis held not across the entire EF distribution but exclusively in its upper quantiles. NICs at lower quantiles remained in the early stages of industrialization, where environmental costs had not yet reached the threshold necessary to activate compensating mechanisms such as sectoral transformation and regulatory strengthening; those at upper quantiles had surpassed this threshold, producing the structural shift that drove the declining portion of the EKC. In Model 2, EG was significant from the 0.30th quantile onward but diminished in magnitude from 1.674 to 1.444 at the 0.90th quantile, while EG^2 was significant and negative across all quantiles (from −0.170 to −0.117), as shown in Table 7. These findings supported the EKC hypothesis, yet the marginal environmental pressure of economic growth was attenuated in countries already experiencing elevated pressure levels, likely because growth was increasingly driven by less resource-intensive service sectors.

These outcomes align with previous studies. For example, the results of studies by Dinda (2004), Kasman and Duman (2015), Stern (2018), Çakmak and Acar (2022), Mahmood (2023), and Shahbaz et al. (2023) demonstrate that while EG initially exacerbates ED, its impact diminishes over time, particularly as factors such as economies of scale begin to exert influence. In contrast, the results of previous studies such as Stern (2018), Dinda (2004), Kasman and Duman (2015), and Shahbaz et al. (2023) suggest that at the initial stages, the EF has increased because of factors such as EG and the use of non-renewable energy sources. Similarly, the validity of Al–Mulali et al.'s (2015) hypothesis on the EKC based on grouping countries by high and middle–income levels is confirmed using the EF. Nonetheless, it is evident that conducting further empirical research on low–income countries would be valuable.

Regarding Model 1, the MMQR results revealed that the FDI was insignificant at the 0.10th quantile but strengthened monotonically to −0.094 at the 0.90th quantile, while FDI^2 was positive and significant across all quantiles (from 0.007 to 0.016). These findings indicated that the U–shaped relationship intensified at upper quantiles. In NICs at lower quantiles, where ED remained relatively limited, FDI inflows had not yet reached the critical mass necessary to exert measurable ecological pressure. At upper quantiles, the negative FDI confirmed that FDI initially reduced the EF through technology

Table 3. CSD Test Results

Variables	Breusch and Pagan (1980) LM	Pesaran (2004) CD_{LM}	Pesaran (2015) CD
EF	81.260***	3.822***	24.974***
EFPI	81.332***	3.830***	18.754***
EG	126.399***	8.580***	36.103***
EG^2	127.466***	8.693***	36.042***
FDI	81.754***	3.874***	26.438***
FDI^2	70.026***	2.638***	18.859***
REC	62.055**	1.798**	35.745***

Note. *** and ** divulge significance levels at 1% and 5%, respectively.

Table 4. Slope Homogeneity Test Results

Delta test	Model 1	Model 2
$\tilde{\Delta}$ test	10.048***	12.414***
$\tilde{\Delta}_{adj.}$ test	11.475***	14.177***

Note. *** divulges significance level at 1%.

transfer (pollution halo hypothesis), while the positive FDI^2 demonstrated that as investment volume increased, the scale effect of expanding production capacity overshadowed technological gains, driving the ecological footprint upward again. In Model 2, the FDI was insignificant at the 0.10th–0.30th quantiles but became significant and positive from the 0.40th quantile onward (from 0.065 to 0.094), whereas FDI^2 remained consistently significant and negative across all quantiles (from −0.026 to −0.029). The insignificance at lower quantiles can be attributed to the fact that these countries' existing biocapacity reserves were sufficient to absorb ecological demand, preventing FDI−driven industrial activity from producing measurable shifts in the pressure ratio. At upper quantiles, diminished biocapacity buffers rendered FDI's initial pressure detectable, yet beyond a certain threshold, the strengthening of institutional oversight and the promotion of energy−efficiency−oriented investments reduced ecological pressure. The uniformity of the FDI^2 across quantiles indicated that efficiency−spillover mechanisms operated independently of the host country's initial pressure level.

The asymmetry between the two models stemmed from the fundamental distinction between what EF and EFPI measure. While the EF captures consumption–based environmental demand alone, the EFPI relates this demand to the ecosystem's supply capacity. In NICs, FDI ultimately increased the ecological footprint in absolute consumption terms through the scale effect (U−shape); however, when pressure on biocapacity was considered, the technology transfer, resource optimization, and efficiency gains accompanying high−volume FDI alleviated pressure relative to the ecosystem's carrying capacity over time (inverted U−shape).

In this context, this divergence can be attributed to the sectoral composition of FDI in NICs. Even though the data limitations in our study prevent a comprehensive analysis of sectoral differences, differing results across the two models can be interpreted in light of established theoretical and empirical evidence. For instance, Cole et al. (2017) show that the environmental pressure of FDI exhibits some heterogeneity depending on sectoral structure, regulatory frameworks, and the nature of technology transfer. Furthermore, according to the findings of some empirical studies such as Eskeland and Harrison (2003) and Dean et al. (2009), the environmental consequences of multinational firms may vary depending on the sector in which they operate. Against this background, we consider that the U-shaped relationship between FDI and EF captures aggregate resource demand, which tends to escalate as FDI gravitates toward resource–intensive manufacturing and extractive sectors. In contrast, the inverted U-shaped relationship between FDI and EFPI normalizes the EF by BC, reflecting relative environmental pressure. FDI concentrated in technology–intensive and service–oriented sectors can reduce this relative pressure through cleaner production processes and enhanced energy efficiency, whereas FDI directed toward primary and heavy industries amplifies the absolute EF without proportionally affecting the pressure index, particularly in countries with relatively higher biocapacity. Thus, the sectoral heterogeneity of FDI provides a plausible explanation for the contrasting U–shaped and inverted U–shaped patterns observed across the EF and EFPI models.

Table 5. Unit Root Test Results

Variables	CIPS test		$IPS_{bootstrapping}$ test	
	Level	First difference	Level	First difference
EF	−2.180	−3.490***	−1.266	−5.767***
EFPI	−2.320	−3.651***	−1.303	−5.145***
EG	−1.822	−2.747***	0.061	−3.754***
EG^2	−1.754	−2.679***	0.314	−3.733***
FDI	−2.535**	-	−2.884***	-
FDI^2	−2.461**	-	−3.219***	-
REC	−2.040	−3.109***	−1.336	−4.092***

Note. *** and ** divulge significance levels at 1% and 5%, respectively.

Table 6. Cointegration Test Results

LM test			
Model 1	Test statistic	Asymptotic p–value	Bootstrap p–value
Constant	5.795	0.000	0.998
Constant & trend	12.264	0.000	0.994
Model 2	Test statistic	Asymptotic p–value	Bootstrap p–value
Constant	7.041	0.000	0.964
Constant & trend	14.727	0.000	0.915
DH test	Model 1		Model 2
	Test statistic		Test statistic
DH_{group}	7.717***		2.215**
DH_{panel}	0.853		0.294

Note. *** and ** divulge significance levels at 1% and 5%, respectively.

Several studies (Balsalobre-Lorente et al., 2023; Baskurt et al., 2022; Bekun et al., 2023; Cole et al., 2011; Esmaeili et al., 2023; Liu et al., 2022) corroborate the claim that FDI inflow causes ecological damage in developing nations. In other words, industrializing countries that draw in FDI through trade relations eventually contribute to higher levels of ED at a later stage. As noted by Fauzel et al. (2016), significant gains for these nations in employment, productivity growth, and poverty reduction can allow the government to make concessions to FDI on environmental harm. Consistent with the findings of Sultanuzzaman et al. (2018) and Dinh et al. (2019), FDI's short–term ecological benefits have turned into lasting economic rewards in these countries. However, these results run counter to the findings of Apergis et al. (2023), Zafar et al. (2019), Sarkodie and Strezov (2019), and Lan et al. (2012). In contrast, they found that FDI leads to ecological losses not only later once long-term economic rewards are reaped but also at the initial stages of the process.

The MMQR results revealed that the REC was negative and significant across all quantiles in both models, confirming RE transition as a consistent instrument for reducing ED in NICs. However, the absolute magnitude increased systematically toward upper quantiles. This pattern indicated that in NICs at upper quantiles, where fossil fuel intensity was higher, RE substitution generated larger marginal pollution reductions through the technique effect. The approximately five fold larger coefficients in Model 2 relative to Model 1 suggested that REC was substantially more effective in alleviating anthropogenic pressure on biocapacity than in reducing absolute resource demand. This finding demonstrated that prioritizing RE investments in NICs facing biocapacity constraints would yield the highest environmental returns. These findings support previous research by Sharma et al. (2021), Alola et al. (2019), Rafique et al. (2022), and Balsalobre-Lorente et al. (2022) and demonstrate that increasing the use of RE resources improves environmental quality. Figures 3 and 4 display the graphical representation of the MMQR estimates for Models 1 and 2, respectively.

Table 7. MMQR Results

Model 1	Quantiles								
Variables	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
EG	−0.0003	0.199	0.318	0.450**	0.561***	0.732***	0.986***	1.237***	1.418***
EG^2	0.030	0.017	0.010	0.001	−0.004	−0.015	−0.031*	−0.047**	−0.058***
FDI	−0.026	−0.035*	−0.041**	−0.047**	−0.053***	−0.061***	−0.073***	−0.085***	−0.094***
FDI^2	0.007*	0.009**	0.009***	0.010***	0.011***	0.012***	0.014***	0.015***	0.016***
REC	−0.116***	−0.126***	−0.132***	−0.138***	−0.143***	−0.152***	−0.164***	−0.176***	−0.185***
Model 2	**Quantiles**								
Variables	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
EG	1.841	1.741	1.674*	1.602**	1.551***	1.526***	1.507***	1.486***	1.444***
EG^2	−0.170*	−0.156**	−0.148***	−0.138***	−0.132***	−0.128***	−0.126***	−0.123***	−0.117***
FDI	0.021	0.039	0.051	0.065*	0.074**	0.078***	0.082***	0.086***	0.094***
FDI^2	−0.026*	−0.027**	−0.027***	−0.028***	−0.028***	−0.028***	−0.028***	−0.028***	−0.029***
REC	−0.674***	−0.727***	−0.762***	−0.799***	−0.825***	−0.838***	−0.849***	−0.859***	−0.882***

Note. ***, ** and * divulge significance levels at 1%, 5% and %10, respectively.

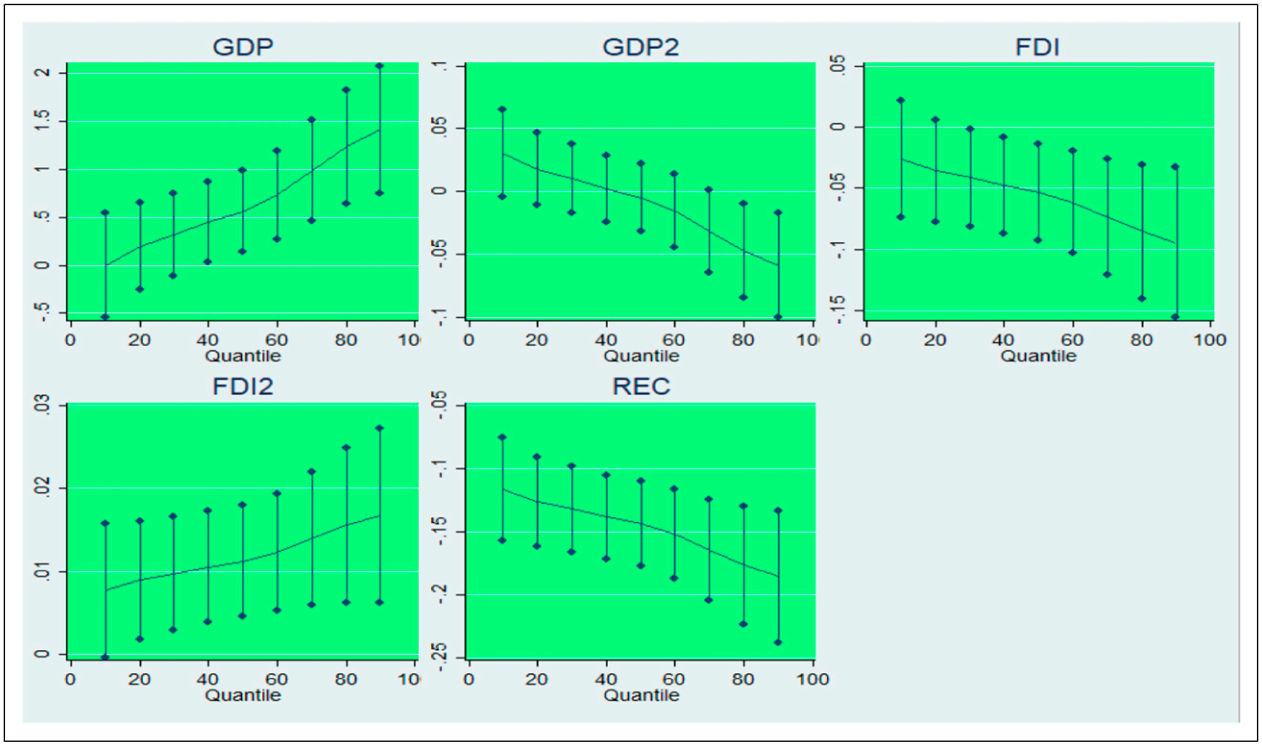

Figure 3. Graphical representation of MMQR for Model 1

The SQR estimation results presented in Table 8 corroborated the MMQR findings for both models. In Model 1, the EG was positive and significant at the 0.75th and 0.90th quantiles, while EG^2 was negative and significant at the 0.75th and 0.90th quantiles, confirming the validity of the EKC hypothesis. The FDI was negative and significant at the 0.50th, 0.75th, and 0.90th quantiles, whereas FDI^2 was positive and significant across all quantiles, validating the U–shaped relationship. In

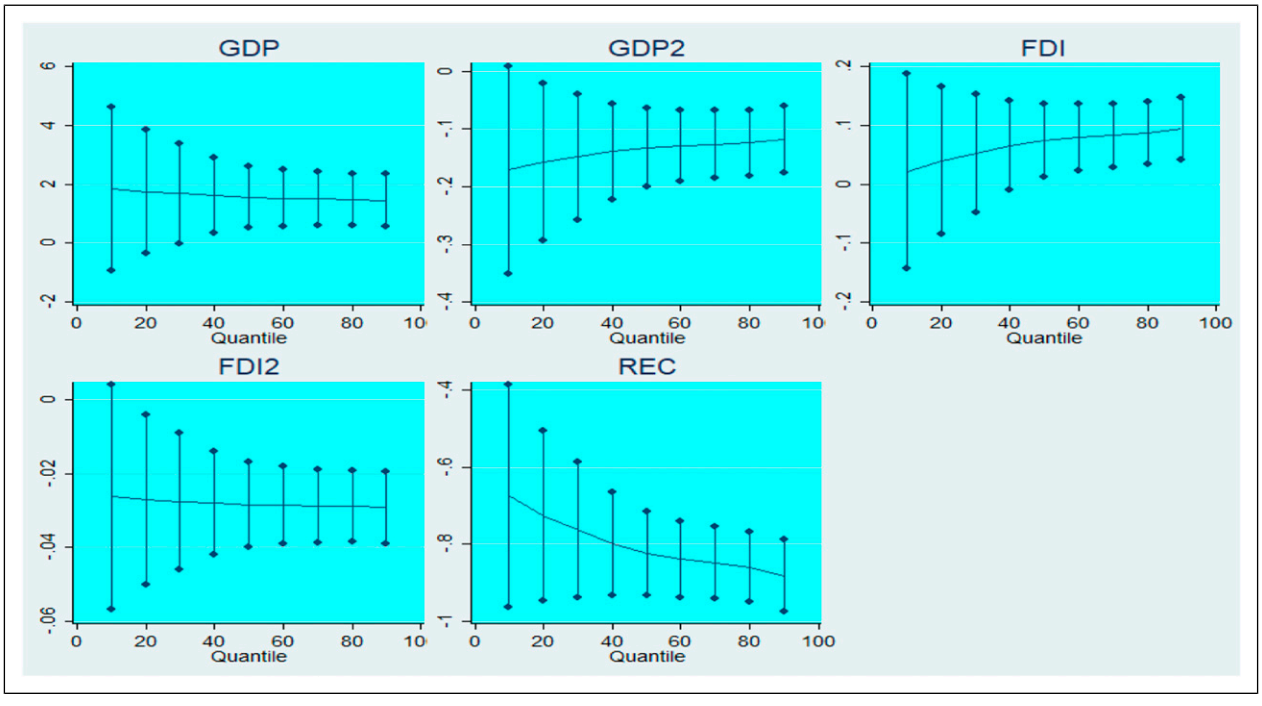

Figure 4. Graphical representation of MMQR for Model 2

Table 8. Simultaneous–Quantile Regression Results for Robustness Check (SQR)

Model 1	Quantiles			
Variables	0.25	0.50	0.75	0.90
EG	0.004	0.203	1.546***	2.074***
EG^2	0.030*	0.018	−0.066**	−0.101***
FDI	−0.023	−0.078**	−0.134***	−0.087***
FDI^2	0.007*	0.018***	0.024***	0.014**
REC	−0.095***	−0.116***	−0.152***	−0.167***
Model 2	Quantiles			
Variables	0.25	0.50	0.75	0.90
EG	1.200	2.138***	1.892***	1.057***
EG^2	−0.118*	−0.183***	−0.156***	−0.095***
FDI	0.063	0.083**	0.094***	0.104***
FDI^2	−0.039**	−0.029***	−0.027***	−0.025***
REC	−0.874***	−1.212***	−1.035***	−1.007***

Note. ***, ** and * divulge significance levels at 1%, 5% and %10, respectively.

Model 2, the EG coefficient was positive and significant at the 0.50th, 0.75th, and 0.90th quantiles, while EG^2 was negative and significant across all quantiles, lending further credence to the EKC. The FDI was positive and significant at the 0.50th, 0.75th, and 0.90th quantiles, whereas FDI^2 was negative and significant across all quantiles, confirming the inverted U–shaped relationship. The REC remained significant and negative across all quantiles in both models, reinforcing the consistent environmental benefits of REC. Figures 5 and 6 summarize the empirical findings for EF and EFPI, respectively.

Conclusion and Policy Implications

This study scrutinized the impact of EG, FDI, and REC on ED in NICs from 1990 to 2018 within the scope of the EKC and PHA/PHH hypotheses. Unlike most previous studies, to capture a more comprehensive picture of ED, this study used two complementary ED indicators: a demand-based measure (EF) and a biocapacity-adjusted measure (EFPI). To this end, MMQR, a novel and robust method, was employed in the study to examine the relationships among variables.

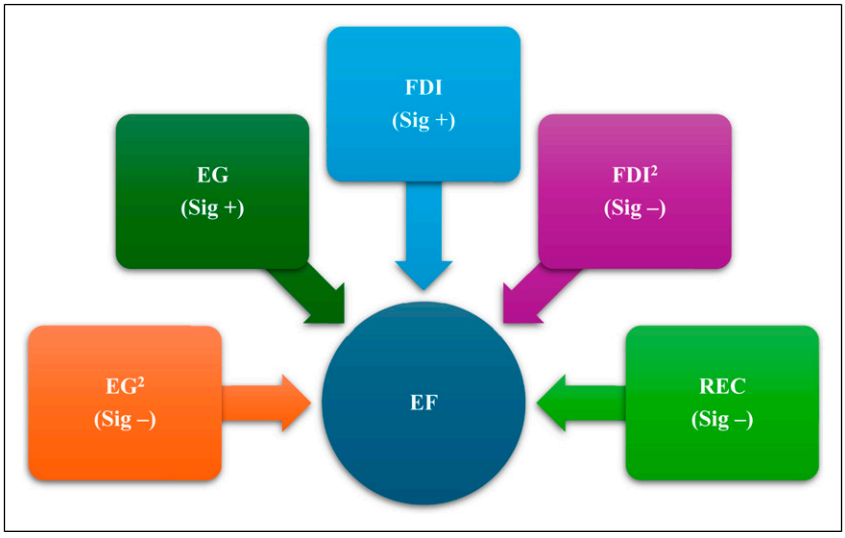

Figure 5. Summary of the empirical findings for EF. The significance ranges vary across quantiles.

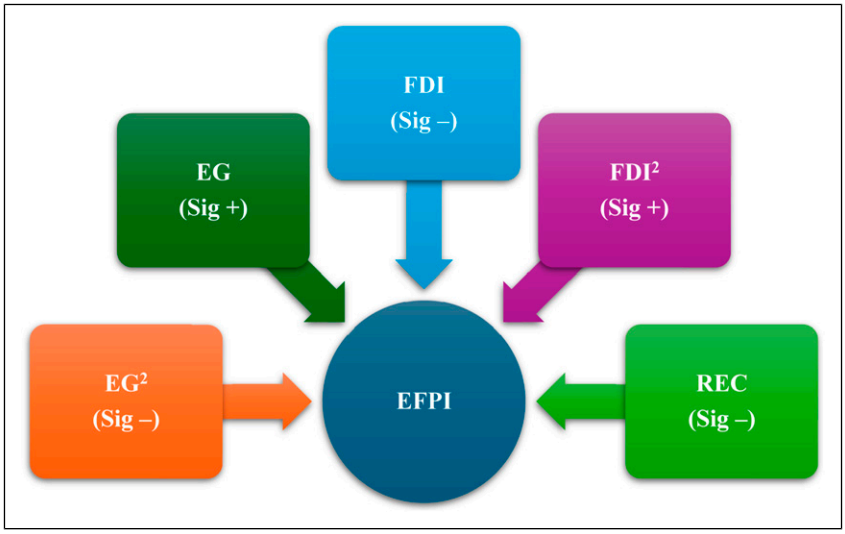

Figure 6. Summary of the empirical findings for EFPI. The significance ranges vary across quantiles.

The study's results can be summarized as follows: *(i)* This study confirms the validity of the EKC, which assumes that EG and ED have an inverted U–shaped connection. *(ii)* A U–shaped relation between the EF and FDI is observed when ED is represented by the EF, which only considers the demand dimension. Nonetheless, an inverted U–shaped linkage between the EFPI and FDI appears when the EFPI portrays ED. This divergence implies that while FDI may initially reduce consumption–based ecological demand through efficiency gains, its long-term expansion can increase scale–driven pressure. However, when biocapacity constraints are incorporated, improvements in environmental regulatory quality may mitigate ecological stress over time. *(iii)* REC has a negative and statistically significant effect on ED, indicating that adoption of renewable energy technologies may alleviate ecological pressure in NICs.

These results yield the following policy implications for NICs:

The MMQR results confirm the EKC hypothesis only at upper quantiles (0.70–0.90) in the EF model but from 0.30 onward in the EFPI model, indicating that the biocapacity–adjusted indicator captures the EKC turning point earlier. Lower–quantile NICs should prioritize pollution–prevention instruments such as sector-specific emission ceilings, while upper-quantile NICs should adopt green–upgrading mechanisms, including carbon market infrastructure. The non–validation of the EKC at 0.10–0.20 in the EFPI model suggests that biocapacity buffers remain sufficient at the lowest–pressure NICs, where the policy priority should be preserving existing ecological capital. The U–shaped FDI–EF and inverted U–shaped FDI–EFPI relationships necessitate indicator–sensitive FDI regulation. The uniformly positive FDI^2 across all EF quantiles, confirming that scale effects suppress technological gains, implies that high–EF NICs should attach mandatory technology transfer and energy efficiency conditionalities to FDI admission. Conversely, the consistently negative FDI^2 in the EFPI model confirms that FDI reduces biocapacity–adjusted pressure; high–EFPI NICs should channel FDI toward technology–intensive sectors, while low–EFPI NICs should shift FDI composition away from resource–intensive manufacturing through protective biocapacity regulations.

The significance of FDI effects emerging from 0.20 in the EF model but only from 0.40 in the EFPI model reveals that FDI's environmental threshold varies by indicator. This asymmetric threshold requires NICs to establish graduated governance mechanisms: voluntary reporting and tax incentives at lower quantiles, transitioning to mandatory environmental impact assessments, binding emission ceilings, and compulsory technology transfer conditionalities as environmental pressure moves into the higher quantiles at which the FDI coefficient becomes statistically significant.

The systematic intensification of REC coefficients toward upper quantiles, with EFPI model coefficients approximately fivefold larger than those in the EF model, implies that RE investment prioritization should be calibrated to quantile position. NICs facing high biocapacity-adjusted pressure should rapidly scale RE capacity through green bond issuance and carbon pricing revenues, while lower–quantile NICs should adopt phased RE targets and public-private partnership models.

This study has several limitations that should be acknowledged. First, the study period is restricted to 1990–2018 due to data availability constraints, as the GFN and WB datasets do not provide sufficiently consistent and comparable observations

for several NICs beyond this period. It should be acknowledged that the COVID-19 pandemic, the accelerating global energy transition, and geopolitical conflicts such as the Russia–Ukraine war may have materially altered FDI allocation patterns, renewable energy trajectories, and ecological footprint pressures across NICs. Specifically, pandemic-induced disruptions in investment flows and post-pandemic energy transition dynamics may have affected the timing, slope, and turning point of the EKC, while geopolitical shocks in energy markets may have further influenced the direction and magnitude of the FDI–environmental pressure relationship identified herein. Given these structural shifts, updating the analysis with more recent data remains a priority for advancing evidence-based environmental policy in NICs. Second, the study evaluated the link between EG, FDI, REC, and ED in detail. A range of economic and socioeconomic aspects, including economic complexity, the use of fossil fuels, institutional quality, trade openness, urbanization, tourism, income inequality, and social capital, should be considered in future research. Third, although the MMQR approach captures distributional heterogeneity, it does not establish strict causal inference. Future studies incorporating more recent data will, therefore, greatly advance our knowledge of how different economic and socioeconomic factors influence environmental deterioration for different country groups, including the G–7, BRICS, and Next–11. Future studies could also extend the analysis to country–level time series and sub–period investigations, and regional or income–level subgroup comparisons to capture nation–specific dynamics and potential structural shifts through panel threshold and spatial econometric models. Furthermore, incorporating the proportion of green FDI, sectoral FDI disaggregation (manufacturing, services, extractive), and environmental technology transfer indices, fossil energy subsidies, green finance indicators, and institutional quality indices as moderating or mediating variables would enable direct testing of PHH mechanisms and substantially contribute to identifying under which conditions and through which channels the PHH operates. In particular, such research would allow for a more explicit identification of the heterogeneous effects of FDI across sectors and regulatory environments, thereby addressing the limitations of the present study.

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Ethical Considerations

This study is based exclusively on secondary, publicly available country-level data and does not involve human participants, animals, or identifiable personal data. Therefore, ethics committee approval was not required for this research.

Consent to Participate

This study did not involve human subjects; therefore, informed consent was not required.

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Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Data Availability Statement

This study used publicly available data and needed no informed consent.

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Appendix

Table A1. Diagnostic Results

Diagnostic test	Test statistic (model 1)	Test statistic (model 2)	Result
Variance inflation factor (VIF) VIF > 10 or 1/VIF < 0.1	Mean VIF= 1.51 1/VIF ranges between 0.572 and 0.902	Mean VIF= 1.51 1/VIF ranges between 0.572 and 0.902	There is no multicollinearity
Breusch–Pagan/Cook– Weisberg test	chi^2 (1)=2.61 (0.025)	chi^2 (1)=13.51 (0.000)	Presence of heteroscedasticity
Wooldridge test for autocorrelation in panel data	F (1, 14)=3.802 (0.083)	F (1, 14)=5.781 (0.039)	There is first-order autocorrelation
Durbin–Wu–Hausman test	chi2 (1)=0.314 (0.575)	chi2 (1)=1.835 (0.175)	There is no endogeneity
Doornik and Hansen (2008) test for normality	chi^2 (14) = 3150.022 (0.000)	chi^2 (14) = 3665.451 (0.000)	Data doesn't follow a normal distribution
Ramsey RESET test for functional form	F (2, 275) = 4.84 (0.009)	F (2, 275) = 10.52 (0.000)	Non-linear specification is required