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Foreign Direct Investment, Economic Growth, Institutional Quality, and Fossil Energy Consumption on Ecological Footprint: Evidence from the Emerging Seven (E7) Countries

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Abstract

Background: The Emerging Seven (E7) China, India, Indonesia, Brazil, Russia, Mexico, and Turkey account for approximately 50% of global carbon emissions while experiencing rapid economic growth, industrialization, and fossil energy dependence. These conditions generate multidimensional ecological pressures, requiring assessment through the Ecological Footprint (EFP).
Objective: This study examines the effects of Foreign Direct Investment (FDI), economic growth, institutional quality, and fossil energy consumption on EFP in E7 countries during 2002–2022.
Methods: Panel data from the seven E7 countries were analyzed using the Fixed Effects (FE) model and Driscoll–Kraay robust standard errors (FE-DK).
Results: Economic growth exhibits an N-shaped Environmental Kuznets Curve (EKC). FDI and fossil energy consumption have significant positive effects on EFP, supporting the Pollution Haven Hypothesis and confirming the ecological pressure associated with fossil-fuel dependence. Conversely, institutional quality has a significant negative effect on EFP, indicating that stronger governance and environmental regulatory effectiveness can reduce ecological pressure. Based on the cubic specification (β_1 = 17.8076, β_2 = −2.1471, β_3 = 0.0853), the first turning point occurs at approximately lnGDP = 7.91 (GDP per capita ≈ USD 2,722), while the second occurs at lnGDP = 9.36 (≈ USD 11,599), highlighting heterogeneous development stages across E7 economies.
Conclusion: The FE-DK results remain consistent with the baseline estimates, strengthening the robustness and empirical validity of the findings. The results underscore the importance of institutional strengthening, cleaner energy transition, and environmentally oriented FDI policies in reducing ecological pressure across E7 countries.

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INTRODUCTION

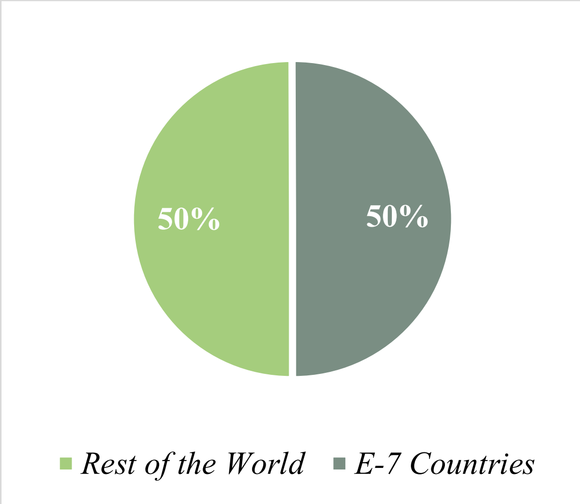
The condition of the global environment in recent decades has experienced increasing pressure due to increasing economic activity, industrialization, urbanization, exploitation of natural resources, and dependence on fossil energy. These activities produce greenhouse gas emissions that accelerate global climate change and cause various environmental impacts such as rising earth temperature, extreme weather, rising sea levels, ecosystem degradation, and loss of biodiversity (Zheng et al., 2024). After the era of industrialization, the world's energy needs increased significantly along with the increase in production and consumption activities. The increase in energy consumption is still dominated by the use of fossil energy which produces large amounts of carbon emissions. In this context, fossil energy is considered to be one of the main causes of global environmental degradation, while renewable energy is considered more environmentally friendly because it is able to reduce emissions and reduce ecological pressure in a more sustainable manner.

Various international commitments have been formed to address these global environmental problems. The UNFCCC in 1997 became one of the first international agreements to require developed countries to reduce greenhouse gas emissions. Furthermore, the Paris Agreement in 2015 targets limiting global temperature rise below two degrees Celsius through reducing emissions and strengthening the clean energy transition. The Sustainable Development Goals (SDGs) also place environmental issues as one of the top priorities for global development through goals related to climate action, clean energy, and sustainable development. In addition, COP26 and COP27 emphasized the acceleration of the "phase-out of inefficient fossil-fuel subsidies," the "phasedown of unabated coal power," and the achievement of net-zero emission targets while increasing climate finance for developing countries. These various commitments show that environmental issues are no longer just a local issue, but have developed into a global challenge that requires the involvement of all countries.

In environmental economics research, environmental degradation measurements generally use carbon dioxide (CO_2) emissions as the main indicator because CO_2 is the largest contributor to global greenhouse gas emissions and has a major contribution to climate change (Assamoi et al., 2020). In fact, about 79% of greenhouse gas emissions come from CO_2 so this indicator is often used to describe global environmental pressures (Al Numan et al., 2025). However, the use of CO_2 is considered not to be able to capture the overall dimension of ecological pressure because it only describes the carbon footprint and does not reflect the overall use of biological resources (Ozturk et al., 2024). Therefore, various studies have begun to use ecological footprint (EFP) as a more comprehensive indicator. The ecological footprint includes not only carbon footprints, but also land use, forest products, consumption of biological resources, waters, and land needs to absorb waste and emissions (Khan et al., 2021).

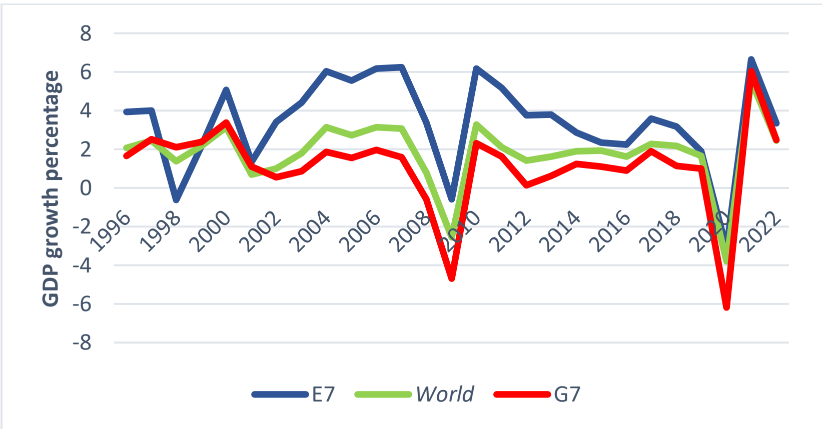
The use of EFP is becoming increasingly relevant in the group of emerging economies that are experiencing rapid economic growth and industrialization. One of the most prominent groups is the Emerging Seven (E7), which consists of China, India, Indonesia, Brazil, Russia, Mexico, and Turkey (PwC, 2017). E7 countries are experiencing large-scale industrial expansion, urbanization, energy consumption, and exploitation of natural resources so that the ecological pressures that arise come not only from carbon emissions, but also from land-use changes, increased resource consumption, and the expansion of economic activity broadly (Xu et al., 2022). Although some developed countries have made measurable progress in energy transition and production efficiency, these achievements vary substantially across nations. The E7 countries, with diverse economic structures and development trajectories, still predominantly face structural ecological pressures driven by the rapid pace of economic transformation, high fossil energy dependency, and expanding industrial capacity (Dam et al., 2024).

Based on data from the Energy Institute Statistical Review of World Energy 2024, the E7 countries collectively account for about 50% of global carbon emissions (Figure 1). China is the largest contributor with more than 11 billion tons of CO_2, followed by India, Russia, and Indonesia. The high contribution of these emissions shows that the E7 countries have an important role in the dynamics of the global environment. In addition, ecological footprint data shows that most E7 countries have ecological stress levels above the world average and tend to increase over time. Indonesia itself experienced a relatively stable increase in EFP during the observation period. This condition shows that economic growth that occurs in emerging countries has not fully gone hand in hand with environmental sustainability.



Source: *Energy Institute* (2024)
Figure 1. E-7 Countries' Carbon Emissions in 2024 compared to the World

In addition to economic growth, Foreign Direct Investment (FDI) flows are also one of the important factors influencing ecological pressures in emerging countries. The E7 countries are a major destination for global investment because they have large markets, relatively low production costs, and high economic growth rates. The IMF (2024) states that emerging economies consistently record higher economic growth than advanced economies. Meanwhile, UNCTAD (2023) shows that global FDI flows in the last two decades have increasingly shifted towards emerging market countries (Figure 2). This condition raises questions about the impact of foreign investment on the quality of the environment in the E7 countries.



Source : World Bank
Figure 2. Average FDI *inflow* (% GDP) of E7, G7, and World countries

In the environmental economics literature, the relationship between FDI and environmental degradation is described through the Pollution Haven Hypothesis (PHH) and the Pollution Halo Hypothesis (PHL). PHH states that multinational companies tend to move pollution-dense industries to developing countries that have looser environmental regulations, thereby increasing environmental pressure in investment destination countries (Destek et al., 2024). On the contrary, PHL states that foreign investment can bring technology transfer, innovation, and cleaner production practices so that it has the potential to improve environmental quality (Murshed et al., 2021). Previous research has shown inconsistent results regarding the influence of FDI on the environment. Several studies have found that FDI increases environmental degradation in developing countries such as China, India, Pakistan, ASEAN, and BRICS-T Du et al., 2022), while other research has found that FDI can improve energy efficiency and encourage the use of environmentally friendly technologies.

The relationship between economic growth and the environment is also widely explained through the Environmental Kuznets Curve (EKC). Grossman & Krueger (1991) stated that in the early stages of economic development, environmental degradation will increase due to industrialization and exploitation of natural resources. However, once income reaches a certain level, environmental pressures begin to decrease due to changes in economic structure, technological improvements, environmental awareness, and better policies. This relationship pattern is known as an inverted U-shape. Various studies have found that EKC patterns occur in many developing countries, but most previous studies have focused only on simple linear or quadratic relationships (Ozturk et al., 2024). In fact, in countries with very fast economic growth such as E7, the relationship between economic growth and the environment can be more complex and dynamic.

In addition to economic growth and foreign investment, the quality of institutions is also an important factor in determining the success of sustainable development. Strong institutions reflect the effectiveness of government, the quality of regulations, law enforcement, and the capacity of the state to manage economic activities (Ha et al., 2016). In the environmental context, good institutions can strengthen the implementation of clean energy policies, increase supervision of industrial activities, and ensure compliance with environmental regulations. Liu et al. (2022) found that institutional quality contributes to reducing carbon emissions in emerging market countries, while Yu & Guo (2023) show that good governance can improve the effectiveness of environmental policies and pollution control.

On the other hand, fossil energy consumption is still one of the main causes of increasing ecological pressure in the E7 countries. Until now, fossil energy still dominates global energy consumption and accounts for most of the world's greenhouse gas emissions. Dependence on fossil energy leads to increased carbon emissions, exploitation of natural resources, and greater environmental damage. Therefore, including fossil energy consumption in the research model is important to more comprehensively capture the relationship between economic activity, energy consumption, and ecological stress.

Despite the growing body of literature on EKC, PHH, and ecological degradation, several critical research gaps persist that this study seeks to address. First, the predominant reliance on CO_2 emissions as the sole environmental indicator in prior studies fails to capture the multidimensional nature of ecological stress, including land degradation, biodiversity loss, and resource depletion. Second, most existing studies restrict their analysis to linear or simple quadratic GDP–environment relationships, thereby overlooking the possibility of more complex cubic or N-shaped non-linear dynamics that are particularly relevant in rapidly industrializing economies. Third, empirical evidence on the FDI–environment nexus remains inconclusive, with conflicting results across the Pollution Haven Hypothesis and the Pollution Halo Hypothesis, partly attributable to differences in country samples, time periods, and methodological approaches. Fourth, the simultaneous examination of institutional quality and fossil energy consumption alongside FDI and economic growth within a unified panel framework for E7 countries remains underexplored in the existing literature.

The novelty of this study lies in three key contributions that distinguish it from prior literature. First, this study employs the Ecological Footprint (EFP) as a comprehensive environmental indicator rather than the conventionally used CO_2 emissions, enabling a more holistic assessment of ecological pressure across biologically productive land and water areas. Second, by simultaneously testing the N-shaped Environmental Kuznets Curve hypothesis (using GDP, GDP^2, and GDP^3) alongside the Pollution Haven Hypothesis and the role of institutional quality within a unified empirical model, this study provides an integrative analytical framework that has not been previously applied to the E7 country group. Third, the application of Fixed Effect estimation with Driscoll & Kraay (1998) standard errors (FE-DK) in the context of E7 countries addresses cross-sectional dependence and heteroscedasticity more rigorously than conventional panel estimators commonly applied in existing studies (Gyamfi et al., 2023).

Based on the research gap, this study aims to analyze the influence of foreign direct investment (FDI), economic growth, institutional quality, and fossil energy consumption on the ecological footprint in E7 countries during the period 2002–2022. This study uses ecological footprint as a more comprehensive indicator of environmental pressure than carbon emissions. In addition, this study integrates the testing of the Environmental Kuznets Curve (EKC) and the Pollution Haven Hypothesis (PHH) simultaneously in one empirical framework.

This study contributes to the existing literature by providing empirical evidence on the N-shaped EKC and Pollution Haven Hypothesis in E7 countries using the Ecological Footprint as a comprehensive indicator of environmental pressure. Methodologically, the study extends previous research by integrating Driscoll–Kraay corrected standard errors within a Fixed Effect framework to address cross-sectional dependence and panel heteroscedasticity. In terms of policy implications, the findings provide a basis for sustainable development strategies in E7 countries, particularly through strengthening institutional quality and environmental governance, implementing selective investment screening for pollution-intensive foreign investors, accelerating the transition toward clean and renewable energy, and designing fiscal instruments that discourage fossil-fuel dependence while encouraging low-carbon innovation.

Literature Review and Hypothesis Development

Foreign Direct Investment (FDI) is a form of foreign investment that gives investors direct control over economic activities in the destination country. Salvatore (2019) explained that FDI is not only in the form of capital transfers, but also includes technology transfer, management, and production processes. Krugman et al. (2018) added that multinational companies conduct FDI to expand the market, increase efficiency, and take advantage of location advantages in the destination country. In the framework of OLI, Dunning (1980) explained that FDI decisions are influenced by ownership, location, and internalization advantages.

In the environmental context, the location advantage aspect is important because companies can consider the differences in environmental regulations between countries. Walter & Ugelow (1979) through the Pollution Haven Hypothesis (PHH) explained that the polluting industry tends to move to countries with looser environmental regulations. Copeland & Taylor (1994) also show that trade liberalization can lead to the transfer of pollution from developed to developing countries. However, the impact of FDI is not always negative. Antweiler et al. (2001) explained that FDI can also reduce environmental degradation through clean technology transfer, energy efficiency, and modernization of production processes, known as Pollution Halo.

The relationship between economic growth and environmental degradation is described through the Environmental Kuznets Curve (EKC). Perman (2003) explained that in the early stages of development, increased income tends to increase pollution due to the expansion of production and energy consumption. However, once it reaches a certain level of income, improvements in technology, efficiency, and environmental awareness can lower environmental pressure. Grossman & Krueger (1995) explain that the process occurs through scale effects, structural effects, and technological effects. Therefore, the relationship between economic growth and the environment is not always linear, but can form an inverted U-pattern as well as other non-linear forms.

This study also uses the STIRPAT approach developed from the IPAT model by (Ehrlich & Holdren, 1971). Dietz & Rosa (1997) developed STIRPAT to be econometrically estimated to measure the influence of population, prosperity, and technology on the environment. This model is widely used because it is able to include additional variables such as FDI, institutional quality, and energy consumption in explaining ecological stresses.

In addition to economic factors, the quality of institutions also affects environmental conditions. North (1990) explains that institutions play a role in reducing uncertainty through regulation and enforcement. In the environmental context, institutional quality determines policy effectiveness, industry supervision, and implementation of emission regulations. Acemoglu and Robinson (2012) assert that strong institutions tend to encourage innovation and more environmentally friendly technologies, while weak institutions can magnify resource exploitation and environmental degradation.

Based on previous theories and research, a conceptual framework was built in Figure 3 with the hypothesis (1) FDI has a significant influence on EFP, both through the Pollution Haven Hypothesis and Pollution Halo mechanisms. (2) Economic growth affects environmental pressures non-linearly as described in EKC, so GDP, GDP^2, and GDP^3 are used to test the possibility of forming an inverted U-pattern or N-shaped EKC. (3) Quality plays a role in suppressing environmental degradation through the effectiveness of regulations and governance (4). Fossil energy consumption is thought to increase EFP due to its high dependence on carbon-based energy sources.

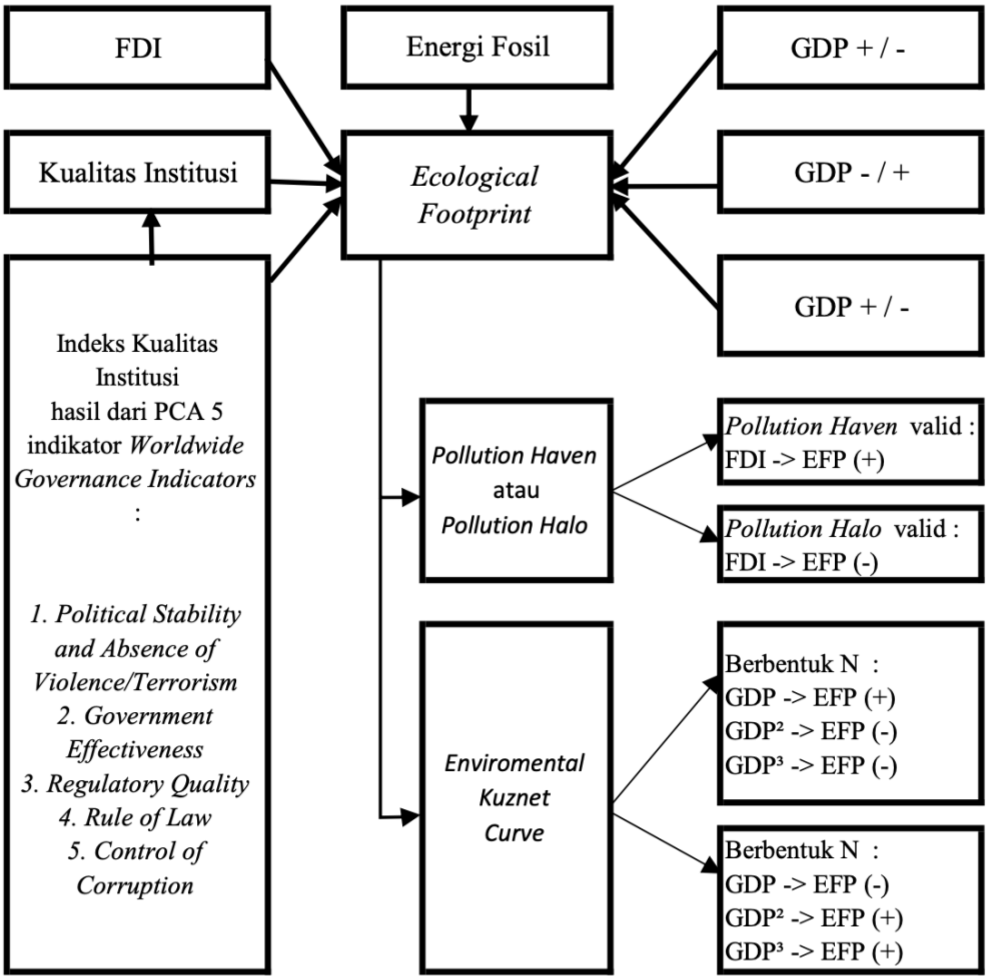


Figure 3. Conceptual Framework

METHOD

This study used panel data from the Emerging Seven (E7) countries, namely China, India, Indonesia, Brazil, Russia, Mexico, and Turkey, covering the period from 2002 to 2022, with a total of 147 observations (7 countries × 21 years). It should be noted that the final regression model used 145 observations, as two observations were excluded due to missing values in the FDI variable for specific country-year combinations. This approach was consistent with standard practice in unbalanced panel data analysis. The measurements and variable sources are presented in Table 1.

Table 1
Research Variables and Sources

Variable	Abbreviation	Description and Measurements	Source
Revenue	GDP	Gross Domestic Product in constant 2015 prices (constant 2015 US$)	World Bank
Foreign Investment	FDI	contribution of foreign investment to the economy in % of GDP	World Bank
Institutional Quality	IQI	The composite index of 5 institutional qualities is calculated using Principal Component Analysis (PCA) and then normalized to 1-10.	World Bank
Fossil Energy	FOSS	per capita fossil energy consumption in units of kWh per person per year	World Bank

Ecological Footprint	EFP	The area of productive land and waters required by the average individual to provide the resources consumed and absorb the waste produced. The unit is global hectares per capita (gha/capita).	GFN

The analysis was carried out in several stages. First, the study conducted descriptive statistical analysis to examine the characteristics of the research data, including the mean, standard deviation, minimum, and maximum values of each variable. Furthermore, a correlation test was conducted to examine the initial relationship between the research variables, and a multicollinearity test using the Variance Inflation Factor (VIF) was performed to ensure that there was no strong linear relationship among the independent variables. The study then conducted a slope heterogeneity test using the Pesaran and Yamagata Delta test to determine whether the coefficients across countries were homogeneous or heterogeneous. After that, a panel unit root test was carried out using the Im-Pesaran-Shin (IPS) method to test the stationarity of the data at the level and first-difference levels. To examine the long-term relationship between variables, the study used Pedroni's panel cointegration test. The main model of the study was estimated using the Fixed Effects (FE) approach. The choice of the Fixed Effects (FE) model was justified on both theoretical and statistical grounds. Theoretically, the FE model was appropriate because the panel units (countries) were not randomly sampled from a larger population but represented all units of analytical interest, which was the case here because the E7 countries were purposively selected. Statistically, the Hausman specification test confirmed that individual country-specific effects were systematically correlated with the regressors ($p < 0.05$), thereby rendering the Random Effects estimator inconsistent and biased. Furthermore, the significant slope heterogeneity identified through the Pesaran–Yamagata Delta test indicated that, although coefficient directions could be generalized across the panel, country-specific fixed effects remained essential to control for unobserved time-invariant heterogeneity (Hashem Pesaran & Yamagata, 2008). Finally, to ensure the robustness of the estimated results against potential heteroscedasticity, autocorrelation, and cross-sectional dependence, the study used the Driscoll–Kraay standard errors (FE-DK) approach.

The empirical model in this study referred to the modified STIRPAT theoretical framework and was expressed in the following equation:

$$ln\,EFP_{it} = \alpha_0 + \alpha_1\, ln\,GDP_{it} + \alpha_2\, ln\,GDP^2{}_{it} + \alpha_3\, ln\,GDP^3{}_{it} + \alpha_4\, lnFDI_{it} + \alpha_5 ln\,IQI_{it} + \alpha_6 \ln FOSS_{it} + \varepsilon_{it}$$

lnEFP = Natural logarithm of ecological footprint
lnGDP = Natural logarithm of gross domestic product (GDP)
$lnGDP^2$ = Natural logarithm of squared GDP
$lnGDP^3$ = Natural logarithm of cubic GDP
lnFDI = Natural logarithm of foreign direct investment (net inflows)
lnIQI = Natural logarithm of the institutional quality index
lnFOSS = Natural logarithm of fossil fuel energy consumption
i = Cross-sectional unit (country)
t = Time period (year)
α_0 = Constant term (intercept)
$\alpha_1, \alpha_2, \alpha_3, \alpha_4, \alpha_5, \alpha_6$ = Long-run coefficients of the explanatory variables
ε_{it} = Error term

RESULTS AND DISCUSSION

Research Results

Based on Table 2 of Descriptive Statistics, the ecological footprint variable (lnEFP) has an average of 0.438 with a standard deviation of 1.163, which shows that the level of ecological pressure between E7 countries varies quite widely. The foreign direct investment (lnFDI) variable has an average of 0.692 with a minimum value of -2.602 and a maximum value of 1.505, which indicates that foreign investment flows in E7 countries tend to fluctuate during the study period. Meanwhile, the economic growth variable (lnGDP) has an average of 8.619 with a standard deviation of 0.749, which shows that the E7 countries have a relatively high and fairly stable level of economic activity. The institutional quality variable (lnIQI) has an average of 1.381 with a value range between 0 to 2.303, which reflects the difference in the quality of governance and regulatory effectiveness between E7 countries. In addition, the fossil energy consumption variable (lnFOSS) has the highest average, which is 9,487, which shows that E7 countries are still heavily dependent on fossil energy to support economic activities and industrialization.

Table 2

Descriptive Statistical Results

Variable	Obs	Red	Std. Dev.	Min	Max
lnefp	147	0,438	1,163	-2,219	1,803
lnfdi	147	0,692	0,579	-2,602	1,505
LNGDP	147	8,619	0,749	6,676	9,551
$lngdp^2$	147	74,856	12,351	44,576	91,217
$lngdp^3$	147	654,429	153,745	297,62	871,186
lniqi	147	1,381	0,507	0	2,303
lnfoss	147	9,487	0,731	8,096	10,853

The correlation matrix in Table 3 was used to see the initial relationship between the study variables as well as detect early indications of multicollinearity. The results showed that there was no very high correlation between independent variables. The findings are strengthened by the results of the Variance Inflation Factor (VIF) in Table 4 which shows that all VIF values are below the critical limit of 10, so that the model is declared free from multicollinearity problems.

Table 3

Results of the Correlation Matrix Test between Variables

Variables	lnEFP	lnFDI	lnGDP	lnIQI	lnFOSS
lnEFP	1.000				
lnFDI	-0.104	1.000			
lnGDP	0.343***	0.189**	1.000		
lnIQI	0.189**	-0.080	-0.115	1.000	
lnFOSS	0.223***	0.087	0.743***	0.294***	1.000

Table 4

VIF Multicollinearity Test Results

Variable	VIVID	Remarks
lnGDP	3,00	No multicollinearity
LnFDI	2,94	No multicollinearity
lnIQI	1,36	No multicollinearity
lnFOSS	1,05	No multicollinearity
BRIGHT RED	2,09	

The coefficient heterogeneity test in Table 5 used the Pesaran and Yamagata method. The test results showed that the statistical values of Delta and Delta adj were significant at the level of 1 percent, so the null hypothesis that the slope coefficient was homogeneous was rejected. These results show that the relationship between independent variables and Ecological Footprint differs in each country in the study sample.

Table 5

Coefficient Heterogeneity Test Results

	Delta	Statistics p-value
Delta	3.877***	0.000
Delta_adj	5.357***	0.000

The next stage is the root test of the panel unit in Table 6 using the Im-Pesaran-Shin (IPS) method. Testing is carried out at the level and first difference levels to determine the degree of integration of each variable. The test results showed that some variables had been stationary at the level level, while others had only become stationary after the first differentiation. These findings show that the research data have different integration characteristics, but there are no variables that are integrated in order two or I(2). Thus, the panel model can still be used for advanced analysis.

Table 6

Root Test Results of Panel Unit (IPS)

Variable	I(0) (Level)	I(1) (First Difference)
lnEFP	0.170	-5.960***
lnFDI	-2.612***	-8.197***
lnGDP	-2.213**	-3.360***
$lnGDP^2$	-1.883**	-3.577***
$lnGDP^3$	-1.476*	-3.822***
lnIQI	2.382	-3.234**
lnFOSS	-0.887	-4.410***

After ensuring the stationarity of the data, the study conducted a panel cointegration test (Table 7) using the Pedroni method. The test results showed that the entire test statistic was significant at the level of 1 percent, both in trending and non-trending models. These results show that there is a long-term equilibrium relationship between economic growth, foreign investment, institutional quality, fossil energy, and environmental pressures in E7 countries.

Table 7

Cointegration Test Results (Pedroni)

Test Statistic	***Trend Included***	***No Trend***
Modified Phillips–Perron v	3.2786***	2.7905***
Phillips–Perron v	-5.3595***	-3.6871***
Augmented Dickey–Fuller v	-4.2167***	-3.6002***

The Fixed Effect (FE) model estimation results in Table 8 reveal substantively meaningful patterns. The positive and significant GDP ($\beta = 17.8076$, $p < 0.01$) and GDP^3 ($\beta = 0.0853$, $p < 0.01$) coefficients combined with the negative GDP^2 ($\beta = -2.1471$, $p < 0.01$) confirm an N-shaped EKC trajectory, signifying that ecological pressure rises during early industrialization, moderates at middle-income levels, and re-escalates at higher income stages, a pattern of critical relevance for E7 economies undergoing rapid structural transformation. The positive and significant FDI coefficient ($\beta = 0.0396$, $p < 0.01$) confirms that foreign investment inflows have predominately augmented ecological pressure in E7 countries, consistent with Pollution Haven dynamics. The negative and significant institutional quality coefficient ($\beta = -0.0686$, $p < 0.01$) demonstrates the protective role of governance in mediating ecological degradation. The fossil energy coefficient ($\beta = 0.3385$, $p < 0.01$) is the largest in relative magnitude among the main regressors, identifying energy structure as the primary ecological stressor in E7 countries. The R-squared values of 0.6204 (FE) and 0.624 (FE-DK) indicate that the model explains over 62% of EFP variation. The consistency of coefficient directions and significance levels across both specifications confirms the empirical robustness of the findings.

Table 8

Model Estimation and Robustness Results

Variables	Model FE	Robustness FE-DK
lnfdi	0.0396*** (0.0095)	0.0396*** (0.0086)
LNGDP	17.8076*** (3.4122)	17.8076*** (3.7603)
$lngdp^2$	-2.1471*** (0.4248)	-2.1471*** (0.4776)
$lngdp^3$	0.0853*** (0.0175)	0.0853*** (0.0201)
lniqi	-0.0686*** (0.0148)	-0.0686*** (0.0161)
lnfoss	0.3385*** (0.0826)	0.3385*** (0.1186)

Constant	-51.2925*** (8.9887)	-51.2925*** (8.8930)
Observations	145	145
R-squared	0.6204	0.624

Discussion

The positive GDP coefficient, negative GDP^2, and positive GDP^3 indicate the formation of an N-shaped Environmental Kuznets Curve (EKC) pattern in E7 countries. In the early stages of economic development, income growth tends to increase environmental pressure through the scale effect, namely increasing production activities, industrialization, urbanization, and energy consumption. However, after reaching a certain level of income, environmental pressures began to decrease due to increased technological efficiency, economic structural transformation, and strengthening of environmental regulations. However, at a higher stage of development, ecological pressures increase again due to the rebound effect of economic activity, increased energy consumption, and dependence on the industrial sector which is still energy-intensive and carbon-intensive. These findings are in line with research by Burki & Tahir (2022) in the ASEAN region which also found an N-shaped EKC pattern, where economic growth in the advanced stages again increases environmental degradation.

The positive results of FDI on EFP support the Pollution Haven Hypothesis, which states that developing countries tend to be the relocation sites of pollution-dense industries due to relatively looser environmental regulations. This condition shows that foreign investment flows in the E7 countries are still dominated by energy- and natural resource-intensive sectors, thus contributing to increased environmental pressures. These findings are in line with research by Murshed et al. (2021) on South Asian countries which found that FDI has a significant positive effect on the ecological footprint. The study explains that weak environmental regulations and high dependence on fossil energy make developing countries more vulnerable to becoming investment destinations for pollution-intensive industries.

It is important to acknowledge, however, that the Pollution Haven Hypothesis does not hold universally across all empirical contexts. Several studies have found evidence of the Pollution Halo Hypothesis, wherein FDI contributes to environmental improvement through clean technology transfer and superior environmental management practices. For instance, Pata et al. (2025) found that FDI exerts a negative influence on the Environmental Performance Index in BRICS+ countries, suggesting that the nature of the FDI–environment relationship is context-dependent and contingent upon the regulatory capacity of host countries. Similarly, Danish et al. (2025) demonstrate that in OECD countries with robust institutional frameworks, FDI is associated with improved environmental outcomes through green technological innovation. These divergent findings underscore that the PHH may be more pronounced in emerging economies with weaker environmental governance, as is the case with several E7 countries, whereas the Pollution Halo mechanism tends to prevail in more institutionally advanced contexts.

The quality of institutions that negatively affect the ecological footprint shows that better institutions are able to increase the effectiveness of regulations, supervision, and implementation of environmental policies. These findings indicate that strengthening governance and environmental governance has an important role in reducing ecological pressures. These results are in line with the research of Yu & Guo (2023) in South Asian countries which found that institutional quality has a significant negative effect on the ecological footprint. The research explains that strong institutions are able to support the effectiveness of environmental policies, reduce corruption, improve energy efficiency, and encourage the use of more environmentally friendly technology and energy

Meanwhile, fossil energy consumption which has a positive effect on the ecological footprint shows that the dependence of E7 countries on fossil energy is still the main factor in increasing environmental pressure. It should be noted, however, that the direct comparison of coefficient magnitudes across variables must be interpreted cautiously, as the variables in this model are measured in different units and logarithmic transformations may not fully standardize their scales. Nonetheless, the relatively larger coefficient of fossil energy consumption compared to FDI and institutional quality provides a directional indication of the dominant role of energy structure in determining ecological pressure in E7 countries. This finding is in line with the research of Al Numan et al. (2025) in ASEAN countries which found that fossil energy consumption has a significant positive effect on the ecological footprint.

In contrast, some empirical studies have found that institutional quality improvements do not always automatically translate into environmental gains, particularly in contexts where regulatory capture, enforcement deficits, and political economy constraints limit policy effectiveness. Azam et al. (2021) observed that in several developing countries, institutional quality had constrained short-run impacts on environmental outcomes due to implementation lags. This highlights that improving institutional quality is a necessary but not sufficient condition for ecological improvement, requiring complementary policy instruments such as environmental taxation, carbon pricing, and binding international climate commitments to achieve full ecological benefits.

CONCLUSION

This study examines the influence of economic growth, Foreign Direct Investment (FDI), institutional quality, and fossil energy consumption on the Ecological Footprint in Emerging Seven (E7) countries using the Fixed Effect–Driscoll–Kraay (FE-DK) approach. The findings confirm an N-shaped Environmental Kuznets Curve (EKC), indicating that economic growth does not automatically lead to sustained environmental improvement. FDI and fossil energy consumption significantly increase ecological pressure, suggesting that investment and energy structures in E7 countries remain closely associated with pollution- and carbon-intensive activities. In contrast, institutional quality significantly reduces the Ecological Footprint, demonstrating the importance of effective governance, environmental regulation, and institutional capacity in controlling ecological degradation. These findings highlight the need for E7 countries to pursue low-carbon economic transformation through cleaner energy adoption, stronger environmental governance, and selective investment policies that encourage environmentally sustainable economic activities.

Despite these findings, this study has several limitations that provide opportunities for future research. The analysis relies on the Ecological Footprint as the primary environmental indicator; therefore, future studies could employ alternative measures, such as the Load Capacity Factor or sector-specific Carbon Footprint, to provide broader environmental assessment. The country coverage could also be expanded to other emerging and developing-country groups to examine whether the N-shaped EKC and Pollution Haven Hypothesis remain consistent across different economic contexts. Future research may further employ dynamic panel approaches that better address potential endogeneity and slope heterogeneity. In addition, disaggregating FDI by sector, particularly manufacturing, services, and extractive industries, could provide deeper insights into the mechanisms through which foreign investment influences ecological pressure.

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AUTHOR CONTRIBUTION STATEMENT

Zakaria Zebua: Conceptualization, Methodology, Data Curation, Formal Analysis, Writing – Original Draft. Miguel Angel Esquivias: Supervision, Validation, and Project Administration. All authors have read and agreed to the published version of the manuscript.

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