

A Step Towards Environmental Mitigation: How Do Economic Complexity And Natural Resources Matter? Focusing On Different Institutional Quality Level Countries

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A step towards environmental mitigation: How do economic complexity and natural resources matter? Focusing on different institutional quality level countries

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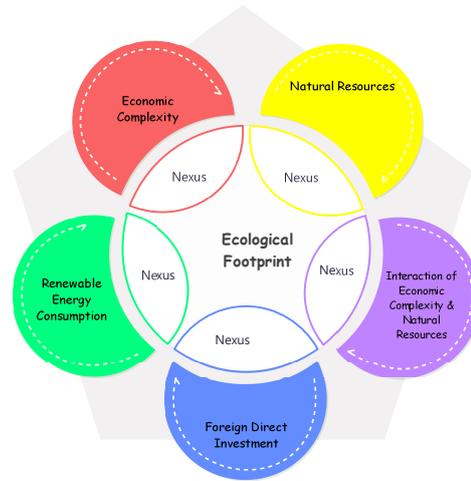
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Abstract

Changes in the economic structure and human lifestyle lead to environmental pollution, one of today's prime challenges. With this in mind, the main objectives of this study are to evaluate the impacts of economic complexity, natural resources, renewable energy consumption, and foreign direct investment on the ecological footprint in weak, medium, and high levels of institutional quality countries. This study is probably one of the first studies to examine the effect of the economic complexity on ecological footprint and classify countries based on their institutional quality levels. Furthermore, the interaction of economic complexity and natural resources is considered a new variable. For this purpose, the panel vector autoregressive model is used. The results revealed that economic complexity in all countries has a positive impact on ecological footprint, and also it has the greatest impact on ecological footprint among the considered variables. Conversely, the interaction of economic complexity and natural resources contributes to environmental quality. Notably, the impacts of study variables on ecological footprint are more robust in a medium level of institutional quality countries. According to the study's outcomes, the main recommendation is the R&D activities improvement to develop environmentally friendly technologies and clean energy infrastructure to improve environmental quality.

Keywords: Ecological Footprint; Economic Complexity; Natural Resources; Institutional Quality; Renewable Energy

Graphical Abstract



Highlights

- The determinants of ecological footprint in countries with different levels of institutional quality are examined.
- The interaction of economic complexity and natural resources is considered as a new variable affecting ecological footprint.
- The interaction of economic complexity and natural resources improves the quality of the environment.
- Economic complexity has detrimental consequences on environmental quality.
- The impacts' of variables are most robust in countries with a medium level of institutional quality.

1 Introduction

Climate change, global warming, and environmental degradation issues have received attention from economists, policymakers, researchers, and ecologists in recent decades throughout the world (Eluwole *et al.*, 2020; Yilanci *et al.*, 2019). Excessive human demand for natural resources in the economic process puts pressure on the ecosystem; it manifests in rising temperatures of air and oceans, declining agricultural production, melting glaciers, rising sea levels, unpredictable rainfall, and wildlife extinction (Hassan *et al.*, 2019). Hence, the unprecedented and unlimited human consumption and exploitation of natural resources suffer irreparable damage to the biosphere. The most important and leading cause of ecosystem degradation is the enhanced greenhouse gas emissions into the atmosphere (Ulucak *et al.*, 2020b). According to IEA (2017), the major part of the energy needed for countries' economic goals comes from the consumption and combustion of fossil fuels (Nathaniel *et al.*, 2020). Accordingly, approximately

68% of greenhouse gases emitted into the atmosphere come from the energy sector, leading to climate and environmental concerns.

In recent decades, the tendency of countries and economies to expand their cross-border interactions and activities has dramatically increased; the human activities resulting from these measures are tied to energy consumption and exploitation of natural resources and affect the quality of the environment. The Economic Complexity Index (ECI) is an economic development index related to countries' exports and analyzes their export structure; the level of knowledge and technology of the manufacturing process and its production productivity is the definition of ECI in international trade literature. Indeed, ECI focuses on the export of products that are technology-intensive and knowledge-based (Doğan *et al.*, 2021; Pata, 2021; Buhari *et al.*, 2020). Hence, different levels of ECI indicate the diversity and sophistication of various countries. Thus, ECI can increase a country's product diversity and amplify countries' production (Sadeghi *et al.*, 2020). Therefore, the economic complexity is highly intertwined with countries' economies and can affect the quality of the environment in two different ways.

On the one hand, it is clear that enhancing the production and manufacturing of countries requires the extraction, exploitation, and utilization of natural resources and energy. Consequently, it has environmental and ecosystem pollution consequences. On the other hand, ECI may also amplify R&D activities. Undoubtedly, R&D dramatically increases the competitiveness, efficiency, and innovations of businesses and occupations, which is associated with structural changes in economies and leads to sustainable development. R&D processes bring technological advancement to communities and stimulate economic growth, encourage countries to use clean energy, and at the same time, reduce the cost of consumption and producing clean energy (Can & Gozgor, 2017). Thus, ECI cradle environmentally friendly technologies and products and improve the quality of the environment (Pata, 2021; Mealy & Teytelboym, 2020).

Given what has been said so far, the environmental crisis that has befallen humanity, affecting economic, social, and health life, is rooted in human activities. Thus, global meetings and agreements such as the Paris Agreement, Kyoto and Montreal Protocols, and Stockholm Conference have been held and concluded to reduce and prevent the greenhouse emissions enhancement (Udemba, 2020). However, environmental concerns are still a major concern for humans, prompting many scholars and academics to study the environment to provide effective policies to policymakers and stakeholders to achieve higher economic growth and a cleaner environment. It is worth noting that the conclusion of such agreements, conferences, and adopted policies to improve the environment's quality strongly depends on the countries' institutional quality. The institutional quality of countries can, directly and indirectly, affect the quality of the environment Saidi *et al.* (2020). Institutional qualities show the structure of effective governance and the quality of performance of a country, the weakness of which can affect environmental policies and regulations. Often countries with weak institutions can not control the quality of the environment

in line with sustainable development goals (Muhammad & Long, 2020). Therefore, our study intends to study a wide range of countries. Unlike other studies, we group countries in terms of their institutional quality level so that countries are categorized based on their performance.

Furthermore, CO₂ emissions have been used as a proxy to express environmental quality in most studies (Zafar *et al.*, 2019). Besides, some other studies used fine smoke, sulfur dioxide, nitrogen dioxide, and suspended particulate matter as proxies of environmental quality (Yilanci *et al.*, 2019; Lee & Chen, 2021). Notwithstanding, these indicators only capture estimates of air contamination and do not definite the deterioration of the environment in areas such as oil, forest, soil, and mining (Khan *et al.*, 2021; Zafar *et al.*, 2019). Therefore, investigating environmental degradation from only one dimension can be misleading (Lee & Chen, 2021). Consequently, there is a need for more general indicators to express environmental degradation to achieve sustainable development. The ecological footprint provided by Wackernagel & Rees (1998) examines the productions of goods and services' environmental consequences (Shahzad *et al.*, 2021; Dogan *et al.*, 2020). It is also only metrics that scrutinize the resource demand of government, individuals, and businesses to land renewability (Nathaniel & Khan, 2020). So, it is a valuable indicator for assigning and managing natural resources (Doytch & Ashraf, 2021; Khan *et al.*, 2021). The ecological footprint measures human pressure on the widespread use of natural resources, and its origin is the principle of classical sustainability. According to this principle, the consumption of natural resources should not exceed the rate of their renewal (Khan *et al.*, 2021; Wang *et al.*, 2020b). Calculation of ecological footprint is through water and land is required in global hectares to waste absorption and goods production. Moreover, it measures in terms of ocean, grazing land, forest products, croplands, carbon footprint, and built-up land. Fig.1 exhibits the contribution of each of these to the ecological footprint.

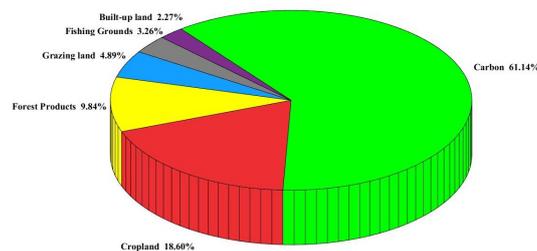


Figure 1: World's Ecological Footprint by Land Type
Source: Global Footprint Network (2017)

Fig.2 and Fig.3 indicate the geographical distribution of ecological footprint and biocapacity, respectively. The more ecological footprint is an obstacle to environmental sustainability and demonstrates the over-consumption of natural resources. China, the United States, India, and Russia have the most ecological footprint in the world.

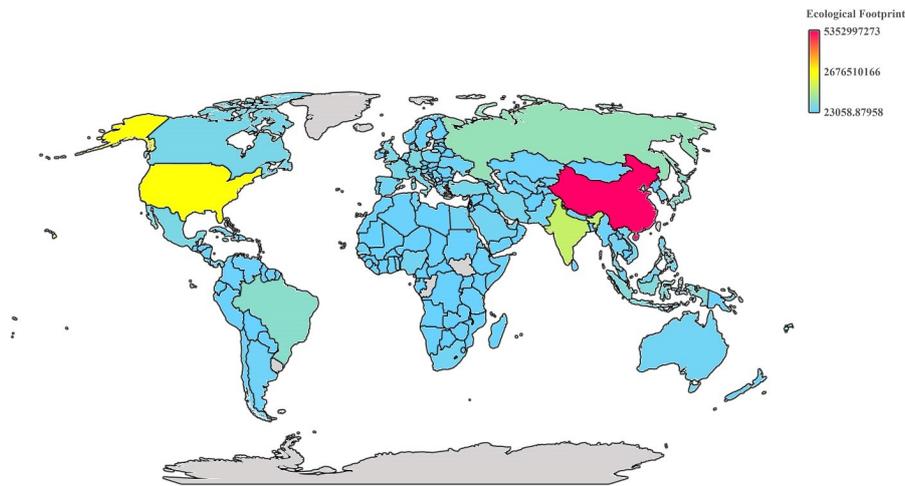


Figure 2: Geographical mapping of Ecological Footprint (global hectare)
 Source: Global Footprint Network (2017)

In contrast, greater biocapacity is a vital lever in achieving environmental sustainability. Brazil, Russia, the United States, and China are also among the most critical points in terms of biological capacity globally. According to GFN (2021) reports, consumption per person of the world’s ecological footprint was 2.77 global hectares, while per person biocapacity was 1.60 global hectares in 2017. In fact, the ecological footprint is near twice the biocapacity of the world; it means that it takes about two years for the natural resources consumed in one year to be renewed and released CO₂ into the atmosphere to be kept. Accordingly, it shows that global resource consumption exceeded the production of earth’s ability, and the current lifestyle is unsustainable worldwide.

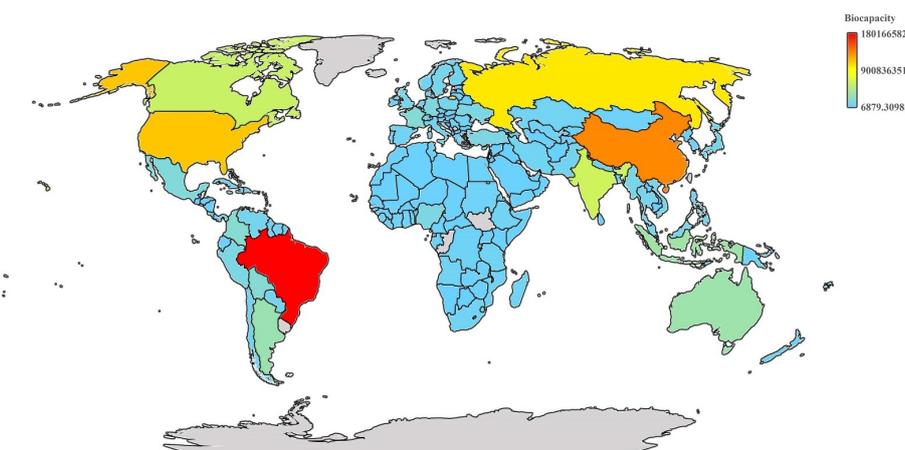


Figure 3: Geographical mapping of Biocapacity (global hectare)
 Source: Global Footprint Network (2017)

Given the above, the purpose of the present study is to investigate and examine the impact of foreign direct investment (FDI), consumption of renewable energy, economic complexity index, and natural

resources on the ecological footprint from 1995 to 2017 with a comprehensive and sweeping data set of 118 countries. Notably, the countries used in the study are classified based on different groups in terms of institutional quality, and the panel vector autoregressive (PVAR) method is used for analysis. Hence, the structure of the present study is as follows: A review of previous literature is provided in Section 2; Section 3 analyzes the methodology and data used; the empirical results are discussed in Section 4; Finally, the study concludes with a conclusion and policy recommendations in Section 5.

2 Literature Review

By changing the human lifestyle from agricultural economics to industrial economics, various societies worldwide sought to improve their economic growth and development. Many challenges for human beings are created to achieve these goals. One of the most vital challenges in today's world is environmental issues, which have become a daunting and alarming concern for humans. Therefore, many scholars have turned to study the environment to develop appropriate policies in this regard. According to the objectives of the present study, we review five nexuses of environmental literature: the energy consumption – environment nexus, the natural resource – environment nexus, the FDI – environment nexus, the economic complexity – environment nexus, and institutional quality – environment nexus.

Since economic and social goals are highly intertwined with energy consumption thus, the first point that draws researchers' attention to environmental issues is the impact of the consumption of the energy on environmental quality. The role of environmental consequences of energy consumption should not be neglected in the study of environmental pollution. Extensive studies have explicitly stated that the consumption of non-renewable energy and the combustion of fossil fuels have devastating consequences for the environment, which, if not addressed, can cause irreparable damage to the environment and its quality (Usman *et al.* (2021); Khan *et al.* (2021); Baloch *et al.* (2019); Destek & Okumus (2019); Ahmad & Majeed (2019)). In contrast, renewable energy consumption is very effective in promoting environmental quality (Usman *et al.* (2021); Khan *et al.* (2021); Sharma *et al.* (2021); Ulucak *et al.* (2020a)). But in a few studies, the insignificant impact of the consumption of renewable energy on improving the quality of the environment has been concluded (Pata & Caglar (2021)). Furthermore, Sahoo & Sahoo (2020) found that the consumption of renewable hydropower energy amplified greenhouse emissions in India. Bölük & Mert (2014), in a study on sixteen European countries, deducted that the use of renewable energy has detrimental impacts on the environment and threatens the quality of the environment.

Environmental degradation and climate change lead to exploitation, extraction, and manipulation of natural resources. All of these human economic activities and the growing utilization of natural resources generate waste beyond the capacity to absorb and deplete the environment, which severely harms the

environment. Hence, some studies such as Khan *et al.* (2021), Zafar *et al.* (2019), and Ulucak *et al.* (2020a) pointed to the significant role of natural resources on economic growth and have confirmed that natural resources and the process of exploiting them have devastating environmental consequences. In comparison, other studies have declared that natural resources do not have a detrimental impact on the environment and improve the quality of the environment and strengthen clean energy industries (Khan *et al.* (2021), Zafar *et al.* (2019), and Ulucak *et al.* (2020a)). Eventually, Khan *et al.* (2020) and Wang *et al.* (2019) argued that the abundance of natural resources did not lead to economic growth and proved the curse phenomenon of natural resources. Consequently, nations rich in natural resources cannot enhance their production and exports in the long run and can not experience high growth rates; natural resources do not have pernicious environmental consequences.

FDI is another concept that is important in examining the quality of the environment. FDI strengthens the growth process of countries by enhancing productivity, capital accumulation, and technology diffusion. FDI can play a notable role in improving the quality of the environment by transferring technology from the host country ((Adeel-Farooq *et al.*, 2021; Doytch, 2020; Ali *et al.*, 2020; Zafar *et al.*, 2019)). Meanwhile, some scholars argue that FDI will increase CO₂ emission and lead to environmental degradation and pollution via encouraging the consumption of heavy machinery and dramatically enhancing energy consumption to trade activities ((Sabir *et al.*, 2020; Udemba, 2020; Baloch *et al.*, 2019)). Besides, Destek & Okumus (2019) concluded that FDI reduces ecological footprint in short-run and increases it in long-run; notably, the relation established between them is U-shaped.

Economic complexity, which means the distance from a low-productivity agricultural economy to the production of more complex products and goods, has recently been highlighted in the environmental literature. Based on Kaufmann *et al.* (1998), the combination of each country's production and economic complexity requires increased use of natural resources and is directly related to the environment. However, few researches have addressed the trace of economic complexity on the quality and pollution of environment. Doğan *et al.* (2019) concluded that economic complexity in the middle- and low-income countries have devastating consequences for the environment and leads to environmental pollution. In contrast, in high-income countries, environmental pollution is controlled by economic complexity. As a result, changes in production and industrial policies in the middle- and low-income countries are felt to protect the environment. In another study, relying on 88 developing and developed countries, Lapatinas *et al.* (2019) deducted that higher levels of economic complexity result in better environmental performance. Consequently, they explicitly stated that economic complexity is not an environmental degradation determinant. Neagu & Teodoru (2019) divided European Union countries into two groups in terms of economic complexity. The results revealed long-run relevance among the structure of energy-consuming, economic complexity, and environmental pollution and degradation. The economic complexity and structure of energy consumption, especially in countries with lower economic complexity, have a more

dramatic and significant impact on environmental degradation.

Yilanci & Pata (2020) identified economic complexity as a destructive factor in environmental degradation in China. Besides, according to Chu (2021) declares, economic complexity is a detrimental determinant for the environment, and by strengthening institutional quality, its detrimental effects on the environmental quality can be prevented.

Institutions determine the competitive and functional environment of societies and limit human behavior. Thus, the institutions are referred to as the rules of the game of societies. The regulatory and institutional framework of each country directly affects the performance of their economic and environmental activities. Despite the direct impact of institutional qualities on environmental quality, there are still very few studies in this regard. Sabir *et al.* (2020) found that the rule of law has almost no impact on the environment, while the stability of the government reduces environmental degradation. Interestingly, corruption control dramatically increases the ecological footprint and plays a significant role in environmental degradation in South Asian countries. Hence, the most critical dimension of institutional quality that affects the quality of the environment is corruption control. Yao *et al.* (2021), Wang *et al.* (2020a), and Masron & Subramaniam (2018) also found that controlling corruption can be very effective in improving the quality of the environment.

In summary, the environmental literature has not yet reached a consensus on how variables affect the quality of the environment, and environmental degradation for humans remains unresolved. Thus, in this study, we used a comprehensive variable, the ecological footprint, that takes into account all aspects of the environment. Furthermore, the economic complexity, which has an undeniable role in the quality of the environment, is highly considered in this study. The inclusion of natural resources in economic complexity and considering their interaction as a new variable has not been studied in the economic complexity and natural resources–environment literature based on the authors’ knowledge. Finally, since institutional quality is critical in environmental performance, we divide the countries considered in the present study based on institutional quality. Thus, countries with similar performance fall into the same groups that create more credible and valid results.

3 Methodology and Data

3.1 PVAR specification

We use the panel data vector autoregressive (PVAR) approach proposed by Love & Zicchino (2006). PVAR has become an appropriate and efficient approach to study the dynamics of macroeconomics. The practical advantages of this model are as follows: (*i*) the PVAR statistical model is not based on a specific theory of development or growth and does not intend to validate a particular macroeconomic concept.

Instead, one variable can be commented on in this model by examining contemporary movements (Kireyev, 2000). (ii) It does not distinguish whether the study variables are endogenous or exogenous and considers the entire of them as endogenous, which is in line with the realities of interdependence (Feng *et al.*, 2020). Meanwhile, each variable in PVAR relies not only on its historical facts but also on other considered variables, which form an actual simultaneity among the considered variables and their treatment.(iii) Macroeconomic dynamics sources are exogenous and endogenous shocks that PVAR allows for consideration of them (Wu *et al.*, 2020; Adedoyin & Zakari, 2020; Charfeddine & Kahia, 2019). Consequently, PVAR has a realistic value for examining the effect of the consumption of renewable energy, natural resources rents, foreign direct investment, economic complexity, and the interaction of economic complexity and natural resources on ecological footprint and provides strategic advice.

The following linear equations system represented a PVAR of order p reduced form with a country-specific fixed-effect model:

$$Y_{it} = \mu_i + A_1 Y_{it-1} + A_2 Y_{it-2} + \dots + A_{p-1} Y_{it-p} + A_p Y_{it-p} + u_i + e_{it}$$

$$i \in \{1, 2, \dots, N\}, t \in \{1, 2, \dots, T_i\} \quad (1)$$

Where Y_{it} determines endogenous stationary variables' vector, and μ_i demonstrates fixed effects of the country-specific matrix. e_{it} and u_i indicate idiosyncratic errors and panel fixed-effects of dependent variable-specific, respectively. $A_1, A_2, \dots, A_{p-1}, A_p$ are parameters ($k \times k$) matrices. The following characteristics for innovations are assumed:

$$E(e_{it})=0, E(e'_{it}e_{it}) = \Sigma, \text{ and } E(e'_{it}e_{is})=0 \text{ for all } t > s.$$

Individual heterogeneity is reflected in the whole series through the fixed effects indicated by u_i so that the constraints are not violated in practice (Seetanah & Teeroovengadum, 2019). Meanwhile, μ_i illustrates all the factors of constant time that did not observe at the level of the country. However, considering the fixed effect of a country in any specification that includes dependent variables' lags can pose an estimation challenge. In this way, the methods used to eliminate the fixed effects can be biased and change the efficiency of the model. Helmert's procedure is very effective in overcoming this challenge (Arellano & Bover, 1995). This procedure maintains orthogonality between lagged and transformed independent variables (Love & Zicchino, 2006). Hence, independent variables' lag by using the GMM system consistently estimates the coefficient (Apostolakis & Papadopoulos, 2019).

The PVAR model is analyzed based on selecting the order of optimal lag in the moment condition and specification of PVAR. According to overidentifying restrictions of Hansen (1982) J , presented MMSC

for models of GMM. Their presented MMSC is similar to model selection criteria of information criteria of Bayesian (BIC), information criteria Akaike (AIC), and the information criteria of Hannan-Quinn (HQIC), and is as follows:

$$MMSC_{BIC,n}(k,p,q) = J_n(k^2p, k^2q) - (|q| - |p|)k^2lnn \quad (2)$$

$$MMSC_{AIC,n}(k,p,q) = J_n(k^2p, k^2q) - 2k^2(|q| - |p|) \quad (3)$$

$$MMSC_{HQIC,n}(p,q) = J_n(k^2p, k^2q) - Rk^2(|q| - |p|)lnlnn, R > 2 \quad (4)$$

Where $J_n(k,p,q)$ indicates the overidentifying restriction of J statistic for k variables of p order PVAR and q lags moment conditions of the dependent variable; also, n shows the sample size. It is worth noting that MMSC can be used when $q > p$ (Abrigo & Love, 2016).

3.2 Data

Our study used ecological footprint to express the state of the environment, which is a prominent environmental indicator. Based on the Zafar *et al.* (2019), the ecological footprint per capita indicator is the best indicator for environmental sustainability. Ecological footprint has become increasingly popular as it reflects an understanding of biological capacity, regenerative capacity, and the impact of human activities. Thus, the ecological footprint is a robust measure to help society achieve clean environment and sustainable development. Along with this background, the impact of foreign direct investment (FDI), consumption of renewable energy (RE), economic complexity index (ECI), and natural resources rent (NR) assesses on ecological footprint (EF). Notably, our particular attention is on the role of economic complexity and natural resources. As a novelty, the interaction of economic complexity and natural resources (ECI×NR) is also considered for better comprehension. Due to the availability of data, the study period is limited to 1995 to 2017 annually. Ecological footprint and economic complexity data are extracted from Global Footprint Network and Atlas of Economic Complexity. The consumption of renewable energy data is achieved from the U.S. Energy Information Administration. Eventually, foreign direct investment and natural resources data are gathered from World Bank Indicators.

It is worth noting that 118 countries are included in this study. These countries are divided into three groups based on their institutional quality. Institutional quality is divided into six dimensions: corruption control, political stability, raw rule, government effectiveness, voice and accountability, regulatory quality. According to the present literature, corruption control is the most important and prominent of them,

which environmental studies have also considered. Corruption control includes grand and petty corruption forms that show the extent to which public power for private gain should be experienced. The percentile rank of countries reveals that the status of their corruption control. So that the highest institutional quality is shown with 100 and the weakest institutional quality with zero, in this respect, we provide countries that rank from zero to 34 as Panel A. Panel B and Panel C includes countries ranked from 34 to 67 and 67 to 100, respectively. Thus, panels A, B, and C are countries whose institutional quality is weak, medium, and high, respectively (see Appendix).

4 Empirical Results and Discussion

The descriptive statistics of study variables for each of the three panels defined in the study are reported in Table 1. Evidence represents that as the institutional quality of countries improves, so do FDI and ECI. On the other hand, in line with the improvement of countries' institutional quality, it seems that the natural resource rents and consumption of renewable energy will also decrease. Thus, it is expected that countries with weaker institutional quality will have better conditions in terms of environmental quality, and countries with stronger institutional quality will not have better environmental quality. The results also support this claim, so that Panel A has a less ecological footprint on average, and by moving to Panel C, the average ecological footprint increases.

First, to use panel data, we must make sure that the variables fluctuate around a constant mean.

Table 1: Descriptive Statistics

Variables	Mean	Maximum	Minimum	Std. Dev.
Panel A				
lnEF	0.4425205	1.763062	-0.7628073	0.5092271
lnFDI	0.7348584	1.614765	-1.185537	0.4397028
lnRE	3.186471	4.588457	-6.228906	1.720904
lnECI	-0.3363843	0.6273892	-0.7927381	0.3229912
lnNR	1.654685	4.457277	-6.613954	1.750026
Panel B				
lnEF	0.8954843	2.355489	-0.2152181	0.5522705
lnFDI	0.7530399	1.613243	-1.53507	0.3822704
lnRE	2.531619	4.570787	-5.119913	1.673189
lnECI	0.0420374	0.6937019	-0.629347	0.3869556
lnNR	0.6711141	4.013521	-6.745781	1.861908
Panel C				
lnEF	1.697478	2.610027	-0.0159406	0.3805203
lnFDI	0.8331473	1.892935	-1.140532	0.4658715
lnRE	2.248828	4.114147	-2.737904	1.408124
lnECI	0.4781343	0.8585427	-0.3971627	0.2888425
lnNR	-1.198033	3.40525	-8.075276	2.320899

Source: Current Research

Therefore, we examine the stationary of the variables because if the variables are nonstationary, the regression results will not be reliable (Nguyen & Kakinaka, 2019). First-generation panel unit root tests

involves Hadri, Breitung, Im-Pesaran-Shin, Levin-Lin-Chu, and Fisher tests are extensively considered and used to examine the stationarity of the study variables (Lin & Zhu, 2017). Unit cross-sections independence is the main assumption of the mentioned tests. It is clear that the results of these tests are not reliable if there is cross-sectional dependence (CSD). Therefore, conducting a CSD test is crucial for all variables. Thus, the CSD test presented by Pesaran (2004) is used in this study, reported in Table 2. It is worth noting that the null hypothesis of the mentioned test is the loss and absence of CSD. As the results represent, the ecological footprint, FDI, renewable energy consumption, ECI, and natural resource rents in all panels prove the presence of CSD. Hence, it is vital to use second-generation panel unit root tests that can control CSD.

Table 2: Cross-sectional Dependence Test

Equation	lnEF	lnFDI	lnRE	lnECI	lnNR
Panel A					
CSD statistic	10.27***	17.33***	37.52***	4.93***	46.37***
Panel B					
CSD statistic	26.04***	17.12***	4.09***	6.18***	33.40***
Panel C					
CSD statistic	23.99***	11.86***	49.77***	4.68***	25.56***

*, **, *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

Source: Current Research

For this purpose, we exploit the cross-sectional augmented modified Dickey-Fuller (CADF) unit root test provided by Pesaran (2007). The results of the CADF reported in Table 3 reveal that all the study variables are stationary at the first difference; videlicet, ecological footprint, FDI, renewable energy consumption, ECI, and natural resource rents are integrated of order one.

Table 3: CADF Unit Root Test

Variable	Panel A		Panel B		Panel C	
	c	c,t	c	c,t	c	c,t
lnEF	-2.80***	0.20	-3.14***	-0.49	2.76	-1.14
lnFDI	-3.33***	-0.85	0.41	-1.04	0.78	2.77
lnRE	1.79	0.86	3.15	1.23	-2.37***	-1.32
lnECI	0.28	3.01	-1.10	-1.76**	3.26	0.45
lnNR	-1.89**	-1.12	-0.32	-0.60	-1.16	-0.37
Δ lnEF	-11.74***	-9.50***	-5.97***	-3.25***	-10.11***	-7.33***
Δ lnFDI	-7.94***	-5.94***	-7.21***	-4.13***	-5.23***	-2.18**
Δ lnRE	-8.35***	-6.47***	-7.75***	-5.28***	-10.27***	-8.21***
Δ lnECI	-6.91***	-4.13***	-12.41***	-9.93***	-10.79***	-8.12***
Δ lnNR	-11.27***	-9.79***	-9.20***	-8.06***	-10.00***	-7.77***

c and c,t denote deterministic components and imply that individual intercept and intercept and trend, respectively.

*, **, *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

Source: Current Research

Given that the results of the unit root test proved that the study variables are I(1), it is possible to evaluate whether there is any long run relationship between the study variables or not. Pedroni (1999)

and Kao (1999) cointegration tests have become popular among researchers and are widely adopted in studies. It should be noted that the null hypothesis of both of these tests is the absence of cointegration in sets of panel data. However, these two cointegration tests have been criticized, and it has been stated that these tests consider cointegrated vectors to be homogeneous across units of cross-sectional. Hence, the results obtained from them are not reliable and robust if there is a CSD. In this regard, the Westerlund (2007) cointegration test eliminates these barriers and reports more efficient and accurate results in the presence of CSD. This test offers four different cointegration tests, two of which determine the cointegration relationship across the whole panel, and the other two at least in one group of the panel. Based on mentioned point, in the present study, due to the existence of CSD, the use of the Westerlund cointegration test is necessary and more impressive. The outcomes of the Westerlund test reveal the presence of a cointegration relationship among the studies' selected variables (Table 4).

Table 4: Westerlund Cointegration Test

Statistic	Panel A			Panel B			Panel C		
	Value	Z-value	P-value	Value	Z-value	P-value	Value	Z-value	P-value
Gt	-3.912	-13.022	0.00	-4.669	-15.473	0.00	-4.430	-13.690	0.00
Ga	-12.056	-2.120	0.01	-15.193	-4.421	0.00	-15.064	-4.188	0.00
Pt	-32.146	-16.533	0.00	-30.986	-16.908	0.00	-29.191	-15.710	0.00
Pa	-13.346	-6.853	0.00	-17.812	-9.466	0.00	-17.254	-8.753	0.00

*, **, *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

Source: Current Research

Before estimating the PVAR model, it is necessary to select the optimal lag for the models. In all panels considered in this study, the smallest value of MBIC, MAIC, and MQIC are for lag one. Hence, the preferred model is the first-order PVAR (Table 5).

In the next step, the PVAR model is estimated using the style of GMM, the results of which are

Table 5: Panel VAR Lag Order

Lag	Panel A			Panel B			Panel C		
	MBIC	MAIC	MQIC	MBIC	MAIC	MQIC	MBIC	MAIC	MQIC
1	-1704.529	-326.912	-866.6222	-1598.427	-324.3798	-830.0808	-1401.245	-293.685	-735.5701
2	-1517.982	-293.4337	-773.1761	-1405.698	-273.2112	-722.7232	-1213.878	-242.8661	-630.2722
3	-1321.631	-250.1516	-669.9261	-1224.423	-233.497	-626.82	-1053.294	-218.8315	-551.7586

Source: Current Research

reported in Table 6. In countries with weak and medium quality of institutions attributed to panels A and B, respectively, FDI has a negative impact on ecological footprint. As one percent of FDI increases, the environmental quality in panels A and B will improve by 0.006 and 0.01, respectively. Therefore, it seems that absorbing foreign investment by improving equipment and technologies can improve the quality of the environment. The results are parallel to the studies of Adeel-Farooq *et al.* (2021), Doytch (2020), Ali *et al.* (2020), Zafar *et al.* (2019). But in countries with the highest levels of institutional quality (panel C), the effect of FDI on ecological footprint is positive, and a one percent increase of FDI

results in 0.004 environmental degradations. The detrimental impact of FDI on environmental quality is consistent with the results of Udemba (2020), Sabir *et al.* (2020), Baloch *et al.* (2019). Along with the claims of a wide range of studies such as Usman *et al.* (2021), Khan *et al.* (2021), Sharma *et al.* (2021), Ulucak *et al.* (2020a) that suggest achieving a cleaner environment is possible through renewable energy consumption, our results also support this claim and make renewable energy a factor in having a clean environment is precious. We note that in countries with medium quality of institutions, the impact of renewable energy utilization is stronger and greater than the other two panels.

Regarding the effect of economic complexity, the evidence shows that moving away from the agricultural economy and moving towards the industrial economy, diversifying products, and enhancing the growth and production of countries leads to environmental degradation. The results confirm the Chu (2021), Yilanci & Pata (2020), Doğan *et al.* (2019), and Neagu & Teodoru (2019). We can boldly conclude that economic complexity has the most important and fundamental impact on environmental degradation in all panels among the various factors considered in this study. Meanwhile, economic complexity has the strongest effect on the ecological footprint in the countries with medium quality of institutions. In countries with weak and high quality of institutions, the rents of natural resources improve the quality of the environment and negatively affect the ecological footprint, which is in line with Khan *et al.* (2021), Zafar *et al.* (2019), and Ulucak *et al.* (2020a). Therefore, in countries that fall into these two panels, natural resources can improve the quality of the environment by strengthening the clean energy industry. Whereas, in countries with medium quality of institutions, the results are similar to Khan *et al.* (2021), Zafar *et al.* (2019), and Ulucak *et al.* (2020a) and reveal the destructive impact of the natural resources on the quality of the environment. The purpose of our study is to shed more light on the economic complexity and natural resources interaction on ecological footprint. The negative coefficient confirms that economic complexity through natural resources diminishes ecological footprint. It should be noted that to analyze further and discuss the impact of FDI, renewable energy utilization, economic complexity, natural resources, and interaction of them (i.e., economic complexity and natural resources) on the ecological footprint, we use the impulse response functions and also variance decomposition.

Table 6: PVAR Regression Results

	Panel A	Panel B	Panel C
	dlnEF	dlnEF	dlnEF
L.lnEF	-0.1368701***	-0.2156661***	-0.0692561***
L.lnFDI	-0.0061675**	-0.0100439***	0.0041261***
L.lnRE	-0.0816543***	-0.1276884***	-0.0544793***
L.lnECI	0.0967149***	0.3773854***	0.1318046***
L.lnNR	-0.0094871*	0.0090926***	-0.0199492***
L.ln(ECI×NR)	-0.0238314***	-0.1163981***	-0.0408566***
J-Hansen	321.08799	323.62018	290.315
p-value	0.535	0.496	0.517

*, **, *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

Source: Current Research

Notably, Impulse response functions in the PVAR model allow us to analyze one variables' reaction to the innovation of other study variables. Also, forecast error variance decomposition in the PVAR model examines cumulative percentage change in one variable explained by another variable's shock. It is important to note that the stability of the PVAR model must be explained before examining impulse response functions and variance decomposition. If all the eigenvalues of the PVAR model are within a unit circle, it proves the stability of PVAR model. Fig.4 exhibits that the entire eigenvalues lie inward the unit circle, and all three panels are stable.

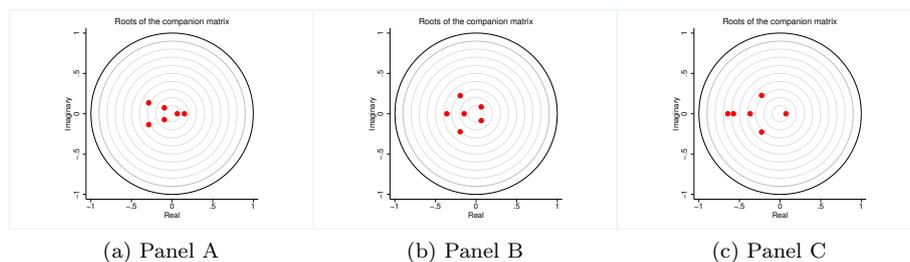


Figure 4: PVAR Stability Test

Impulse response functions have been used to investigate the dynamic relationships among variables. Impulse response functions as a powerful statistical tool, show well how one variable responds if one variable changes a standard deviation. It is worth noting that in the estimation of the PVAR model, the variables' order in the system is so important (Hamilton, 1990). Usually, the order of the variables is such that first, the most exogenous variable is selected, and we move to the most endogenous variable. Thus, we obtained the impulse response functions for the defined panels.

Fig.5 to 7 demonstrates the response of ecological footprint to change of a standard deviation in renewable energy consumption, FDI, natural resources, economic complexity, and the interaction of economic complexity and natural resources in panels A, B, and C, respectively, over 10 periods. Fig.5 reveals that the ecological footprint responds negatively to the sudden renewable energy consumption shock in early periods. Also, the ecological footprint responds positively to FDI and natural resources, and their effect disappears after almost two periods. The response of ecological footprint to a change of standard deviation in economic complexity in the first period is positive and then gradually disappears. Finally, the ecological footprint responds negatively to the shock of the interaction between economic complexity and natural resources for one period of time. While in the second period, it positively affects the ecological footprint, and from the third period onwards, it has no impact.

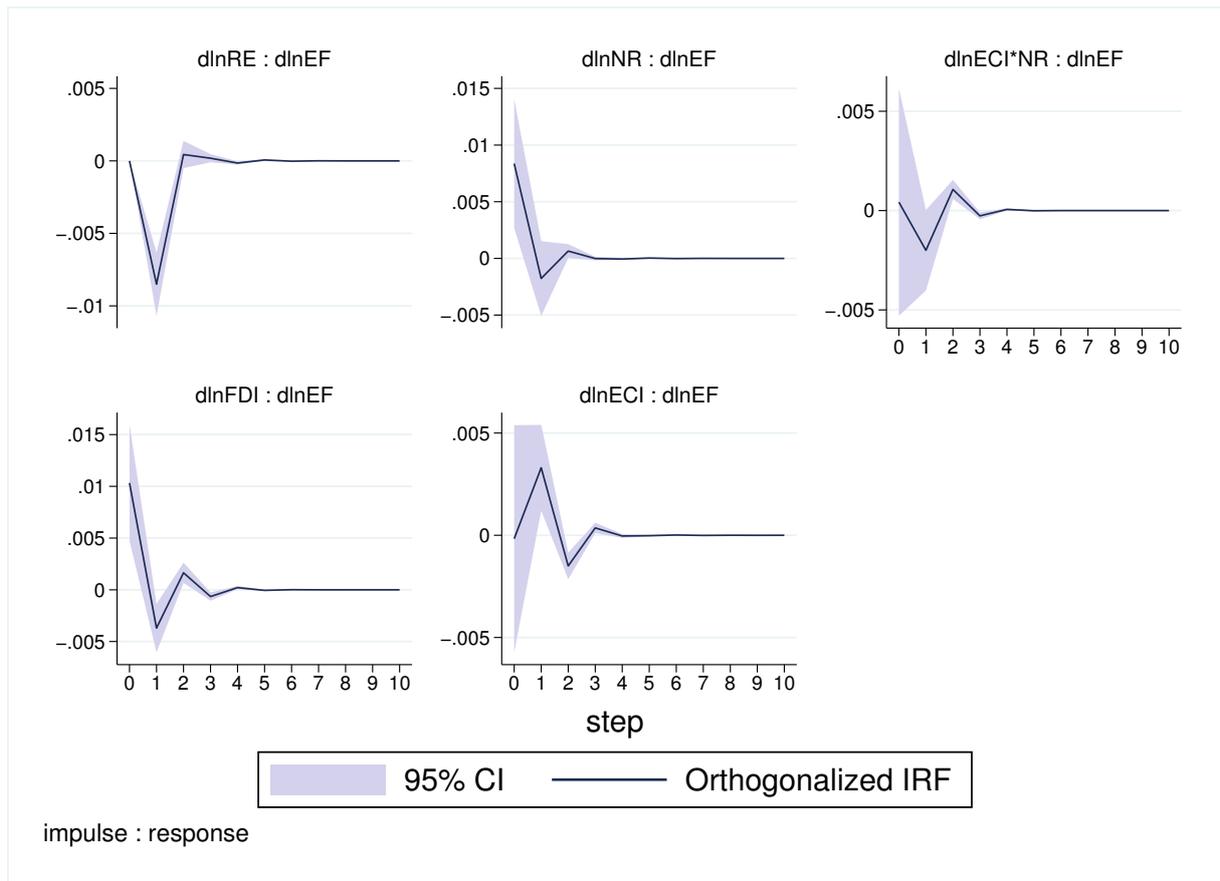


Figure 5: Impulse Response Function (Panel A)

In countries with a medium level of the quality of institutions, the response of ecological footprint to the shock of renewable energy consumption is negative and becomes positive only in the second period. The ecological footprint responds to sudden shocks of FDI of up to four periods, which in the first and third periods, unlike other periods, is negative. The ecological footprint is positively affected by a change of standard deviation of the natural resources and economic complexity for almost two periods. Shocks of economic complexity and natural resources robustly and negatively affect the ecological footprint for up to two periods. Furthermore, it positively influences the ecological footprint in the third period and gradually vanishes from the third period onwards.

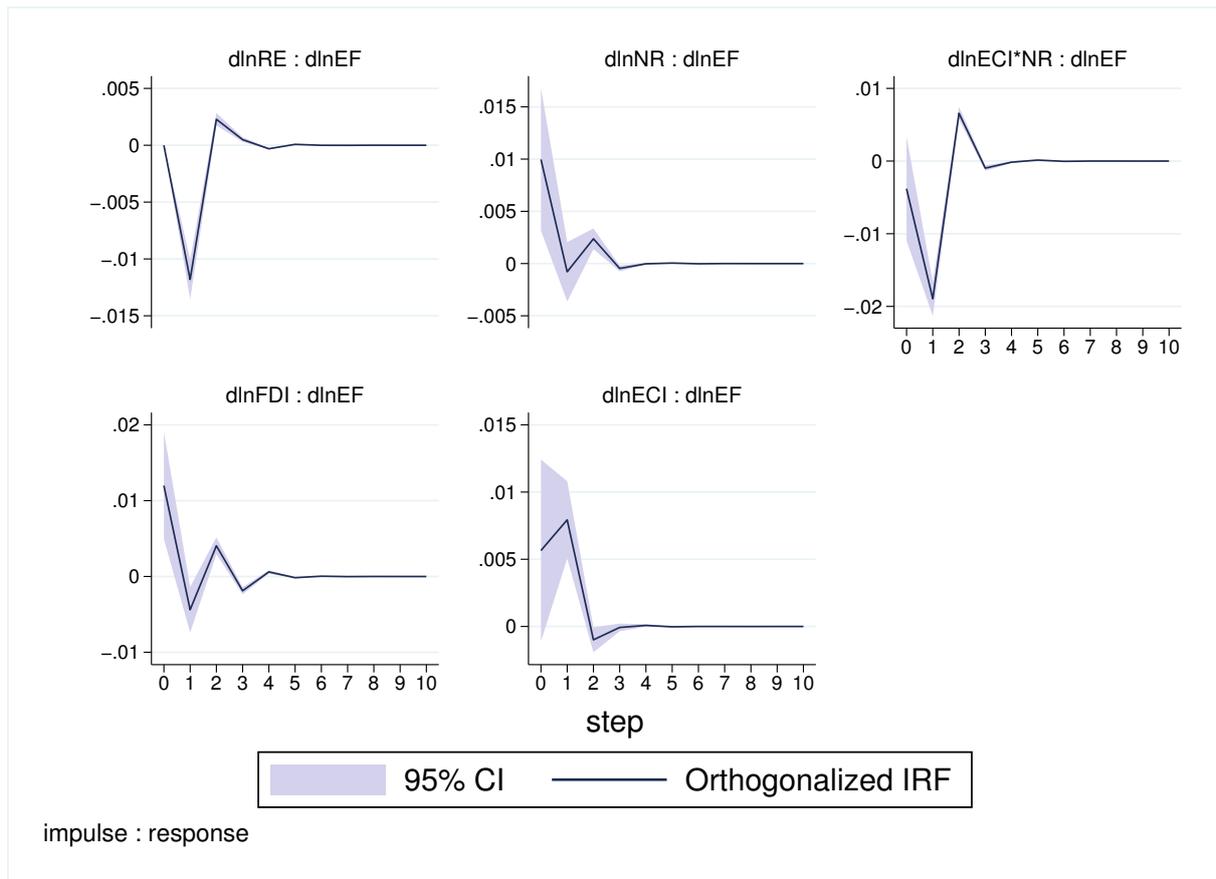


Figure 6: Impulse Response Function (Panel B)

Eventually, in countries with the highest level of institutional quality, the negative magnitude of ecological footprint response to renewable energy consumption shocks in the second period is severe and vanishes from the fourth period onwards. Also, the ecological footprint responds positively to a change of standard deviation of FDI. So that from the first period onwards, it has a very moderate slope and gradually disappears. Natural resources in the early periods negatively affect the ecological footprint. The ecological footprint responds positively to a sudden economic complexity shock in the first period and negatively in the second period, and its impact on the ecological footprint gradually evanesce. Ecological footprint up to the second period is negatively affected by the interaction of economic complexity and natural resources shock, and positively in the second and third periods. The magnitude and intensity of its impact on the ecological footprint are more severe in the second period.

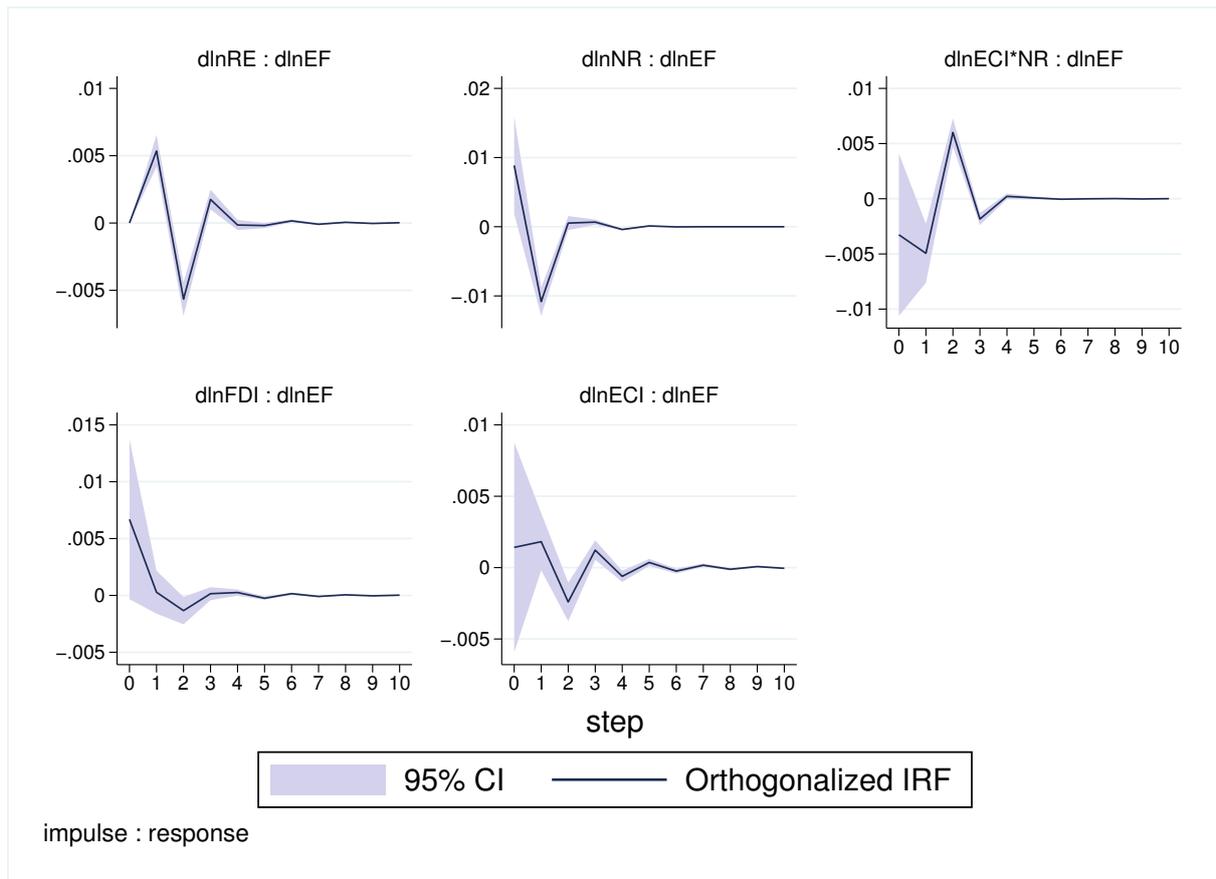


Figure 7: Impulse Response Function (Panel C)

Analysis of variance decomposition is performed to detect and identify the source of variance changes in ecological footprint in the PVAR model. It is worth noting that the variance decomposition in VAR models is obtained from the moving averages section and expresses the source of shocks. In other words, the variables' explanatory power for ecological footprint variations is shown by variance decomposition. Fig.8 exhibits the results of variance decomposition. The most robust and main variation in ecological footprint is detected by its innovations in all panels. In panel B, which is attributed to countries with medium institutional quality, the interaction of economic complexity and natural resources in ecological footprint variations gradually increases in the long run.

The results of the causality test as the last step are reported in Table 7. In countries with weak, medium, and high levels of institutional quality, the existence of the bi-directional causal relationship between ecological footprint and FDI, between ecological footprint and renewable energy consumption, between ecological footprint and natural resources are confirmed. Moreover, there is a bi-directional causal relationship between economic complexity and ecological footprint in countries with weak and high levels of institutional quality. Only the uni-directional causality from economic complexity to ecological footprint can be detected in the countries with a medium level of institutional quality.

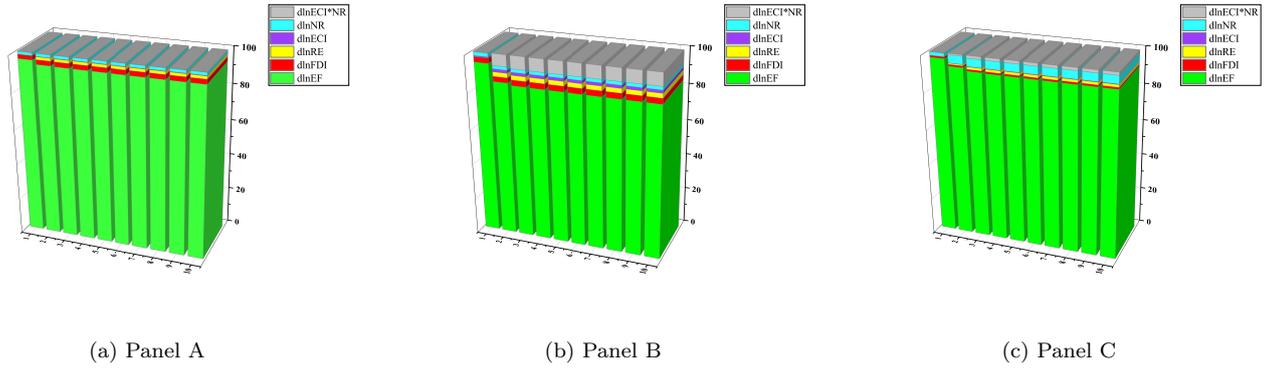


Figure 8: Variance Decomposition

Table 7: Granger Causality Test

Causality Direction	Panel A	Panel B	Panel C
dlnEF → dlnFDI	411.993***	29.423***	45.370***
dlnFDI → dlnEF	3.568*	30.135***	11.638***
dlnEF → dlnRE	115.534***	28.618***	645.836***
dlnRE → dlnEF	59.403***	207.617***	78.519***
dlnEF → dlnECI	6.488**	0.104	64.974***
dlnECI → dlnEF	18.876***	977.081***	15.383***
dlnEF → dlnNR	203.053***	56.118***	108.956***
dlnNR → dlnEF	3.334*	30.315***	50.642***
dlnEF → dlnRE	115.534***	28.618***	645.836***
dlnRE → dlnEF	59.403***	207.617***	78.519***

*, **, *** denote statistically significant at the 10%, 5%, and 1% levels, respectively.

Source: Current Research

Overall, the results indicate that factors considered in our study affect the environment. In particular, economic complexity, which is a highly influential factor in the ecological footprint, whose role on environmental quality has been examined in a few studies. Meanwhile, the environmental quality of countries with medium level of institutional quality is more affected by these factors than other countries.

5 Conclusion and Policy implications

Today, climate change and soil, water, and air pollution have posed irreparable dangers to national economies and human health. The source of these problems facing human beings is the change in lifestyle, the structure of the economy, and the ever-increasing demand for natural resources. Hence, this empirical study has considered the ecological footprint, which shows the human pressures on natural resources, an environmental indicator. In line with the objectives of this study, the effects of FDI, consumption of renewable energy, natural resources, and economic complexity on the ecological footprint have been examined using the PVAR model in 118 countries. The interaction of economic complexity

and natural resources entered the model as a new variable to clarify better. The results revealed that in all three groups of countries, divided based on institutional quality, economic complexity has the most significant effect on ecological footprint and causes environmental pollution. Furthermore, economic complexity through natural resources has a positive effect on environmental quality. It is worth noting that the effects of ecological footprint determinants considered in the present study are more substantial in countries with medium levels of institutional quality rather than two other groups.

The novel results of this study enable us to propose strategic policies to policymakers and governments. Policymakers in all countries surveyed in this study should adopt policies that encourage and impel investors to invest in clean energy, thereby enhancing and promoting the advanced technologies and infrastructures of renewable energy. Due to the structural changes of economies and the distance from the agricultural economy, and the move towards the industrial economy, countries are looking to increase the complexity of products, which leads to excessive consumption of natural resources. In this regard, governments should improve their R&D processes. R&D activities not only improve product knowledge and economic growth but also enhance the quality of the environment by enhancing technologies and reducing the costs of clean energy development.

A caveat of this empirical study is that the bureaucratic and institutional quality factors, which significantly impact environmental and energy regulations and policies, have not been directly included in the model. In future studies, institutional qualities can be included so that results are based on the performance of the governments. Future studies may also examine environmental quality by interacting with many environmental determinants such as human capital, income inequality, human development, trade diversity, and export quality to provide more accurate and practical conclusions. Finally, it is suggested that instead of using panel data models, a single country be conducted to achieve more attractive results by using more diverse econometric models.

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Consent to Publication not applicable

Consent to Participate not applicable

Appendix

The 118 countries considered in this study are classified based on institutional quality (corruption control).

Countries with weak levels of institutional quality (Panel A) include:

Albania; Algeria; Angola; Azerbaijan; Bangladesh; Bolivia; Bosnia and Herzegovina; Cambodia; Cameroon; Republic of the Congo; Democratic Republic of Congo; Cote d'Ivoire; Dominican Republic; Ecuador; El Salvador; Gabon; Guatemala; Guinea; Honduras; Iran; Kenya; Kyrgyz Republic; Lao PDR; Lebanon; Madagascar; Malawi; Mali; Mauritania; Mexico; Mozambique; Nicaragua; Nigeria; Pakistan; Panama; Papua New Guinea; Paraguay; Philippines; Russian Federation; Tajikistan; Togo; Turkmenistan; Uganda; Ukraine; Uzbekistan; Vietnam; Yemen; Zambia; Zimbabwe.

Countries with medium levels of institutional quality (Panel B) include:

Argentina; Armenia; Belarus; Brazil; Bulgaria; Burkina Faso; China; Colombia; Croatia; Cuba; Ethiopia; Ghana; Greece; Hungary; India; Indonesia; Italy; Jamaica; Jordan; Kazakhstan; Malaysia; Mauritius; Mongolia; Morocco; Peru; Romania; Saudi Arabia; Senegal; Slovak Republic; Sri Lanka; Tanzania; Thailand; Trinidad and Tobago; Tunisia; Turkey.

Countries with high levels of institutional quality (Panel C) include:

Australia; Austria; Belgium; Canada; Chile; Costa Rica; Cyprus; Czech Republic; Denmark; Estonia; Finland; France; Georgia; Germany; Ireland; Israel; Japan; South Korea; Latvia; Lithuania; Netherlands; New Zealand; Norway; Poland; Portugal; Singapore; Slovenia; Spain; Sweden; Switzerland; United Arab Emirates; United Kingdom; United States.

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