Financial and Economic Drivers of Ecological Footprint: a Panel Quantile Regression Analysis of the EU

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Abstract

The European Union (EU), as a signatory to the Paris Climate Agreement, aims to take on a global leadership role in sustainable environmental initiatives. This study explores the contribution of economic and financial developments to environmental sustainability in EU member states with successful environmental policies. The impacts of economic growth, financial development, and foreign direct investments on the ecological footprint are examined for 16 EU member states. Data from 1990–2021 is analysed using panel quantile regression and the Dumitrescu-Hurlin causality test. According to the results, the overall impact of economic growth and financial development on the Ecological Footprint is positive. Additionally, foreign direct investments contribute to an increase in ecological footprint. According to the causality test results, economic growth and ecological footprint mutually influence each other. There is a unidirectional causality from financial development and foreign direct investments to ecological footprint. Implementing financial policies directed towards eco-friendly technologies in EU member states will positively impact environmental sustainability.

Keywords	***DOI***	***JEL code***
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INTRODUCTION

Global economic growth, increasing economic activities, and some adverse effects such as environmental degradation, pollution, global warming, and climate change have raised concerns worldwide. Economic activities geared towards rapid economic growth, neglecting environmental impacts, have put the world at risk of extinction. Sustainable development, which integrates economic growth, environmental protection, social justice, and democracy in a holistic manner, has emerged as a response to the environmental crisis caused by overpopulation, resource depletion, and pollution (Critsu, 2017). Sustainable development comprises three main pillars: economic, social, and environmental. Within the framework of the 2030 Agenda for Sustainable Development, adopted by all United Nations (UN) member states in 2015, 17 Sustainable Development Goals (SDGs) have been identified to achieve sustainable development by 2030. These include clean energy (SDG7), sustainable economic growth (SDG8), innovative industry (SDG9), and climate action (SDG13) (UNDP).

High-income countries worldwide improve environmental quality, while middle-income economies face increasing emission levels. The predominant factor behind this phenomenon is the widespread implementation of growth strategies relying on fossil fuels within these countries (Naqvi et al., 2023; Mirza et al., 2022). This situation leads countries to deviate from SDG 8, SDG 9, and SDG 13 goals.

The United Nations Framework Convention on Climate Change (UNFCCC) was adopted at the Earth Summit held in Rio de Janeiro in 1992 and entered into force in 1994. This convention aims to provide an international framework for combating climate change and mitigating its effects. Through the UNFCCC, a cooperation mechanism was established among member countries to control greenhouse gas emissions and develop policies aligned with sustainable development goals (UNFCCC, 1994). Since 1994, the Conference of the Parties (COP) has been convened periodically.

The Kyoto Protocol is the first binding international agreement based on the UNFCCC. It was adopted at COP3, held in Kyoto, Japan, in 1997, and came into effect in 2005. The protocol required developed countries to reduce their greenhouse gas emissions by 5.2% compared to 1990 levels, while no binding obligations were imposed on developing countries.

The Paris Agreement was adopted at COP21, held in Paris, France, in 2015, to address the shortcomings of the Kyoto Protocol and adopt a more inclusive approach. However, it only became effective starting in 2020. The Paris Agreement aims to limit the global temperature increase to below 2°C above pre-industrial levels and pursue efforts to restrict it to 1.5°C.

The European Union's environmental policy aims to achieve sustainable development by eliminating, reducing, and preventing pollution; using natural resources in a way that does not harm the ecological balance; preventing environmental damage at its source; and integrating environmental protection with other sectoral policies. The fundamental principles of the EU's environmental policy include "polluter pays," "integration," "high level of protection," "prevention at source," "precaution," and "preventiveness." According to the EU's Intended Nationally Determined Contribution (INDC) submitted during the preparations for the Paris Agreement, the EU was the first major economy to sign the Paris Climate Agreement on April 22, 2016, committing to reducing its emissions by at least 40% by 2030. The environmental policy of the EU aims to ensure sustainable development by eliminating, reducing, and preventing pollution, using natural resources in a way that does not harm the ecological balance, preventing environmental damage at the source, and integrating environmental protection with other sectoral policies. The fundamental principles of the EU's environmental policy are "polluter pays," "integration," "high level of protection," "prevention at the source," "precaution," and "preventiveness." According to the Intended Nationally Determined Contribution presented by the EU in preparation for the Paris Agreement, the EU, as the first major economy, signed the Paris Climate Agreement on April 22, 2016, with a commitment to reduce its emissions by at least 40% by 2030.

As of the end of 2021, the EU countries have produced just over 17% of cumulative global carbon emissions since the commencement of the Industrial Revolution. As one of the region's most responsible for historical emissions, the EU has set numerous emission reduction targets. Despite making good progress in recent years by achieving a 20% reduction target by 2020, the EU remains the third-largest emitter of greenhouse gases in 2021 (Ian, 2023). Urgent actions, particularly in economic growth, energy, and finance sectors, are called to eliminate unsustainable growth mechanisms and promote more systematic transformation with environmentally friendly and renewable resources (IPCC, 2022).

In the context of economic growth (EG), the influence of financial development (FD) and foreign direct investment (FDI) on the environment is significant. Generally, it is suggested that an increase in the level of FD will enhance economic growth by promoting research and development expenditures, and consequently, this may have implications for the environment (Yuan and Gallenger, 2018; Nasir et al., 2019). Zhang (2011) explains the connection between FD and the environment through three different linkages. In the first linkage, FD increases FDI and EG, consequently resulting in increased energy consumption. Environmental degradation also increases when this rise in energy consumption is sourced from fossil fuels. The second linkage is attributed to the increased efficient financial intermediation created by FD, which leads to an expansion in credit creation. This, in turn, intensifies the use of energy-intensive goods and services, negatively impacting the environment (Sadorsky, 2010). In the third linkage, FD lowers the financing costs of publicly traded firms, enhances financing channels, distributes business risk, and optimizes asset/liability structure, enabling them to acquire new facilities, invest in new projects, and subsequently increase energy consumption, thereby causing environmental degradation (Dasgupta et al., 2001).

FDI inflows not only contribute to capital accumulation but also provide opportunities for local firms to benefit from new technology, technical knowledge, and management skills (Javorcik, 2004; Osei and Kim, 2023). It is well-known that FDI has scale, composition, and technological effects on economies. The scale effect impacts the level of economic activity caused by additional investment flows into the economy, and this effect is expected to contribute to environmental degradation. The component effect refers to the structural difference in the sectors of the economy, and environmental outcomes can vary depending on the affected sectors. The technological impact involves the transfer of new knowledge and techniques, which can enhance environmental quality (Doytch, 2020). The EU is one of the regions globally that attracts the highest FDI. In 2021, the total value of FDI made in the European Union was $461.37 billion (worldbank.org). Within the EU member nations, variations exist concerning their levels of EG. The separation from the economically less developed communist Eastern Bloc has, in modern times, boosted EU member countries' direct investment promotion policies, resulting in increased EG (Burlea-Schiopoiu et al., 2023). This situation necessitates the investigation of the relationship between FDI and the environment in European Union member countries.

FD, EG, and the influence of FDI on the environment require a more comprehensive indicator due to the limited representation of carbon emissions, pollutant emissions, and fossil fuel data, which are intensively used in research (Ulucak and Apergis, 2018; Solarin and Bello, 2018). The ecological footprint (EF) is considered a more reliable indicator for calculating environmental quality (Solarin and Bello, 2018; Chen et al., 2010). Moreover, the EF is distinguished as a pivotal metric in evaluating environmental sustainability (GFN, 2012) within scholarly analysis. The EF is articulated as the aggregate expanse of productive land (and water ecosystems) requisite for generating the resources consumed by a particular population globally, along with the capacity to absorb the resulting waste generated in this consumption process (Aall and Thorsen, 2005; Usman and Radulescu, 2022).

SDG 8 and SDG 13 highlight the need to manage the delicate balance between environmental sustainability and economic growth. The ecological footprint is a crucial tool for measuring the success of these goals and understanding their environmental impacts. The EU, by adopting green growth and low-carbon development strategies, aims to prevent environmental degradation and ensure that economic growth aligns with the SDGs, making it sustainable in the long run.

This paper explores the interconnections among EG, FDI, and environmental deterioration in EU nations, examining these relationships within the framework of the environmental Kuznets curve and pollution haven/halo assumptions (PHH/PHE). The rationale behind selecting the EU lies in its status as the second-largest economy globally, next to the United States, boasting a Gross Domestic Product (GDP) totalling $15.1 trillion. Additionally, as a unified entity, the EU represents 15.2% of global goods exports and 14.7% of global imports, securing the second position worldwide in both goods exports and imports. In line with existing studies, this study investigates three hypotheses. These hypotheses are; (1) the EKC hypothesis is valid for EU member states, (2) financial development contributes to the increase in environmental degradation, and (3) foreign direct investment reduces environmental degradation.

The theoretical framework related to the subject is given in Section 1. A summary of past studies is presented in Section 2. Section 3 discusses the model and methodology, while Section 4 presents the results and recommendations.

1 THEORETICAL FRAMEWORK

The literature has three theories regarding the influence of EG, FD, and FDI on a sustainable environment: i) the Environmental Kuznets Curve Hypothesis, ii) the Pollution Haven Hypothesis, and iii) the Pollution Halo Hypothesis.

1.1 EKC hypothesis

The linkage involving economic growth and environmental pollution is articulated in scholarly works through the EKC hypothesis, originating from the seminal study by Grossmann and Krueger (1991). Per the EKC hypothesis, once a particular threshold of EG is attained, the correlation between economic advancement and environmental deterioration tends to diminish (Mahmood et al., 2023; Aydın et al., 2023), as positive in scholarly sources. This hypothesis is fundamentally based on the inverted U hypothesis established by Simon Kuznets (1967), known as the Kuznets Curve, which relates income inequality to per capita income (Panayotou, 1993; Roberts and Grimes, 1997). The EKC hypothesis is that the initial effect of EG on environmental pollution is an increase followed by a decrease. In the initial stage of the EKC hypothesis, economies shift from basic economic activities towards industrialization. During this stage, countries prioritize economic growth and employment over the environment (Dasgupta et al., 2002). Large-scale use of natural resources and energy occurs to support economic growth (scale effect), leading to environmental pollution (Grossman and Kruger, 1991). The increase in income resulting from achieving economic growth raises individuals' demands for a clean environment, directing companies towards environmentally friendly production technologies (technological effect). As a result of the Technological effect, the reduction in the share of goods causing pollution in production leads to a decrease in environmental pollution (Komen et al., 1997).

1.2 Pollution Haven Hypothesis

FDI affects the environment differently depending on the country's level of development. Studies show that multinational corporations shift their investments to «dirty» sectors and economies with lower environmental standards to maximize profits from investments in developing countries (Bekun et al., 2023). The concept is known as the Pollution Haven Hypothesis (PHH). PHH is based on the approach that developed countries, by relocating heavy and polluting industries to developing countries with cheaper labour and weaker environmental regulations, contributing to environmental pollution in those countries. Strict environmental standards in developed countries negatively impact the production costs of multinational corporations, affecting their competitive advantage. Through FDI, multinational corporations shift their operations to countries where environmental standards are less emphasized to avoid losing their competitive advantage. Due to insufficient capital accumulation, developing countries, in their pursuit of attracting FDI, provide flexibility in environmental regulations and taxes, placing environmental standards in the background (Doytch, 2020; Haciimamoğlu, 2022). While developing countries specialize in producing and exporting dirty goods, developed countries specialize in producing and exporting clean goods. As a result, developing countries become pollution havens for the dirty industries of developed countries (Gill et al., 2018).

1.3 Pollution Halo Hypothesis

The environmental impact of FDI can be positive. Through their FDI in developing countries, multinational corporations facilitate the transfer of technology and new management techniques to these countries. Consequently, local firms in developing countries can adopt cleaner technologies. This situation improves environmental quality in developing countries through FDI (Zhang, 2011; Kisswani and Zaitouni, 2023). This phenomenon is referred to as the Pollution Halo Hypothesis.

2 LITERATURE SURVEY

In most of the literature, carbon emissions have been heavily utilized as an indicator of environmental degradation (Ahmad et al., 2016; Sun et al., 2017; Rafindadi et al., 2018; Le et al., 2020; Chaudhry et al., 2021; Caetano et al., 2021; Ke et al., 2022; Opoku et al., 2022; Pirgaip et al., 2023). In the literature, it is evident that in recent years, there has been a shift towards using EF as an alternative and inclusive measure, representing not only environmental degradation but also a sustainable environment. The existing literature in this study is divided into three segments: the relationship between EG and EF, the correlation between FD and EF, and the connection between FDI and EF.

2.1 The literature of the EG and EF

The EKC hypothesis suggests an increasing relationship between EG and environmental degradation up to a certain point of per capita income, followed by an environmental quality improvement with further income increases (Pablo-Romero et al., 2017). Balsalobre-Lorente et al. (2019), Haciimamoğlu (2022), Udemba (2021), and Khan et al. (2021) found that demonstrated the validity of the EKC hypothesis and indicated an inverse U-shaped relationship between income and EF. In contrast, Dogan et al. (2020), Yilanci and Pata (2020), and Mehmood (2022) found inconclusive evidence regarding the validity of the EKC.

When examining the EKC hypothesis applied to BRICS nations, Aydin and Turan (2020) found that it was only valid for India and South Africa, not Brazil, Russia, and China. Similarly, Murshed et al. (2022) demonstrated that the EKC hypothesis holds for South Asian countries and Bangladesh, Sri Lanka, Nepal, and Bhutan, but not for India and Pakistan. Various studies have determined that EG significantly contributes to environmental degradation (Destek and Okumus, 2019; Nathaniel and Khan, 2020; Baloch et al., 2019; Ponce et al., 2023). While Udemba (2021) and Murshed et al. (2022) identified a bidirectional causality relationship between EG and EF, Khan et al. (2021) demonstrated a unidirectional causality from EG to EF.

Saqib et al. (2023) analyzed the legitimacy of the EKC hypothesis from 1990 to 2020, focusing on the relationship between EG and EF in EU member states. The research findings indicated that the EKC hypothesis is applicable to EU member states and identified a bidirectional causality relationship between EG and EF. Building on these findings, this study aims to clarify the relationship between EG and EF using panel data for 16 EU member states. In this direction, the following hypothesis is investigated.

H_1: The EKC hypothesis is valid for EU member states.

2.2 The literature of the FD and EF

When examining research exploring the relationship between FD and EF, Baloch et al. (2019), Ahmad et al. (2022) concluded that FD increases EF. However, Idrees and Majeed (2022), found that FD increases EF over the long term. Studies by Wen et al. (2022), and Uddin et al. (2023) confirm that FD has a positive long-term effect on EF. On the other hand, there are studies in the literature indicating that FD reduces EF (Mishra and Dash, 2022). Additionally, studies such as those by Balsalobre-Lorente et al. (2023), and Ashraf et al. (2022) confirmed a reversed U-shaped relationship between FD and EF. Balsalobre-Lorente et al. (2023) explained this phenomenon through the diminishing scale effect and advancing FD technology and structural effects. Olowu et al. (2018), and Ozturk et al. (2023) found a causal relationship between FD and EF. On the other hand, Uddin et al. (2023) identified a bidirectional causality relationship between FD and EF.

Wang et al. (2023) examining a sample of 14 developing EU economies, asserted that FD contributed to the long-term increase in environmental degradation. Therefore, they emphasized the necessity of developing clean technology without compromising ecological superiority. Additionally, a bidirectional causality relationship between FD and EF was identified. Based on this approach, the following hypothesis will be investigated using panel data from 16 EU countries:

H_2: Financial development contributes to the increase in environmental degradation.

2.3 The literature of the FDI and EF

In the literature, studies have identified both favorable and unfavorable consequences of FDIs on environmental degradation. Uddin et al. (2023) demonstrated a positive relationship between FDIs and EF. Studies by Balsalobre-Lorente et al. (2023), Haciimamoğlu (2022), Baloch et al. (2019), Liu and Kim (2018), Murshed et al. (2022), Chishti (2023) and Usman et al. (2022) confirmed the validity of the PHH by indicating that FDIs increase EF. Chowdhury et al. (2021) demonstrated a positive impact of FDIs on EF, suggesting that environmental degradation increases with the increase in the amount of FDI. Khan et al. (2021) validated the legitimacy of the PHH. However, they also showed a bidirectional causality relationship between EF and FDIs. Usman et al. (2022) determined a long-term decrease in environmental quality due to FDIs and established the validity of the PHH.

Bakkal (2022) stated that FDIs contribute to environmental quality in the US and China. Due to the advanced status of the US and the fact that developed nations within the European Union make a significant portion of foreign direct capital inflows, it is suggested that the pollution halo effect is dominant. Udemba (2020) identified an adverse connection between FDIs and EF in the specific case of India, indicating a unidirectional relationship between FDIs and EF. Udemba (2021), and Sun et al. (2022) confirmed the validity of the PHOH for the United Arab Emirates and G-11 countries, respectively, emphasizing the significant contribution of FDIs to environmental performance. Balsalobre-Lorente et al. (2019), and Destek and Okumus (2019) tested the pollution haven hypothesis. Both studies revealed a reverse U-shaped relationship between FDIs and EF. Supporting these findings, Balsalobre-Lorente et al. (2019), Ozturk et al. (2023), and Uddin et al. (2023) provided further support by identifying a bidirectional causality relationship between FDIs and EF in their studies.

Research examining the relationship between FDIs and EF in EU nations is scarce in the literature. Wang et al. (2023) stated that FDIs lead to increased environmental degradation, while Saqib et al. (2023) argued that FDIs contribute to its decrease. Wang et al. (2023) explored the influence of FDI inflows on EF in the economies of 14 developing EU countries from 1995 to 2020, concluding that FDIs contribute to long-term environmental degradation. On the other hand, Saqib et al. (2023) confirmed the validity of the PHOH for 16 EU member states from 1990 to 2020, demonstrating a negative correlation between FDI and EF. The study determined that FDIs enhance environmental quality, promote disseminating environmentally sustainable technologies and managerial strategies, and establish a unidirectional causality relationship between FDIs and EFs.

Building on previous findings, this study aims to shed light on the Pollution Halo Hypothesis (PHOH) in EU countries. Using panel data from 16 EU member countries, the following hypothesis is investigated.

H_3: Foreign direct investment reduces environmental degradation.

This study's contributions to the existing body of literature can be outlined as follows: Initially, in contrast to numerous studies that rely on carbon emissions as a metric for environmental degradation, this research employs a more comprehensive gauge of the ecological footprint. Secondly, it is one of the few studies testing the EKC, PHH, and PHE formulas using the EF specifically for the EU. The primary distinctions from the limited array of extant studies in the literature are twofold: firstly, the divergence in data periods considered for individual countries, and secondly, the incorporation of economic and financial dimensions within the scope of this issue. Thirdly, instead of traditional testing methods, the study's empirical analysis applies methods considering cross-sectional dependence and heterogeneity, providing another contribution to the literature. Panel quantile regression is an approach that takes heterogeneity into account. It enriches the results by allowing estimation at different quantile levels and providing a clearer understanding of the heterogeneous structure. On the other hand, while outliers in the classical regression approach produce seriously deviant results, PQR can produce more reliable results for the quantiles where these values are collected (Koenker, 2004). The method offers flexibility in terms of compliance with the normal distribution for the dependent variable. It is also successful in reflecting the characteristics of the distribution, especially in cases where the normal distribution assumption is not provided. It can contribute to a more comprehensive consideration of the results obtained along the cross-sections in the heterogeneous structure and to the creation of target-oriented policies in this respect for policy makers (Cameron and Trivedi, 2005). Thus, the purpose of this research is to examine how EG, DYY, and environmental degradation are interrelated in EU countries.

3 DATA

This research investigates how financial and economic factors influence environmental sustainability across EU countries. For this purpose, foreign direct investments (FDI), financial development (FD), and economic growth (EG) were included in the study as independent variables, and ecological footprint representing environmental sustainability was included as dependent variables. Accordingly, the dependent variable EF is taken as Global hectares per person based on Ponce (2023), Nathaniel and Khan (2020), Saqid (2023), Uddin (2023). Among the independent variables, FDI is defined as net inflows (BoP) as in Liu and Kim (2018) and Wang et al. (2023), FD is defined as financial development index as in Uddin (2023), Balsalobre-Lorente et al. (2023), Balsalobre-Lorente et al. (2023), Ashraf (2022). And EG is defined as the annual percentage growth rate of GDP as in Liu and Kim (2018), Chike et al. (2023), Gaidhani et al. (2022), Shaikh and Noorani (2021).

16 EU countries (Austria, Belgium, Bulgaria, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Malta, Netherlands, Portugal, Spain, and Sweden) where data are accessible in the relevant period were considered, and the annual period of 1990–2021 data was used. There are 512 observations in panel data. Nominal values of the variables were included in the analyses. It can be discovered details regarding the variables utilization in the investigation are in Table 1.

The general research model is expressed as Formula (1) to determine the relationship between the dependent and independent variables:

$$EF_{it} = \delta_0 + \delta_1 EG_{it} + \delta_2 EG_{it}^2 + \delta_3 FDI_{it} + \delta_4 FD_{it} + \varepsilon_{it} , \qquad (1)$$

where: EF, EG, FDI, and FD are the abbreviations for ecological footprint, economic growth, foreign direct investments, and financial development variables. Additionally, i refers to the cross-section, t is time, and ε is the error term. δ shows estimated parameters.

Table 1 Variables

Variable	Abbr.	Description	Period	Source
Ecological footprint	EF	Global hectares per person	1990–2021	Global Footprint Network
Economic growth	EG	GDP growth (annual %)		World Bank
Foreign direct investment	FDI	Foreign direct investment, net inflows (BoP, current US$)		World Bank
Financial development	FD	Financial development index		International Monetary Fund

Source: Own construction

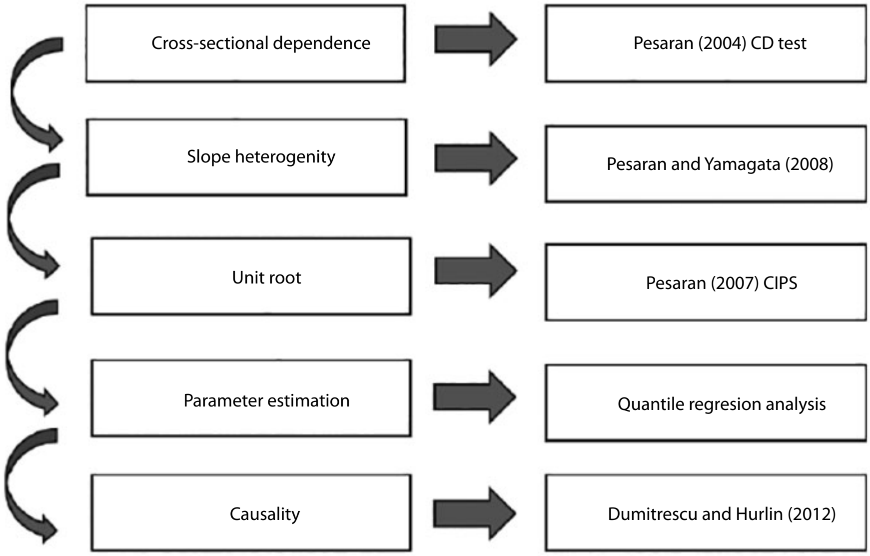
4 VARIABLE SELECTION

The variables were selected based on the discussions presented in the previous sections. In this study, ecological footprint (EF) was used as the dependent variable. The ecological footprint is recognized as a significant indicator for measuring environmental sustainability and impact. This concept refers to the total area of land and aquatic ecosystems required to produce the resources consumed by a population and to absorb the waste generated in the process (Aall and Thorsen, 2005; Curry et al., 2011). Today, the ecological footprint provides a more holistic "picture" of environmental issues and serves as a guide for measures to be taken at the societal level (Dam et al., 2017; Ramzan et al., 2022; Usman and Radulescu, 2022; Buyuksarikulak et al. (2023). Foreign direct investment (FDI), financial development (FD), and economic growth (EG) were included in the study as independent variables. The relationship between economic growth and environmental sustainability is explained through the Environmental Kuznets Curve (EKC) hypothesis. According to the EKC hypothesis, once a certain level of economic growth is achieved, additional economic growth can minimize the extent of environmental degradation. In general, the initial impact of economic growth on environmental pollution is an increase, followed by a decrease in the later stages (Dasgupta et al., 2002; Saqip et al., 2023). In the context of economic growth, the impact of financial development and foreign direct investment (FDI) on the environment is significant. It is suggested that a country's level of financial development supports economic growth by increasing R&D expenditures, which can, in turn, affect the environment (Yuan and Gallenger, 2018; Nasir et al., 2019; Frankel and Romer, 1999). Foreign direct investment, as a critical driver, promotes economic growth by enhancing capital flows and technology transfer. However, FDI often increases production and consumption activities, leading to higher energy consumption and environmental degradation, posing risks to environmental sustainability, particularly in developing countries (Zhang, 2011). Moreover, multinational corporations, through their FDI in developing countries, can contribute to improved environmental quality by transferring cleaner technologies and new management techniques (Zhang, 2011; Shao et al., 2019; Ashraf et al., 2021; Kisswani and Zaitouni, 2021).

5 METHODOLOGY

In order to reach the model results expressed in Formula (1), some priori analyses were carried out before the basic method of the study. The methodology followed is presented in Figure 1.

Figure 1 Econometric methodology



Source: Own constructions

The panel quantile regression (PQR) approach was used as the primary method of the study. PQR is a frequently used method in recent years as an option to the classical regression approach. One of the points where the method is superior is that it can estimate the conditional median distribution or the dependent variable across quantiles. In this way, it effectively detects cases where heteroscedasticity and normality in the series cannot be achieved. It is also essential to define nonlinear relationships between variables along quantiles (Raghutla et al., 2022). The method offers estimates of the conditional distribution of the dependent variable in different quantiles in determining the relationship between variables and does not require various assumptions as in OLS (Singh et al., 2022: 7; Opoku and Aluko, 2021: 178). Heterogeneity in estimating panel data is one of the main problems in producing reliable estimates. The panel quantile regression method can address the issue, which incorporates a penalty term into the minimization process, thereby mitigating undetected fixed effects (Koenker, 2004).

In the mathematical representation of the panel quantile regression model, different quantiles of y_{it} for x_{it} is shown in Formula (2):

$$y_{it} = \gamma_i + x_{it} + \varepsilon_{it}, \quad (2)$$

where: γ_i are the individual fixed effects, y_{it} the dependent variable, x_{it} the independent variable, and ε_{it} the error term. The coefficient estimator for the τ^{th} conditional quantile function is obtained with Formula (3), and the function is defined with Formula (4) (Banday and Kocoglu, 2022; Bhowmik et al., 2022).

$$Q_{y_{it}}\left(\tau|\gamma_i,\ x_{it}\right) = \gamma_i + x'_{it}\psi(\tau) + (\tau)\varepsilon_t, \quad (3)$$

$$\begin{pmatrix} \text{argmin} \\ \psi \end{pmatrix} = \sum_{n=1}^{n}\sum_{i=1}^{N}\sum_{t=1}^{T} v_w \rho_w \left(y_{it} - \gamma_i - x'_{it}\psi(\tau) + (\tau)\varepsilon_t\right), \quad (4)$$

where: v_w and ρ_w are functions that control the relative effect of n quantiles. Here ψ is the coefficient of the control variables (x'_{it}) and the dependent variable (y_{it}).

6 RESULTS AND DISCUSSION

To better identify the variables included in the study, summary statistics are presented in part A of Table 2, and correlation coefficient values are shown in part B.

Table 2 Variables

A: Statistics

	EF	EG	FD	FDI
Mean	5.7148	2.1247	0.6147	2.50E+10
Median	5.6660	2.2138	0.6359	7.83E+09
Maximum	9.7963	24.3704	0.9014	5.96E+11
Minimum	3.1244	–14.1153	0.2294	–2.89E+11
Std. deviation	1.3739	3.6076	0.1471	6.36E+10
Skewness	0.4875	–0.0894	–0.3119	3.9856
Kurtosis	3.0364	8.5988	2.2121	32.2357
Jarque–Bera	20.3143	669.4103	21.5460	19 589.74
Prob.	0.0000	0.0000	0.0000	0.0000

B: Correlation

	EF	EG	FD	FDI
EF	1			
EG	0.1351	1		
FD	0.2271	–0.0483	1	
FDI	0.1389	0.0494	0.3133	1

Source: Own construction

The results obtained in Table 2 provide information about each variable's mean, variability, and suitability to normal distribution and the direction and strength of the relationship between the variables. Probabilities of the Jarque-Bera test statistics show that none of the variables has a normal distribution. When descriptive statistics are examined in the study conducted specifically for 16 EU countries, since FDI is a variable with higher values than other variables, its mean and variability are higher than others. The FDI variable is followed by EF, EG and FD in terms of mean, respectively. For the variability structure, the order is EG, EF and FD. When the minimum and maximum values for each variable are determined from the data set; it is seen that the maximum value of the EF variable is in Denmark in 2000, and the minimum value is in Bulgaria in 1998. The minimum value for EG is in Bulgaria in 1997 and the maximum value is in Ireland in 2015. FD appears to have the highest value in Spain in 2017, and the lowest value in Bulgaria in 1999. The kurtosis and skewness coefficient values support the Jarque-Bera test, indicating that EF and FDI are positively skewed, while EG and FD are negatively skewed. The height value of the distribution of the EF variable has a kurtosis measure close to the normal distribution, while EG and FDI are more pointed, and FD is flatter. The correlation coefficient values show that there are positive but weak relationships between EF and all independent variables. The values are below 0.30. It is also noteworthy that there are no strong correlations between the independent variables. This indicates that a model free from the multicollinearity problem has been created.

In studies using panel data, various preliminary tests are required to decide on appropriate methods. The first is to determine whether there is a dependency between cross-sections. To assess cross-sectional dependence in the study, the Pesaran (2004) CD test and some other tests were used. The results are given in Table 3.

Table 3 Cross-sectional dependency

Variables	Pesaran CD test	Bias-Corrected scaled LM	Pesaran scaled LM	Breusch–Pagan LM
EF	35.2777***	93.7445***	94.0025***	1 576.2810***
EG	36.7479***	91.9549***	92.2130***	1 548.5580***
FD	45.0075***	140.2671***	140.5252***	2 297.0070***
FDI	14.9300***	22.1409***	22.3990***	467.0043***

Note: *** indicates 1% significance.
Source: Own construction

According to Table 3, in all tests used for cross-sectional dependence, the zero-hypothesis stating that the absence of cross-sectional dependence exists for all variables in the study was rejected, and the presence of dependency was revealed.

On the other hand, Pesaran and Yamagata's (2008) methodology was used to determine slope homogeneity. In the slope homogeneity test, the alternative hypothesis, indicating the existence of a heterogeneous structure, is tested against the zero hypothesis, indicating the presence of homogeneity. Table 4 shows the Pesaran and Yamagata Test results for slope heterogeneity.

Table 4 Testing for slope heterogeneity

	Statistics	p-value
Delta	7.3850	0.0000
Adj. Delta	8.0400	0.0000

Source: Own construction

The fact that the p-value value of both test results in Table 4 is less than 1% significance level causes the null hypothesis indicating homogeneity to be rejected. Applying methods that consider heterogeneity according to the test result will provide more reliable results.

The next step of the preliminary tests is to determine the stationarity levels of the variables. At this point, it is necessary to use the method that considers the cross-sectional dependency. The stationarity of the data will be investigated with the CIPS test, which is a second-generation unit root test (Pesaran, 2007). The zero hypothesis in the unit root test indicates the presence of a unit root. Table 5 presents the CIPS test results for the variables.

Table 5 CIPS Test

Variable	Constant	Constant + trend	Result
EF	−2.7460***	−3.5397***	I(0)
EG	−4.1186***	−4.1900***	I(0)
FD	−2.6743***	−3.1211***	I(0)
FDI	−3.9116***	−4.1034***	I(0)

Note: *** indicates 1% significance.
Source: Own construction

Considering the CIPS test results, the zero hypothesis was rejected when all variables have constant and constant and trend models. This result means that all variables included in the study have a level-stationary (I(0)) structure.

PQR analysis is a method that allows the heterogeneous effects between variables to be observed. For this purpose, estimations were made for different quantile levels (10th, 20th, …, 90th) and results were presented for 16 EU countries. Table 6 shows the estimation parameters obtained at different quantile levels.

When the results obtained in Table 6 are evaluated, it is seen that all independent variables generally have a significant effect on the ecological footprint, with a few exceptions. It has been determined that the coefficient of EG across all quantiles is positive and statistically significant for 16 European Union countries. Except for the median quantile, the coefficient value increased as the quantile level increased. This result is compatible with the literature (Destek and Okumus, 2019; Nathaniel and Khan, 2020; Bakkal, 2022; Baloch et al., 2019; Ponce et al., 2023). EG increases the EF, in other words, environmental degradation in EU, as in many countries worldwide. The square of economic growth was added to the model to determine the status of the Kuznets hypothesis. Notably, the relevant variable's coefficient is negative and statistically significant in all quantiles except the 10th. The coefficient values obtained for EG, and its square indicate that the Inverted-U EKC structure is valid for the relevant panel. The finding that the environmental Kuznets curve hypothesis is valid and supported by Balsalobre-Lorente et al. (2019), Haciimamoğlu (2022), Udemba (2021), Khan et al. (2021) study findings, while Dogan et al. (2020), Yilanci and Pata (2020), and Mehmood (2022) are contrary to the study findings. The effect of FD on the EF was determined to be positive and significant except for the 90th. Like economic growth, financial development also has a positive impact on environmental degradation in the relevant country group (Baloch et al., 2019; Bakkal, 2022; Ahmad et al., 2022; Idrees and Majeed, 2022; Wen et al., 2022; Uddin et al., 2023). The effects of FDI, one of the important economic indicators for countries, on the environment, have been studied by researchers for many years. The environmental impact of this variable gives essential clues as to whether investors see the countries in which they invest as pollution havens. It is noteworthy that although the coefficient values for FDI in the study are minimal, they are statistically significant and positive up to high quantile levels (Uddin et al., 2023; Balsalobre-Lorente et al., 2023; Haciimamoglu, 2022; Baloch et al., 2019; Liu and Kim, 2018; Murshed et al., 2022; Chishti, 2023; Chowdhury et al., 2021).

The study's final analysis was the Dumitrescu and Hurlin (2012) (DH) causality test to reveal the causality relationship between the variables. The results of the DH causality test, which is a causality method especially suitable for heterogeneous panels are given in Table 7.

Table 6 PQR for EF

Quantiles	Variables			
	EG	EG^2	FD	FDI
10th	0.0374***	–0.0019	1.8619***	4.98e–12***
20th	0.0621***	0.0063***	2.6635***	3.68e–12***
30th	0.0691***	0.0088***	1.9698***	3.30e–12***
40th	0.0858***	–0.0067**	1.7541***	2.71e–12***
50th	0.0811***	–0.0051*	1.4018***	2.44e–12***
60th	0.0931***	–0.0059**	1.4978**	1.88e–12**
70th	0.0872***	–0.0026**	1.8521**	1.14E–12
80th	0.1050***	–0.0052**	1.4995**	5.78E–13
90th	0.1218***	–0.0096**	1.2472	1.02E–12

Note: *, **, *** indicate 10%, 5% and 1% significance.
Source: Own construction

Table 7 DH causality

Hypothesis	W-Statistics	Zbar-Statistics	Probability	Result
EG ⇏ EF	3.5563	2.3313	0.0197	EF ⇔ EG
EF ⇏ EG	3.4517	2.1549	0.0312	
FD ⇏ EF	5.8691	6.2316	5.00E–10	FD ⇒ EF
EF ⇏ FD	1.7269	–0.7537	0.451	
FDI ⇏ EF	5.119	4.9665	7.00E–07	FDI ⇒ EF
EF ⇏ FDI	2.2748	0.1701	0.8649	
FD ⇏ EG	5.4372	5.5032	4.00E–08	FD ⇔ EG
EG ⇏ FD	1.1581	–1.7129	0.0867	
FDI ⇏ EG	4.9059	4.6073	4.00E–06	FDI ⇒ EG
EG ⇏ FDI	2.9239	1.2648	0.2059	
FDI ⇏ FD	1.5865	–0.9905	0.3219	FD ⇒ FDI
FD ⇏ FDI	3.4034	2.0734	0.0381	

Source: Own construction

Causality test results provide evidence for the presence of a bidirectional causal relationship between EF and EG, as well as between FD and EG. On the other hand, there is a causal relationship in the direction of EF from both FD and FDI. In addition, other situations are detected by one-way causality relationships from FDI to EG and from FD to FDI. Causality test results are consistent with theoretical expectations.

While economic growth triggers the EF, developments in the EF in the opposite direction impact economic growth, according to the Kuznets approach. Financial development and foreign investments are also the cause of EF. Mutual causality between FD and EG in the relevant country group shows that movements in two variables trigger the other. Again, according to these results, financial development changes impact investors.

CONCLUSION

The sensitivity and concrete steps of the EU in sustainable environmental policies from the past to the present are closely followed worldwide. Although the existing literature has mainly focused on countries with intensive impacts on environmental degradation, examining countries with successful environmental policies as examples within the context of contributing to environmental sustainability is essential. In this framework, the study aims to examine the contribution of economic and financial developments to environmental sustainability in the EU with successful environmental policies.

PQR and causality analysis were used to determine the structure of the EKC and evaluate the effects of EG, FD, and FDI on EF. The results of the PQR indicate that EG generally has a positive impact on EF. On the other hand, the squared term of EG has a negative effect on EF. In the EU, the process of economic growth and industrialization initially led to the intensive use of natural resources and an increase in environmentally harmful polluting activities. However, it is anticipated that the economic growth achieved, and the resulting higher income levels have enabled the development of solutions that mitigate environmental impacts, such as eco-friendly technologies, energy efficiency, and sustainable production methods. Additionally, rising income levels in EU countries are believed to have fostered environmental awareness within society. This growing environmental awareness has facilitated the implementation of effective environmental policies and the tightening of environmental regulations in EU countries. Consistent with the findings of Saqib et al. (2023), the study confirms the validity of the inverted U-shaped EKC in EU member states.

Panel quantile regression results show that FD increases EF. Another result of the study is that the increase in environmental degradation due to financial development is not immediately reflected in financial returns, which can be considered as an indicator that investors tend to make investments that yield high profits in the short term. However, in the long term, economic and social risks that environmental degradation will create may lead investors to consider environmental risk factors more in their decisions and turn to sustainable investments. The increase in environmental degradation due to financial development may lead to a significant change in investor behaviour. While some investors see this situation as an opportunity, others may tend to turn to more sustainable and ethical investments. This interaction depends on the value priorities of both individual and institutional investors. The findings support the conclusion suggested by Wang et al. (2023) that FD contributes to environmental degradation in the long term.

The theoretical expectation about the influence of foreign direct investments (FDIs) on the environment in the EU, as detected in the study by Saqib et al. (2023), is to reduce environmental degradation. According to the findings, direct FDIs have a positive effect on the EF up to high quantile levels and the results are found to be consistent with Wang et al. (2023). However, it is observed that this effect is relatively small, and the coefficient is not significant at high quantiles. The fact that the impact of foreign direct investment in reducing the ecological footprint in European Union countries decreases after a certain level may be due to the FDIs being directed towards environmentally unfriendly sectors and the tendency to evade environmental regulations. This result suggests that the EU, which implements numerous sanctions to prevent environmental degradation, must further increase these measures. Examining the causality analysis results between variables reveals mutual influences between EG and the EF. On the other hand, there is a unidirectional causality from FD and direct FDIs towards the EF.

Based on the research findings, this research provides several policy suggestions to promote environmental sustainability. Policymakers in these economies should encourage FDIs and capital flows. FDI should be directed towards production processes that use eco-friendly technologies and contribute to a sustainable environment. Utilizing more clean energy during FDI implementations in the EU and employing clean technologies in institutions contributing to FD will have a positive impact on the EF. Additionally, focusing on green investments by financial institutions can reduce environmental degradation in parallel with the growth in the financial sector. Environmentally friendly investments and financial policies towards eco-friendly technologies can support a positive relationship between FD and a sustainable environment.

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