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Green environment in the EU countries: The role of financial inclusion, natural resources and energy intensity

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ABSTRACT

The European Union pursues the European Green Deal strategy as well as Sustainable Development Goals, the main target of which is to become a carbon-neutral continent by 2050. Hence, a lot of environmental challenges need to be solved. Possible determinants in mitigating environmental challenges are financial inclusion, natural resources and interaction with a green environment. This concept implies preserving natural resources and a clean environment for future generations. However, there is still no clear evidence in the literature on how natural resources and financial inclusion interact with the green environment in the EU. Therefore, this paper aims at filling this gap. In order to obtain empirical results, the quantile regression econometric technique proposed by Koenker has been applied. The analyzed period was from 2004 to 2019 for EU-26 countries. The results show that higher energy intensity is the main cause of environmental degradation. However, financial inclusion in higher quantiles and natural resources rent lead to a reduction in carbon emissions. Our results also confirm that the EU has succeeded in decoupling economic growth from pollution. The robustness of the results was checked using a Powell's quantile regression, which confirmed the relationship between a green environment and the variables analyzed. Thus, the results suggest that financial inclusion needs to be more integrated into energy and climate policies, especially in the early stages of development. In addition, large-scale green investments are needed in EU countries to further reduce energy intensity and create an effective green environment.

1. Introduction

Given the rapid pace of economic development and its negative impact on the environment, economies must find solutions to mitigate climate change, reduce carbon emissions and create a green environment. The concept of green environment is related to sustainable development. It covers several points, including promoting the use of renewable energy and materials, applying sustainable consumption and production, minimizing waste and reducing environmental pollutants (Li et al., 2022). To date, greenhouse gas (GHG) emissions, particularly carbon dioxide (CO_2) emissions, are the largest contributor to climate change and environmental sustainability degradation (IPCC et al., 2022). More than 75% of GHG emissions in the EU are due to energy production and consumption (Eurostat, 2022a). Addressing the problem of GHG emissions, i.e., CO_2 emissions, remains the most important task for all countries to achieve environmental sustainability. In this regard, reducing GHG emissions in the natural environment has become a global priority, especially for EU countries that have decided to take the lead in addressing the problems of climate change. As a result, GHG emissions in the EU are steadily declining and in 2021 were 30% below 1990 levels (EEA, 2022). However, to achieve the goal of climate neutrality by 2050, the EU will need to triple its efforts.

When determining the level of CO_2 emissions, it is necessary to consider the role of financial inclusion, natural resources rent and energy intensity. Financial inclusion means that all individuals and businesses have access to financial products and services (transactions, payments, savings, credit and insurance) to meet their needs in an affordable and sustainable manner (World Bank, 2022a). Current restrictions on access to energy and environmental barriers, such as the release of pollutants from energy sources, have increased the tendency

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to improve energy intensity. In other words, countries are looking for solutions to optimize energy production and consumption, preferring to use less energy for a given level of gross domestic product (GDP), which means a reduction in energy intensity. This measure of energy consumption is superior to traditional energy consumption because it reveals the impact of GDP (Shahbaz et al., 2015). Energy intensity is essentially a measure of energy efficiency calculated in units of energy consumed per GDP in an economy (Martínez et al., 2019). Thus, high energy intensity means that more GDP is spent on one unit of energy consumed, making energy prohibitively expensive. It also means that energy consumption is not efficient. Inefficient energy consumption has an impact on the climate, as high energy consumption contributes to global warming. Many countries in the world, especially the EU, have adopted policies and programs to reduce energy intensity and promote energy efficiency. According to Le Pen and Sevi (2010), the extent to which energy and climate policy goals can be achieved depends largely on how energy intensity is distributed across countries. Since 2000, the EU has reduced its energy intensity by about 2% per year (Enerdata, 2022). This is thanks to energy efficiency efforts (especially in the electricity sector) and, to a lesser extent, a structural shift toward less energy-intensive industries and the growing share of services in GDP. In 2021, the improvement was much slower (−0.8%), largely due to the rebound in energy consumption and economic growth. However, at these rates, it is unlikely that the EU will meet its 2030 energy efficiency target, which calls for a 36%–39% reduction in energy consumption (European Commission, 2019). This target was further increased by the REPowerEU package (European Commission, 2022), paving the way for the overall goal of carbon neutrality by 2050.

While the impact of financial development on CO_2 emissions or the impact of natural resources rent and energy intensity on economic growth have been documented in many studies, the number of studies addressing the role of financial inclusion, natural resources rent and energy intensity in climate change mitigation is extremely limited. Therefore, the main objective of this paper is to examine the impact of financial inclusion, natural resources rents and energy intensity on climate change and the green environment in the EU-26 countries over the period 2004–2019. EU countries were selected for this analysis because the EU is a leader in global governance and has decided to become a carbon-neutral continent by 2050 by focusing on increasing renewable energy and energy efficiency while adopting green technologies Moreover, there is a lack of empirical evidence on EU countries. In addition to the main objective, the paper also aims to answer the following research questions:

- To what extent do financial inclusion and energy intensity have an impact on CO_2 emissions in the EU-26 countries?
- Does the depletion of natural resources rent have an impact on CO_2 emissions in the EU-26 countries?
- What is the impact of the determinants analyzed in support of a green environment for the EU-26 countries?

Following everything stated above, the main contribution of the paper is that this is a first attempt to fill the literature gap regarding the nexus between financial inclusion, natural resources rent and energy intensity, which is important for supporting the green environment concept. It was determined to be very important for climate change mitigation and one of the main priorities of the European Green Deal and Sustainable Development Goals for EU countries. Besides the main contribution, the second contribution lies in applying a novel research methodology, i.e., a quantile regression analysis, which allows a full representation of the stochastic relationship between the variables and provides more efficient and robust estimates. Therefore, it is likely that this analysis will contribute to the current literature by incorporating new variables and robust results. The third contribution can be found in the first analysis for the EU-26 countries, where the results confirm that the variables analyzed have a significant impact on carbon emissions, emphasizing financial inclusion. Based on those results, recommendations for policymakers are provided which can be of importance for the establishment of the green environment concept in every EU country. The fourth contribution lies in confirming the existence of the Environmental Kuznets Curve (EKC) hypothesis for CO_2 emissions.

The rest of the paper is organized as follows. After a brief introduction, Section 2 presents the literature review. Section 3 contains a description of the materials and methods, while Section 4 presents the empirical results. Section 5 provides conclusions, practical implications for policymakers, limitations and recommendations for further research.

2. Literature review

Since the late 2000s, research studies have focused on the question of the relationship between financial inclusion and economic development (Kim et al., 2018; Van et al., 2019, 2021; Karim et al., 2022). The authors agree that financial inclusion plays an important role in economic growth by ensuring the creation of capital through distribution, pooling and savings and by improving investment and the efficient allocation of resources. The financial sector also plays a critical role in reducing energy emissions by promoting new and environmentally friendly technologies to minimize pollution. However, financial inclusion can also have negative environmental impacts by encouraging industrial activities that can cause greater environmental damage. In empirical studies, evidence on the relationship between financial inclusion and environmental degradation is mixed. For example, Dou and Li (2022) used panel data for BRICS countries and the Augmented Mean Group (AMG) method to examine the effects of financial inclusion and energy efficiency on limiting trade-adjusted emissions. They found a positive impact of financial inclusion and a negative impact of energy efficiency on CO_2 emissions. Using panel data from EU-27 countries and the method of moments quantile regression, Fareed et al. (2022) examined the role of innovation activity, financial inclusion and environmental degradation for the period 1995–2018, and their results show that financial inclusion is detrimental to the environment in the Eurozone. However, the authors acknowledge that innovation activity significantly and negatively weakens this relationship. Zaidi et al. (2021) found similar results for 23 OECD countries and concluded that the government needs to align financial inclusion targets with energy consumption behavior and environmental policies. In addition, analyzing 31 Asian countries, Le et al. (2020) found that financial inclusion led to higher CO_2 emissions in the region, while greater openness to trade reduced CO_2 emissions. Lin and Wu (2022) examined the effects of financial inclusion and energy efficiency on CO_2 emissions in the seven emerging economies (E7) from 2004 to 2019, and using quantile regression, they found that financial inclusion was one of the main drivers of environmental degradation in the region, while energy efficiency negatively affected CO_2 emissions. Mukalayi and Inglesi-Lotz (2023) analyzed the effect of the expansion of innovative digital services and financial inclusion on energy consumption and the environment in 39 countries. They concluded that higher financial inclusion is associated with higher energy consumption and CO_2 emissions. Tufail et al. (2022) also confirmed that there is a positive linkage between CO_2 emissions, financial inclusion, energy efficiency, exports, imports and gross domestic product in the long run for BRICS countries. On a sample of Regional Comprehensive Economic Partnership (RCEP) countries, Dai et al. (2022) found that financial inclusion induces a positive impact on renewable energy efficiency, but on the other hand, ensures low energy sources.

Usman et al. (2021), on the other hand, confirmed the negative impact of financial inclusion on CO_2 emissions in the case of the 15 largest emitting countries. However, he used financial development as a proxy for financial inclusion, which can be strongly criticized. Shahbaz et al. (2022) also found negative effects of financial inclusion on pollutant emissions using a sample of 30 Chinese provinces from 2011 to 2017. By analyzing a panel of 103 countries during 2004–2014, Renzhi and Baek (2020) found an inverted U-shaped relationship between financial inclusion and CO_2 emissions. At the initial stage, financial inclusion can improve access to basic financial services and increase CO_2 emissions. However, at a later stage, improved financial inclusion leads to financial market development and investors expect companies to take environmentally friendly measures to reduce CO_2 emissions. Doaa and Doaa (2022) examined the linkage between digital finance, financial inclusion and renewable energy on carbon emissions in Egypt over the period 1990–2020. They found that, in the long run, digital financial services limit carbon emissions, but not in the short run. Dogan and Seker (2016) found that financial development increases the use of renewable energy resources and thus contributes to the reduction of GHG emissions. Bai et al. (2022) pointed out that improving the quality of green finance and increasing the level of green finance strengthened by science and technology are key to achieving sustainable green development. According to the European Green Deal (European Commission, 2019), sustainable finance plays a key role in achieving policy goals as well as the EU's international commitments on climate and sustainability goals. It does so by channeling private investment into the transition to a carbon-neutral, climate-resilient, resource-efficient and fair economy, as a complement to public funding. Moreover, Mahmood et al. (2022) suggested that even Brazil, Russia, India, China and South Africa need to implement financial inclusion with environmental policies to achieve climate-related goals.

When determining the level of carbon emissions and environmental sustainability, the role of natural resources rent cannot be neglected. The relationship between natural resources rent and CO_2 emissions has been widely studied and studies have reached different conclusions. For example, Lei et al. (2022) examined how the extensive use of natural resources prevents G-20 countries from achieving carbon control targets. Using the cross-sectional method CS-ARDL for panel data from 1991 to 2019, the study shows that an increase in natural resources rent is causing a huge increase in CO_2 emissions. He et al. (2022) also confirmed that there is a strong positive relationship between China's total natural resources and GHG emissions. Similar results were found by Tauseef Hassan et al. (2021) for Pakistan, Dagar et al. (2022) for the 38 OECD countries and Huang et al. (2021) for the United States. Wang et al. (2020) examined the role of natural resources rents, financial development and agricultural value added in explaining CO_2 emissions in G7 economies. The results of the study show that natural resources rents cause more CO_2 emissions in G7 countries. Bekun et al. (2018) analyzed the relationship between natural resources rent, renewable and non-renewable energy consumption, economic growth and carbon emissions in 16 EU economies during 1996–2014. Using the PMG panel method, they found that natural resources rents increase CO_2 emissions. Ullah et al. (2021) reached similar conclusions for the 15 countries with the highest renewable energy consumption in the world. Hajko et al. (2018) examined the nexus between energy consumption, economic growth and environmental degradation. They found that fossil fuels are based at the first stage of economic development.

However, Altinoz and Dogan (2021) examined how renewable energy use and natural resources availability affects the amount of CO_2 emissions produced in 82 countries. According to the quantile regression results, renewable energy reduces CO_2 emissions. In contrast, abundant natural resources have a negative effect on CO_2 emissions at the lower quantiles, but have a positive effect at the middle and higher quantiles. Similarly, in an analysis of OECD countries from 1980 to 2016, Ulucak et al. (2020) found that natural resources extraction increases CO_2 emissions, but renewable energy reduces environmental degradation. The authors emphasize that efficient and sustainable use of natural resources and an increasing share of renewable energy in the energy mix are urgently needed for a sustainable environment and development. Based on a case of Iran, Balsalobre-Lorente et al. (2019) found that natural gas consumption as an alternative to non-renewable energy is a driver of long-run economic growth. Moreover, Dogan et al. (2022) confirmed that renewable energy and employment contribute to a decline in the ecological footprint and carbon ecological footprint. Hence, the use of renewable resources should be promoted more. By analysing various renewable energy indicators, Dogan et al. (2021) found interesting results. For example, irrespective to the indicator choice, the impact of economic growth on renewable energy is positive.

Nevertheless, there is a contradiction in the empirical evidence on the environmental impact of natural resources. In this regard, the study by Tufail et al. (2021) found that natural resource rent improves the natural environment by reducing CO2 emissions in OECD economies over the period 1990–2018. Balsalobre-Lorente et al. (2018) found similar results for five European (EU-5) countries over the period 1985–2016. Similarly, Khan et al.'s (2021) study for the United States concluded that natural resource rents reduce pollution. Danish et al. (2019) also found that the availability of natural resources in BRICS countries reduces pollution, with the exception of India. The experts suggested that natural resource renewal should be combined with resource conservation to reduce CO2 emissions. They also recommended that replacing old technologies with more advanced and environmentally friendly technologies would lead to environmental sustainability. Kongbuamai et al. (2020) analyzed ASEAN countries for the period 1995–2016 and showed that natural resources contribute to improving environmental quality. In addition, Anwar et al. (2021) argued that the use of non-renewable energy sources increases carbon emissions, while the use of renewable energy sources leads to a decrease in carbon emissions. They concluded that governments should promote the production of renewable energy sources and integrate them into a national energy grid to minimize the environmental damage.

As for the relationship between energy intensity and the environment, there are few studies that provide empirical evidence. Amin and Dogan (2021) analyzed the role of the nexus between energy intensity, income and environment including policy-induced uncertainty, for China from 1980 to 2016 using the novel bound-testing with dynamic simulations. The empirical results show that increases in real income and energy intensity contribute to pollution, while increases in renewable energy reduce emissions. They argue that the government should align economic and environmental policies to curb pollution in order to achieve environmental sustainability. Similarly, Danish et al. (2020) used annual data from 1985 to 2017 for the United States to analyse the relationship between energy intensity and CO2 emissions, incorporating economic policy uncertainty. They found that energy intensity leads to an increase in pollution, but economic policy uncertainty also contributes to an increase in CO2 emissions. These results are consistent with those of Shahbaz et al. (2016), who showed that energy intensity contributes to an increase in CO2 emissions in 24 African countries. Moreover, similar to the results of Namahoro et al. (2021) for 50 African countries from 1980 to 2018 and Amuakwa-Mensah and Adom (2017) for 43 sub-Saharan African countries. Mahmood and Ahmad (2018) analyzed energy intensity in Europe using a panel of 19 countries over the period 1995–2015 and concluded that the declining energy intensity in Europe is due to the gradual adoption of energy-saving techniques in both manufacturing and household sectors and a shift to less energy-consuming sectors like the service sector. Salahuddin et al. (2020) show that renewable energy and energy intensity contribute to the reduction of CO2 emissions, while economic growth increases emissions in 34 African countries. Similarly, Dogan and Shah (2022) analyzed the role of real output, energy intensity and renewable energy on the environmental footprint of the United Arab Emirates. By applying the novel bounds testing with dynamic simulations to the data from 1992 to 2017, the results of this paper show that energy intensity and renewable energy have a negative and significant impact on the ecological footprint, while real output has a positive and significant impact on it. The authors argue that the government should create new programmes, investment opportunities, and incentives in favour of reducing energy-intensive technologies and increasing renewable energy to achieve environmental sustainability. Higher energy intensity worsens environmental quality. However, with good institutional set-tings in place, the negative consequences of high energy in-tensity diminishes.

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Following the aforementioned arguments, one can conclude that the results of various samples are quite contradictory. For example, some studies (Dou and Li, 2022; Fareed et al., 2022; Zaidi et al., 2021; Lin and Wu, 2022; Tufail et al., 2022) found that there is a positive impact of financial inclusion on environmental degradation, while other studies (Usman et al., 2021, Doaa and Doaa, 202) confirmed a negative impact of financial inclusion on carbon emissions. Based on the aforementioned arguments, it can be concluded that limited studies have analyzed the nexus of financial inclusion and specific variables important for establishing the green environment concept in the EU. Besides the nexus between financial inclusion, natural resources rent and energy intensity, the empirical evidence on the effects, especially in the EU, still remain unexplored. Hence, there is a significant gap in the literature that must be tackled by using more advanced estimation techniques and exploring the effect of financial inclusion, natural resources rent, energy intensity and CO_2 emissions in the EU countries. Therefore, the main hypothesis is that financial inclusion, natural resources rents and energy intensity have a significant impact on CO_2 emissions in the EU-26 countries. In addition, the results of this paper will contribute to the literature by providing the relationship between a green environment and the variables analyzed in EU-26 countries.

3. Materials and methods

Within this section, the paper refines the theoretical framework and presents the model construction. Moreover, Section 3 describes the data, as well as the fundamental estimation techniques, that have been used to examine the nexus between financial inclusion, natural resources rent and energy intensity regarding a green environment in the EU-26 countries.

3.1. Theoretical framework, model construction and data

In line with economic theory, financial inclusion is an essential component of financial development and promotes the development of financial institutions and sectors. According to Ahamed and Mallick (2019), financial inclusion improves a country's financial stability by increasing the number of sectors in areas where banks are not present, offering credit facilities in new areas and activating funds. In addition, financial inclusion is a priority in seven of the 17 Sustainable Development Goals (SDGs) (United Nations, 2015). Since 2010, more than 55 countries have committed to improving financial inclusion, and more than 60 countries have adopted or are developing a national strategy (World Bank, 2022a). In addition to that, a special challenge to enhancing a green environment is the environmental impact of financial inclusion. In theory, financial inclusion can affect CO_2 emissions in a positive or negative way (Zaidi et al., 2021). On the positive side, financial inclusion allows companies and individuals easier access to useful and affordable financial systems, making investments in green technologies readily available. In this regard, inclusive financial systems have positive environmental impacts, as better environmental practices can be adopted, especially those that mitigate climate change (IPA, 2017). The negative side is that improved access to financial services increases manufacturing and industrial activities, which can lead to higher CO_2 emissions and eventually global warming (Svilokos et al., 2019). In addition, consumers with higher financial inclusion can afford more energy-intensive goods, such as cars, air conditioners and refrigerators, which emit more GHG emissions. However, Liu et al. (2022) found that expanding financial inclusion can help increase green economic performance, primarily by tightening credit constraints on carbon-emitting firms. Moreover, it has been shown that there is a strong correlation between the financial sector and energy consumption (Ingrao et al., 2018; Esquivias et al., 2021). Therefore, the financial sector is becoming an important factor in promoting a low-carbon energy transition (Chenet et al., 2019). According to research by Yu and Tang (2023), financial inclusion significantly improved energy efficiency in Chinese cities during 2011–2015.

Theoretically, one of the factors that can also influence CO_2 emissions are natural resources rents. According to the World Bank (2022b), natural resources rents (the sum of oil rents, natural gas rents, coal rents, mineral rents and forest rents) are calculated as the difference between the price of a commodity and the average cost of its production. More precisely, natural resources rent is the total revenue earned from the extraction of the natural resources. Classical theory suggests that countries that have abundant natural resources are more likely to perform better than countries that do not. However, some authors argue that countries with abundant natural resources may have higher levels of income inequality and poverty than others that are less well endowed (Ben-Salha et al., 2018). In this context, the question of the impact of natural resources on economic growth has attracted considerable attention from researchers and policymakers (Cavalcanti et al., 2011). However, there is no consensus on whether natural resources rents have a significant positive or negative impact on carbon emissions. The relationship between natural resources and CO_2 emissions is important because an increase in commodity prices, especially oil and gas prices, could reduce energy consumption and consequently reduce CO_2 emissions. On the other hand, a decrease in oil prices leads to an increase in economic activity, which promotes economic growth and increases CO_2 emissions. Wise management of natural resources combined with environmental conservation strategies is a key element of European environmental policy, in particular the European Green Deal (European Commission, 2019). Meeting the challenge of global climate change requires deep systemic reforms in the type and amount of resources used for energy.

This paper analyzes the impact of financial inclusion, natural resources rent and energy intensity on CO_2 emissions in the EU-26 countries from 2004 to 2019. Due to missing data, Malta was excluded from the analysis. Overall, in line with recently published studies (Le et al., 2020; Dou and Li, 2022), the following model was proposed:

$$\text{Model: } CO_{2it} = f\,(GDP_{it}, GDP^2_{it}, FI_{it}, EI_{it}, NRR_{it}) \quad (1)$$

where CO_2 stands for carbon dioxide emissions in metric tons per capita, GDP denotes gross domestic product per capita in current USD, GDP^2 stands for GDP per capita squared to observe whether environmental degradation decreases when per capita income reaches a threshold as underscored by the EKC hypothesis (Grossman and Krueger, 1995), FI stands for financial inclusion as measured by access to financial institutions that collect ATM data per 100,000 adults, EI stands for primary energy intensity (MJ/$2017 PPP GDP) and NRR stands for total natural resources rents as a percentage of GDP. Annual data for all variables were taken from the World Bank. Available data for ATMs per 100,000 adults are from 2004 to 2019, so that period was chosen for the analysis. Primary energy intensity is the ratio of energy supply to GDP measured at purchasing power parity. Energy intensity is an indicator of how much energy is used to produce a unit of economic output. A lower ratio means that less energy is used to produce a unit of economic output. Contrary to the majority of existing literature, energy intensity is utilised here as a proxy for energy consumption instead of energy consumption per capita, because energy consumption is highly influenced by per capita output. Measuring energy production and consumption per unit of GDP reveals for the effect of country income. The data are in the level and converted into a natural logarithm.

Table 1 summarizes the descriptive statistics for these five variables

Table 1
Descriptive statistics of the variables.

Variable	Obs	Mean	Std. Dev.	Min	Max	Jarque–Bera
CO_2	416	7.571158	3.540118	3.36703	25.6687	13.22***
GDP	416	32391.16	22379.58	3389.71	123678.7	22.84***
EI	416	3.895853	1.14473	1.32	7.68	4.39
NRR	416	0.5761755	0.7010491	0.00059	5.69236	4.07
FI	416	80.16578	36.08442	18.29	194.63	6.90***

for the observed countries. The mean, standard deviation, minimum and maximum values and Jarque–Bera test statistics were calculated for each variable.

CO_2 emissions in the EU-26 countries averaged 7.57 tons per capita over the 2004–2019 period. The highest value was recorded in Luxembourg in 2005 at 25 tons per capita, while the lowest value was recorded in Latvia in 2004 at 3.36 tons per capita. The average value of GDP in the EU-26 countries is $32,391 per capita. The country with the highest GDP per capita was Luxembourg ($123,678) in 2014, while the lowest value was recorded in Bulgaria ($3389) in 2004. The highest energy intensity was 7.68 (MJ/$2017 PPP GDP) and was recorded in Bulgaria in 2004, while the average energy intensity in the EU was 3.89. For natural resources rents, the average value is 0.58 (% of GDP). The highest value was recorded in Poland in 2011 and the lowest in Cyprus in 2006. The country with the highest financial inclusion was Portugal in 2010 (194 ATMs per 100,000 adults), and the country with the lowest financial inclusion was Romania in 2004 (18.29). The Jarque-Bera test indicates that the null hypothesis can be rejected for most of the variables, which means they do not follow the normal distribution. Therefore, the OLS is not correct for parameter estimation when modelling these variables.

3.2. *Estimation techniques*

In this paper, the fundamental estimation techniques important to obtain significant empirical results were as follows (Fig. 1).

After the descriptive statistics, the test of Pesaran (2007, 2015) was undertaken to reveal the potential presence of cross-sectional dependence (CD). As EU countries become more interdependent due to energy imports, trade or foreign direct investment etc., they are more likely to be cross-sectionally interdependent. A shock in one country can affect macroeconomic performance in others. Ignoring the cross-sectional interdependence between countries may lead to biased and incorrect results (Baltagi, 2014). The empirical results of the CD and second-generation unit root tests are presented in Table 2 and confirm the presence of cross-sectional dependence in the dataset, suggesting that shocks in one country spill over to other countries in the panel. After confirming CD in the data, the integrated level of variables was examined using the cross-sectionally augmented Dickey-Fuller (CADF) panel unit root test (Im et al., 2003) and the cross-sectionally augmented I.P.S. test (CIPS) (Pesaran, 2007).

Based on the results of the CADF and CIPS panel unit root tests, all variables are stationary in first difference. To check whether the variables move together in the long run, the Pedroni panel cointegration test (Pedroni, 1999) and the Westerlund panel cointegration test (Westerlund, 2005) were applied. Both tests account for heterogeneity across countries. The Westerlund cointegration test was developed to account for cross-sectional dependence in a panel study. The results are presented in Table 3.

Table 2
Results of cross-sectional dependence test and unit-root tests.

Variable	CD-test	CADF Level	CADF Difference	CIPS Level	CIPS Difference
CO_2	44.542***	−1.975	−2.141**	−1.780	−4.470***
GDP	53.446***	−1.973	−2.489***	−1.696	−3.861***
EI	62.269***	−1.905	−2.982***	−2.532	−4.435***
NRR	31.753***	−2.024	−2.071**	−2.278*	−4.817***
FI	14.144***	−1.977	−1.812	−1.090	−3.234***

Notes: Null hypothesis: No cross-section dependence (correlation) in residuals. *** and ** significance level at 1% and 5%.

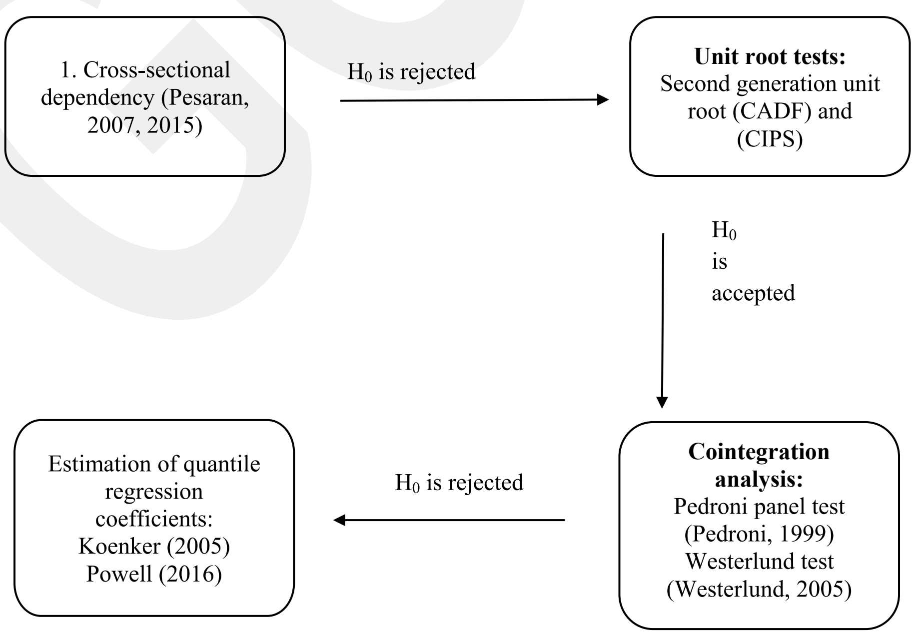

Fig. 1. Flowchart of estimations techniques.

Table 3
The results of the panel cointegration test.

Pedroni cointegration		Westerlund cointegration	
	Statistics		Statistics
Modified Phillips-Perron t	6.1148***	Variance ratio	1.9831***
Phillips-Perron t	−3.8250***		
Augmented Dickey-Fuller t	−4.0007***		

Note: **, *** represents the statistical significance at 1% and 5%.

According to the results of the two panel cointegration tests, there is strong evidence of a long-run relationship between the variables. It can be concluded that CO_2 emissions per capita, GDP per capita, energy intensity, financial inclusion and natural resources rent move together in the long-run, which means that the analyzed variables have a stable long-run relationship. To examine the effects of financial inclusion, energy intensity and natural resources rent on CO_2 emissions, this paper uses the standard ordinary least squares (OLS) method and the quantile regression method of Koenker (2005). The classical OLS method provides an estimate for Gaussian linear structural equation models with additive errors. However, this method only provides a view of the conditional mean of the structural relationship, implicitly making restrictive locational shift assumptions regarding how covariates are allowed to affect the conditional distributions of the endogenous variables.

4. Empirical results

In order to obtain empirical results, the novel methodology, i.e., quantile regression, has been applied. Quantile regression methods attempt to extend this view by providing a more complete characterization of the stochastic relationship between variables and providing more robust and consequently more efficient estimates in some non-Gaussian settings (Ma and Koenker, 2006). Quantile regression can better justify the conditional distribution by examining the association between variables at different quantiles. In addition, quantile regression does not require strict assumptions regarding normality, homoscedasticity and absence of outliers (Johnston and DiNardo, 1997). The advantage of this method is that it maps the cause of change in a regressor at different points in the conditional distribution. The results of the quantile regression are shown in Table 4.

First and foremost, the OLS results show that almost all variables have a significant impact on CO_2 emissions, with the exception of financial inclusion. However, the OLS results only calculate the conditional mean and are therefore not robust. The panel quantile method of Koenker (2005) is performed and estimated in five quantiles. These are the lower (10th quantile), middle lower (25th quantile), middle (50th quantile), middle upper (75th quantile), and upper quantile (90th quantile). The quantile regression results show that the variables GDP per capita, energy intensity, financial inclusion and natural resources rent have a highly significant impact on CO_2 emissions in almost all quantiles. The coefficient of GDP per capita is positive and statistically significant. A 1% increase in GDP per capita causes a decrease in CO_2 emissions per capita from 3.980% in the lower quantile to 2.565% in the upper quantile. This factor proves that GDP is not the cause of environmental degradation in the EU-26 countries. A possible reason for this result is that EU countries have implemented many climate policies and regulations in the last two decades and managed to decouple economic growth from CO_2 emissions. Environmental-economic decoupling is a key component of the European Green Deal. The goal is to achieve economic growth while maintaining a healthy environment and to combine increasing GDP with decreasing (or net zero) carbon emissions. EU GHG emissions were reduced by 24% between 1990 and 2019, while the economy grew by around 60% over the same period (European Commission, 2022). The EU's commitment to reducing GHG by 55% by 2030 requires a tripling of efforts to reduce fossil fuel consumption and introduce alternative energy sources that promote environmental sustainability and a green environment.

Conversely, squared income has a positive impact on carbon emissions for all quantiles. The results of this paper confirm the validity of the EKC hypothesis in the EU-26 countries, which states that environmental degradation decreases over time once per capita income reaches a critical value. The validity of the inverted U-shaped EKC hypothesis in EU economies implies that these economies have reached a certain level of economic growth and are now moving toward environmentally friendly economic growth or green growth (Grossman and Krueger, 1995). According to Ulucak et al. (2020), as income increases, production/consumption patterns may change and people become more aware of the clean environment and demand greener goods that contribute to sustainable material use and environmental quality.

Energy intensity has a significant impact on the increase in CO_2 emissions in all quantiles, which means that the increase in energy intensity also increases pollution. Interestingly, the effect of energy intensity on CO_2 emissions is small at the lower quantiles (0.272 at the 0.10th quantile) and increases to 0.590 at the upper quantile. As energy intensity increases from the lower to the upper quantile, the magnitude of environmental degradation also increases. In the initial stages of growth, fossil fuels are used intensively, and thus the level of pollution emissions grows rapidly (Harbaugh et al., 2002). This is due to the fact that, at the lower level of development, politicians and the general populace are more concerned with economic growth rather than environmental concerns. Our results are consistent with studies by Amin and Dogan (2021) for China, Danish et al. (2020) for the United States, Shahbaz et al. (2015) for 24 African countries, Namahoro et al. (2021) for 50 African countries and Amuakwa-Mensah and Adom (2017) for 43 Sub-Saharan African countries. If energy intensity decreased, it would contribute to achieving sustainable development goals and to fulfilling basic human needs (Amin and Dogan, 2021). An alternative strategy to

Table 4
Koenker (2005)'s quantile regression results.

	OLS	QR10	QR25	QR50	QR75	QR90
GDP	−2.703**	−3.980**	−3.989**	−2.415**	−2.185*	−2.565**
	[0.521]	[0.590]	[0.444]	[0.829]	[0.863]	[0.659]
GDP^2	0.145**	0.206**	0.208**	0.134**	0.125**	0.147**
	[0.026]	[0.029]	[0.022]	[0.041]	[0.043]	[0.032]
EI	0.271**	0.272**	0.265**	0.337**	0.490**	0.590**
	[0.061]	[0.069]	[0.052]	[0.097]	[0.100]	[0.077]
NRR	−0.102**	−0.141**	−0.124**	−0.108**	−0.095**	−0.076**
	[0.012]	[0.013]	[0.010]	[0.019]	[0.019]	[0.015]
FI	0.035	0.126**	0.165**	−0.012	−0.217**	−0.480**
	[0.040]	[0.045]	[0.034]	[0.064]	[0.066]	[0.051]
Constant	13.704**	19.631**	19.452**	12.072**	11.497**	14.383**
	[2.638]	[2.988]	[2.248]	[4.199]	[4.371]	[3.336]
Number of observations	416	416	416	416	416	416

Note:*,**, *** represents the statistical significance at the 90%, 95% and 99% confidence levels, t-statistics are in parentheses.

address the problem of energy intensity is to increase energy efficiency to mitigate CO_2 emissions and to promote energy-efficient technologies, which are one of the indispensable conditions for the green growth of economies (Danish et al., 2020). Our results are not consistent with studies by Mahmood and Ahmad (2018) for 19 EU countries and Salahuddin et al. (2020) for 34 African countries.

However, the natural resources rent as a share of GDP is closely related to CO_2 emissions: a 1% change in natural resources rent leads to a 0.141% decrease in CO_2 emissions in the first quantile and decreases with higher quantiles. Although natural resources exploitation often has a negative impact on environmental sustainability by increasing pollution, the present results show that the natural resources rent has a negative impact on CO_2 emissions in the EU-26 countries. This is mainly because EU countries do not have many natural resources and rely on energy imports to meet their energy needs. In 2020, the EU imported 57.5% of the energy it consumed (Eurostat, 2022b). The EU also used renewable energy sources (water, air and solar). According to Bekun et al. (2018), switching from outdated technologies that consume more natural resources to modern technologies that integrate recycling, reuse, innovation, value addition and artificial resources can promote economic development while reducing environmental degradation. These results are supported by the findings of Tufail et al. (2021) for OECD countries, Balsalobre-Lorente et al. (2018) for EU-5 countries, Khan et al. (2021) for the United States, Danish et al. (2019) for BRICS countries and Kongbuamai et al. (2020) for ASEAN countries.

A mixed (positive and negative) relationship was found between financial inclusion and environmental degradation in EU countries, with varying coefficients and significance levels. The result shows a positive relationship between financial inclusion and environmental degradation in the initial stage (0.10th and 0.25th quantiles), which means that financial inclusion initially causes an increase in environmental degradation. This result indicates that, in the initial stage, access to financial institutions allows investors and the industrial sector to invest in production that requires more fossil energy, but pollutes the environment. In addition, in the initial phase, citizens buy more emission-generating items such as cars, refrigerators and air conditioners, whose widespread use accelerates fossil fuel consumption and leads to higher CO_2 emissions. A 1% increase in financial inclusion leads to a 0.16% increase in CO_2 emissions per capita in the middle lower quantile. The results are consistent with the studies of Dou and Li (2022) for BRICS countries, Fareed et al. (2022) for 27 EU countries, Le et al. (2020) for 31 Asian economies and Lin and Wu (2022) for E7 economies. Similar results were found by Zaidi et al. (2021) for 23 OECD countries, who concluded that the government must align financial inclusion goals with energy consumption behavior and environmental policies. The result of the OLS and the 0.50th quantile shows the same finding, namely insignificant results for financial inclusion. However, higher quantiles (0.75th and 0.90th) show a negative relationship between financial inclusion and environmental degradation. This could be because countries with higher financial inclusion tend to use more environmentally friendly technologies. Renzhi and Baek (2020) found similar results for a panel of 103 countries. The authors argue that, at the initial stage, financial inclusion can improve access to basic financial services where people will focus on improving their standard of living and companies will try to expand their businesses with new loans, which results in greater consumption, leading to higher CO_2 emissions. However, at a later stage, improved financial inclusion leads to financial market development and investors expect companies to take environmentally friendly measures to reduce CO_2 emissions. Therefore, raising the level of financial inclusion can achieve development, adaptation and mitigation goals. Bai et al. (2022) pointed out that improving the quality of green finance and increasing the level of green finance strengthened by science and technology are key to achieving sustainable green development.

The present results show that although EU-26 countries have

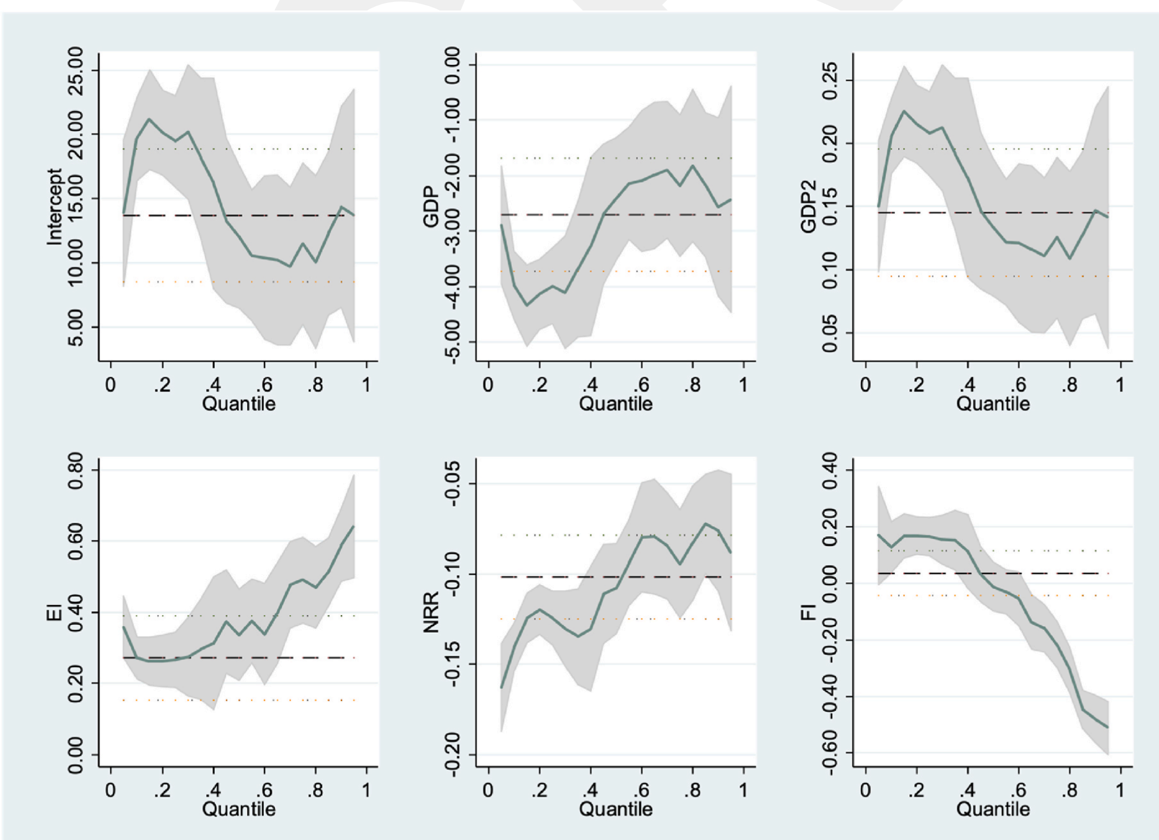

Fig. 2. Results from quantile regression of Koenker (2005).

continued to develop economically, they have still managed to decrease CO_2 emissions. Fig. 2 shows the quantile regression plots of the per capita CO_2 emissions (horizontal axes) versus each explanatory variable. For comparison purposes, the horizontal line in each plot represents the estimated coefficient obtained by the OLS and its corresponding 95% confidence interval indicated by the dotted lines. The curve represents the estimated coefficient using quantile regression, and the shaded area shows the corresponding 95% confidence interval.

The results suggest that energy intensity and financial inclusion in lower quantiles have a positive impact on CO_2 emissions in the EU-26 countries. This would mean that higher financial inclusion in the first stage puts more environmental pressure on the EU economy. The government needs some immediate steps and green strategies to control the harmful effects of such development. Government should focus on widening financial coverage, starting with basic financial services provided by credit markets. Then, a financial infrastructure will gradually emerge as more financial institutions are attracted to the rising demand for financial services.

Although it is expected that all countries will develop their financial systems and increase financial inclusion levels, climate change is an urgent issue that needs to be resolved immediately. Governments should support financial inclusion by setting up regulatory and legal frameworks to ensure a transparent and reliable financial system. In addition, it is important to raise consumers' awareness to consume less energy and use renewable energy. In addition, the financial literacy of consumers should be improved to make use of the available financial services and seek green investments.

As a robustness check, quantile regression of Powell (2016) was used. This approach permits non-additive fixed effects, maintaining the non-separable disturbance term commonly associated with quantile estimation. This method estimates the impact of exogenous or endogenous treatment variables on the outcome distribution using within variation in the treatment variables or instruments for identification purposes. Most quantile panel data estimators include additive fixed effects, which separates the disturbance term and assumes the parameters vary based only on the time-varying components of the disturbance term. This quantile panel data estimator provides points estimated that can be interpreted in the same manner as cross-sectional regression results while allowing an arbitrary correlation between the fixed effects and the instruments. In addition, it is also one of the few quantiles (additive or non-additive) fixed effects estimators to provide consistent estimates for (t) and one of the few instrumental variables quantile panel data estimators. The empirical results of Powell's quantile regression are presented in Table 5. It is obvious that the signs of the Koenker (2005) and Powell (2016) estimates are very similar. Also, Powell's quantile regression method confirmed that energy intensity and financial inclusion (in the 0.10, 0.25 and 0.75 quantiles) have a significant positive impact on CO_2 emissions per capita in the EU-26 countries, while GDP per capita, natural resources rent and financial inclusion (0.90 quantile) have a negative impact.

5. Conclusions and policy implications

To combat global warming and climate change, the EU has made serious policy changes and taken action to reduce CO_2 emissions. The goal of a carbon-neutral economy by 2050 requires a completely different development path than the current one. The aim of this paper was to investigate the relationship between financial inclusion, energy intensity, natural resources rent and green environment in the EU-26 countries during the 2004–2019 period. By applying a novel methodology, namely panel quantile regression, the empirical results show interesting findings. First, the influences of covariates on CO_2 emissions are heterogeneous, and second, all analyzed variables are key factors in determining CO_2 emissions. It was found that energy intensity and financial inclusion increase CO_2 emissions in the first stage. The results show that there is an inverted U-shaped relationship between per capita income and environmental degradation, as emphasized by the EKC hypothesis in the long run. Given the statistically significant results for the relationship between income and pollution in EU countries, environmental degradation will decrease over time after per capita income reaches a critical level in the long run. The empirical results of the paper show that energy intensity is a major cause of environmental degradation. Nevertheless, an increase in natural resources rents will significantly reduce negative environmental impacts, but this is mainly because the EU is highly dependent on fossil fuel imports. Finally, this study empirically demonstrates that effective and coordinated energy and climate policies can improve environmental sustainability and lead to a reduction in CO_2 emissions while maintaining inclusive growth. Financial inclusion can play a key role in achieving sustainable development by financing green and sustainable projects that are beneficial to the environment.

The EU is largely made up of high-income countries that should introduce more technology and innovation to their energy sectors to increase energy efficiency and invest in renewables to produce clean energy. Increased use of renewable energy and technological innovation seems to be the most plausible way to reduce environmental degradation. Currently, there are no policy synergies between improving financial inclusion and reducing CO_2 emissions. Therefore, financial inclusion should be integrated into climate change adaptation strategies, especially to address the negative impacts of higher CO_2 emissions associated with financial inclusion in the early stages. Policymakers need to promote environmental and sustainable finance that is more accessible and equitable for the underprivileged or financially excluded. Efficient and sustainable use of natural resources, combined with an increasing share of renewable energy in the energy mix, is essential for sustainable development and thus a green environment.

Based on the empirical results, two recommendations were made for policymakers. The first is that policymakers must act appropriately to

Table 5
Powell (2016)'s quantile regression results.

	OLS	QR10	QR25	QR50	QR75	QR90
GDP	−2.703**	−2.155**	−3.601**	−1.597**	−2.329**	−2.281**
	[0.521]	[0.472]	[0.003]	[0.163]	[0.446]	[0.315]
GDP^2	0.145**	0.120**	0.186**	0.092**	0.130**	0.133**
	[0.026]	[0.022]	[0.000]	[0.008]	[0.020]	[0.015]
EI	0.271**	0.288**	0.263**	0.157**	0.160**	0.445**
	[0.061]	[0.052]	[0.000]	[0.026]	[0.061]	[0.104]
NRR	−0.102**	−0.157**	−0.132**	−0.072**	−0.301**	−0.070**
	[0.012]	[0.013]	[0.000]	[0.005]	[0.027]	[0.007]
FI	0.035	−0.010	0.226**	0.142**	0.121*	−0.488**
	[0.040]	[0.064]	[0.000]	[0.025]	[0.073]	[0.028]
Constant	13.704**					
	[2.638]					
N	416	416	416	416	416	416

Note:*,**, *** represents the statistical significance at the 90%, 95% and 99% confidence levels t-statistics are in parentheses.

improve the financial system through financial inclusion, which has important implications for energy efficiency and natural resources. This can be done by introducing policies aimed at educating people on the importance of environmental and sustainable finance to establish a green environment concept. The second recommendation is that large-scale green investments are needed in EU countries to create a more effective green environment to achieve the Sustainable Development Goals and other EU goals. In addition, green investments should be aligned with green business to save the environment, not only in the EU, but also beyond.

As with any research, this one has its limitations, too. The first limitation consists in data availability – short time period and not all EU countries. The second one is the indicator of financial inclusion, i.e., the number of ATMs. Therefore, more financial inclusion indicators should be available and included in the analysis. The third limitation refers to recommendations for improving the green environment in the EU, and may not be generalizable to other countries or regions due to differences in economic, political and cultural factors. Based on the results presented, future research studies may examine the linkage between the aforementioned variables for each EU country individually and for a longer time period. Moreover, future research may investigate whether there is convergence in achieving sustainable and green environment goals among EU countries. Also, one of the suggestions is to examine the direct and indirect effects of financial inclusion on environmental quality. The results of the proposed analysis can provide more meaningful and robust policy-based outcomes.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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