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FISCAL DECENTRALIZATION, RENEWABLE ENERGY CONSUMPTION AND CARBON EMISSIONS IN THE OLD AND NEW EU COUNTRIES

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Abstract

Purpose: As climate change poses a threat to environmental and economic stability, it is increasingly important to understand the role of fiscal policy in promoting sustainability. To address environmental challenges, EU countries need to integrate sub-national levels of government into their environmental strategies and policy frameworks. Therefore, fiscal decentralisation plays an important role in the transfer of financial resources from the central government. Consequently, fiscal decentralisation has proven to be a crucial strategy to mitigate climate change and environmental degradation. This paper examines the linkage between fiscal decentralisation and the use of renewable energy to mitigate carbon emissions in EU countries from 2004 to 2022.

Design/methodology/approach: For this paper, the authors used a Method of moments quantile regression as the primary estimation method, complemented by established techniques such as unit root tests, Kao and Westerlund cointegration tests, and Pedroni residual cointegration tests to assess stability and cointegration among the variables in the panel data sample. As a robustness check, Driscoll and Kraay's standard errors were applied.

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Findings: The empirical results reveal asymmetric environmental effects of fiscal decentralisation across EU countries. In new EU countries, expenditure decentralisation is associated with higher CO_2 emissions, while revenue decentralisation shows no systematic mitigation effect. This suggests that without strong environmental safeguards, local spending autonomy may reinforce pollution-intensive development. In contrast, fiscal decentralisation in old EU countries shows only modest and statistically weak relationships with emissions, reflecting more mature institutional and regulatory settings. Across all models, economic growth remains the primary driver of emissions, while renewable energy use consistently reduces them. Overall, the study highlights that decentralisation alone does not guarantee environmental gains; its effectiveness depends on the institutional context and the alignment of local fiscal powers with environmental objectives. Strengthening local environmental governance and expanding renewable energy investment appear essential, particularly for newer EU countries undergoing institutional convergence.

Research limitations/implications: Although the study represents a unique, complex and dynamic research, it also has limitations. The first limitation is the restriction of the sample and the time period. Different results could be obtained for a longer period and for a larger sample of countries, while the second is the availability of data for certain variables.

Originality: To the best of our knowledge, there is a notable research gap focusing on fiscal decentralisation to enhance environmental performance, especially in the context of old and new EU countries. Therefore, this paper represents a first attempt to investigate the linkage between fiscal decentralisation and renewable energy in reducing CO_2 emissions to enhance environmental performance. By using quantile regression analysis as a methodological approach, the results also point to a further direction of research for each individual EU country and over a longer period of time.

Keywords: fiscal decentralization, carbon emissions, renewable energy, EU countries, quantile regression analysis

JEL Classification: H70, H72, C23, Q58

1. Introduction

Over the past half-century, global energy consumption, along with associated emissions, has surged dramatically, leading to significant environmental concerns regarding global warming and climate change. The primary drivers of this increase are the rising use of fossil fuels and overall energy consumption. Despite international efforts such as the Paris Climate Agreement, the United Nations Sustainable Development Goals, and recent COP26 and COP27 conferences, progress has been hindered by additional challenges, including the COVID-19 pandemic and geopolitical tensions like the ongoing war between Russia and Ukraine. As a result, global temperatures continue to rise, with projections indicating an increase of 2% if current trends persist. To achieve net-zero emissions by 2050, a comprehensive transformation across political, social, and economic dimensions is essential. This includes decisive actions across various sectors, from government institutions to the financial industry. According to a World Bank report (Fay et al., 2015), key strategies include decarbonizing electricity generation, transitioning to cleaner fuels, enhancing efficiency across sectors (including buildings, transportation, and agriculture), and preserving carbon sinks such as forests and soils to improve carbon removal from the atmosphere. In addition to these decarbonization efforts, governments at all levels must manage land-use planning, water utilities, waste disposal systems, urban management, and infrastructure investments in energy and sanitation. To effectively enhance environmental sustainability, local governments must engage in participatory decision-making that addresses pressing environmental challenges. Decentralized governance fosters greater ownership and accountability, leading to more robust environmental initiatives (DiPietro & Anoruo, 2006). Consequently, fiscal decentralization has emerged as a critical strategy for mitigating climate change and environmental degradation. The question is can local governments hold the key to reversing climate change through fiscal decentralization?

Fiscal decentralization refers to the transfer of revenue and expenditure powers from central governments to local authorities, enabling them to make decisions that directly affect their communities'. Its primary objective is to empower lower-level governments financially and administratively to stimulate economic growth. Local governments may create and execute policies that are in line with regional needs and goals because they have a better understanding of regional environmental concerns. Greater ownership and responsibility are encouraged by this decentralized decision-making, which leads to more successful environmental management and conservation initiatives (DiPietro and Anoruo, 2006). However, concerns have been raised regarding potential negative consequences of fiscal decentralization (Sun et al., 2023). Economically disadvantaged regions may struggle to provide essential infrastructure and services due to limited resources, hindering their capacity for both economic development and environmental progress (Ji et al., 2020).

Two distinct approaches to fiscal decentralization can be identified to enhance environmental performance in the old and new EU countries. The "race to the top" approach encourages lower levels of government to prioritize environmental issues by aligning investments with quality targets aimed at reducing CO_2 emissions. Such nations could prioritise plans to mitigate climate change in public policy and structurally change the energy sector through innovation or invention. For example, Aldieri et al. (2022) found that innovations in renewable energy improve the efficiency of carbon emissions and particulate matter in 148 developing and newly industrialising countries. Furthermore, Sadik-Zada and Gatto (2023) found that civic engagement contributes positively to the energy transition from fossil fuels to renewables in the North Sea-Baltic region. It emphasises the importance of polycentric governance involving different sub-national governance bodies to interact and design comprehensive energy transitions for appropriate environmental management policies.

Conversely, the "race to the bottom" approach suggests that local governments may focus on spending that does not contribute to emission reductions, often leading to unsustainable and energy-intensive practices (Ji et al., 2020; Zhao et al., 2023). They fall into the traps of poor environmental quality as they pursue weak environmental protection policies to attract domestic and international investment for regional growth (Kassouri, 2022), allowing polluting industries to exploit local environmental quality. Nevertheless, local governments are required to implement policies specific for their local environmental circumstances. They also provide support and basis for new environmental innovation, solutions and technology. This will increase the standard of living for future generations and social well-being. The interplay between fiscal decentralization and renewable energy is pivotal in shaping policies that address climate change effectively.

However, disparities exist between old and new EU countries regarding fiscal decentralization levels. For instance, Denmark, Spain, and Belgium reported the highest levels of fiscal decentralization in 2022 (between 50% and 65%), while Malta (an outlier due to its size), Cyprus, Greece, and Ireland exhibited the lowest levels (see Figure 1 in Appendix). The countries with the highest level of fiscal decentralisation appear to be among the most developed, and they are all classified as old EU countries. On the other hand, all of the new EU countries fall below the EU average. Variations in fiscal decentralization across Europe can be attributed to each country's unique political systems, territorial structures and budgetary organization. Maximizing fiscal decentralization can help meet local government needs while rationalizing public financial flows and ensuring environmental performance. As global temperatures rise, local governments may indeed play a crucial role in reversing climate change through effective fiscal decentralization strategies.

Following the empirical literature, there is no unique approach on the influence of fiscal decentralization on environmental performance. This paper aims to investigate the linkage between fiscal decentralization, the adoption of renewable energy, and carbon emissions across both old and new EU countries during the period from 2004 to 2022. The ultimate goal is to contribute to strategies aimed at reducing CO_2 emissions. While prior research has examined the impact of fiscal decentralization on economic growth, there is a notable gap in studies focusing on its role in enhancing environmental performance, particularly within the context of both old and new EU countries. The selection of EU countries for this analysis is particularly relevant, as the EU has committed to leading efforts in minimizing CO_2 emissions through the promotion of renewable energy sources and the implementation of green technologies. Additionally, this study distinguishes between old and new EU countries, as both groups of countries share similar political and economic characteristics that indicate similar trends in fiscal decentralization and renewable energy consumption.

This paper addresses the following research questions:

1) What role does fiscal decentralization play in improving environmental performance in old and new EU member states?
2) Can fiscal decentralization, together with the use of renewable energy, serve as an effective strategy for reducing CO_2 emissions in these countries?

3) Do these relationships differ significantly between old and new EU member states?

Our hypothesis is that fiscal decentralization, coupled with the adoption of renewable energy sources, contributes positively to environmental performance and facilitates the reduction of CO_2 emissions.

The contributions of this paper are as follows: first, it evaluates the linkage between fiscal decentralization and renewable energy in mitigating CO_2 emissions. The analysis will also consider the impact of GDP, energy intensity and trade on CO_2 emissions. The research covers the EU countries, including both the old developed and the new transition countries that joined the EU after 2004, to understand how fiscal decentralization interacts with renewable energy and affects CO_2 emissions. Second, while previous studies have predominantly focused on the aggregate effect of fiscal decentralisation, this research emphasizes a disaggregated approach (revenue and expenditure decentralization) to understand its various impacts. Third, this paper employs Method of moments quantile regression analysis as a methodological approach for primary estimates, complemented by established econometric techniques such as unit root tests, Westerlund cointegration tests, Kao and Pedroni residual cointegration tests to assess stability and cointegration among variables within the panel data sample. Finally, the paper will help researchers, academics, and policymakers to understand the role of fiscal decentralisation in environmental performance, as well as the policy implications that could help EU economies achieve carbon neutrality in the future.

The structure of the paper is as follows. After the brief introduction and explanation of research problem, Section 2 reviews relevant literature. Description of the data and methodology is presented in Section 3. Section 4 presents empirical results and discussion. The last section furnishes conclusions, policy implications, limitations and recommendations for further research.

2. Literature Review

Nowadays, due to increased energy consumption and related emissions, fiscal policy plays an important role to enhance environmental performance. Therefore, the linkage between fiscal decentralization and the reduction of environmental degradation in EU countries is an important research subject. Research has shown that fiscal decentralization, together with investment in renewable energy and environmental policies, plays an important role in promoting environmental performance and combating climate change (Hu et al., 2023; Xie et al., 2024).

The research of Grossman and Krueger (1995) was the pioneer in examining the causal interconnection between economic growth and environmental degradation. Based on an inverse U-shaped connection between growth and environmental degradation, environmental contamination increases at the first phase of economic growth, and consequently decreases as the level of economy passes a threshold. Following that, Ji et al. (2020) confirmed that economic development affects the quality of the environment, where fiscal decentralization will have an indirect impact on environmental sustainability. This is in line with Oates's (1972) framework, which allows the local authorities to monitor their emission levels. This is highly dependent on interest groups and political allocation. For example, local authorities have more knowledge and ideas how to improve local environmental sustainability by investing more in the environmental sustainability.

More recent studies find that fiscal decentralization leads to a reduction in CO_2 emissions across OECD and EU countries, indicating that decentralized policymaking can promote better environmental management. Cheng et al. (2020) investigated the relationship between CO_2 emissions and fiscal decentralization. Their empirical results showed that fiscal decentralization had an impact on the reduction of CO_2 emissions in China. They found that increasing fiscal decentralization and the measures initiated by the government improved environmental quality. Similarly, Chen & Liu (2020) investigated the impact of fiscal decentralization on environmental degradation using annual data from 31 Chinese provinces between 2003 and 2017. They concluded that fiscal decentralization affects the quality of the environment, i.e. a race to the bottom. Similar results were reached by Khan et al. (2021) for seven OECD countries between 1990 and 2018. In a study by Tufail et al. (2021) on a sample of seven highly fiscally decentralized countries (Spain, Belgium, Austria, Switzerland, Germany, Australia and Canada), the results confirm the link between fiscal decentralization and the use of natural resources to reduce CO_2 emissions. Furthermore, they found that fiscal decentralization and revenues from natural resources not only reduce CO_2 emissions in the long term, but also significantly improve institutional quality. They suggest that devolving powers to local governments and setting environmental standards lead to a country's environmental sustainability. Wang et al. (2022) analysed environmental impact of fiscal decentralization, green technology innovation and institution's efficiency in seventeen developed countries using advance panel modelling. They emphasize that fiscal decentralization positively impacts environmental sustainability in EU countries by mitigating carbon emissions, particularly at higher emissions quantiles. However, its effectiveness is lower at lower quantiles, indicating an asymmetric effect on emissions reduction across different levels of environmental degradation. In a similar study, Hu et al. (2023) examined the relationship between fiscal decentralization and natural resource markets in promoting environmental sustainability in OECD countries for the period 1995 and 2021. They concluded that fiscal decentralization and resource management are crucial in reducing carbon emissions and promoting environmental sustainability.

In contrast, there's another strand of literature that argues for the opposite effect, i.e., decentralization has a negative impact on the overall environmental quality. Farzanegan & Mennel (2012) find that decentralization is positively related to different indicators of pollution for more than 80 countries from 1970 to 2000, while institutional quality can mitigate some of these detrimental effects. By examining specific factors such as financial inclusion and fiscal decentralization on CO_2 emission in top emerging economies from

2004 to 2022, Xie et al. (2024) confirmed the link to environmental degradation. The empirical results were tested with the second generation of panel data tools, such as CD and SH tests as general diagnostic tests, CIPS test for unit root, Westerlund and Kao residuals for cointegration, and the method of moments of quantile regression as primary methods. According to their estimations when fiscal decentralization increases by 1% it will lead to rise in CO_2 emissions of 1.9% in lower and 2.2% in the higher quantiles. The outcomes are supported by the studies of Ji et al. (2020) and Liu et al. (2022). Emerging economies use intensive energy products and consumption, reducing environmental quality and increasing CO_2 emissions. Moreover, emerging economies needing high energy consumption shift from traditional biomass fuels to fossil fuels in the early stages which emit many emissions into the economy. Sun et al. (2023) inspected the influence of expenditure and revenue decentralization on renewable energy transition and sustainable environment in decentralized nations via employing panel CS-ARDL. The study concluded that revenue decentralization induces environmental degradation. Satrovic et al. (2024) investigated the impact of fiscal decentralization, economic abundance, human capital, energy use, and green innovation on environmental degradation in 9 EU member states from 1995-2018. They found that green innovation moderates the negative effect of fiscal decentralization on ecological intensity and carbon intensity. They emphasized that empowering local authorities can lead to innovative approaches in climate change mitigation, particularly through green technologies.

Based on previous research, there are conflicting evidence in the empirical literature on the impact of fiscal decentralization on environmental quality. Likewise, He (2015), concluded that decentralization and environmental degradation are not linked. Thus, the linkage between fiscal decentralization and CO_2 emissions is ambiguous and may require additional research.

Several factors led the authors to carry out this econometric research. Given the necessity of the transition to green energy, EU countries have implemented a variety of policies to enhance environmental performance, including renewable energy, environmental taxes and carbon pricing policies. Environmental taxation and carbon pricing can help promote environmental performance by raising the cost of polluting industries and technologies. Second, the creation of new green technologies necessitates substantial resources for research and development. Third, when compared to centralised policies, regional policies have a significantly greater influence on industries in these areas to adopt and enforce environmental rules (Hu et al., 2023). Local and regional authorities represent one third of public spending and two thirds of public investment and they are expected to deliver the European Green Deal on the ground (European Committee of the Regions, 2019). These two data indicate the increasing importance of local and regional governments in Europe, both for the global economy and for residents' lives.

3. Data and Methodology

3.1. Sample

The current paper investigates the linkage between financial decentralisation, renewable energy consumption and CO_2 emissions in eleven new EU countries (Bulgaria, Czech Republic, Croatia, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia) and sixteen old EU countries (Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Spain, and Sweden) between 2004 and 2022.

The dependent variable used to quantify environmental degradation was carbon dioxide (CO_2) emissions, measured in metric tons per capita. This indicator was chosen because CO_2 is the primary greenhouse gas resulting from the burning of fossil fuels in human and economic activities (Fatima et al., 2024). The independent variable of interest is fiscal decentralization. To accurately capture the dimensions of fiscal decentralization, two representative variables, which have achieved some consensus in the literature, are used: First, expenditure decentralization (expd), measured as the proportion of total subnational government (regional or local) expenditure relative to national public expenditure. This indicator reflects the degree of autonomy decentralized governments have in allocating public resources; Second, revenue decentralization (revd), defined as the proportion of revenues generated by subnational governments relative to total general government revenues. This indicator captures the capacity of subnational governments to raise and generate their own resources, thus reflecting their level of financial autonomy (He, 2015; Carrillo-Pulgar et al., 2025).

Following recent empirical work on the drivers of environmental quality (Shrestha et al., 2025), four control variables are included in the model. GDP per capita (GDP) captures the level of economic development, while its squared term (GDP^2) is used to account for the Environmental Kuznets Curve hypothesis. Energy intensity reflects the amount of primary energy required to generate one unit of economic output (PPP-adjusted) where lower values indicate greater energy efficiency. Trade openness is measured as the ratio of total trade (exports plus imports) to GDP, illustrating the degree of integration into international markets.

The variable names, description, measuring units and data source are all listed in Table 1.

Table 1. Data and variables description

Abbreviation	Description	Measurement unit	Data source
CO_2	carbon dioxide emissions	metric tonnes per capita	World Bank (2024)

EXPD	expenditure decentralisation	share of subnational expenditures in general government expenditures	Eurostat (2024)
REVD	revenue decentralisation	share of subnational revenues in general government revenues	Eurostat (2024)
REC	renewable energy consumption	share of renewable energy in gross final energy consumption	Eurostat (2024)
GDP	gross domestic product	chain linked volumes 2010, in euros per capita	Eurostat (2024)
EI	Energy intensity level of primary energy	ratio between energy supply and gross domestic product measured at purchasing power parity. MJ/$2017 PPP GDP	World Bank (2024)
TRADE	Trade	sum of exports and imports of goods and services expressed as % of GDP	World Bank (2024)

Since the study uses two variables to capture the effects of fiscal decentralization, we have put forth two empirical models.

Model 1:

$$lnCO_{2it} = \beta_0 + \beta_1 EXPD_{it} + \beta_2 REC_{it} + \beta_3 lnGDP_{it} + \beta_4 lnGDP_{it}^2 + \beta_5 EI_{it} + \beta_6 TRADE_{it} + \delta_{it} \quad (1)$$

Model 2:

$$lnCO_{2it} = \beta_0 + \beta_1 REVDit + \beta_2 REC_{it} + \beta_3 lnGDP_{it} + \beta_4 lnGDP_{it}^2 + \beta_5 EI_{it} + \beta_6 TRADE_{it} + \delta_{it} \quad (2)$$

where, ln represents the natural logarithm, β_0 is the constant of the model, $\beta_1, \ldots, \beta_6$ are the coefficients to be estimated for the independent variables, and δ is the stochastic error term. Additionally, i represents the cross-sectional dimension (27 countries) and t the time dimension (2004 to 2022). In the above model, the dependent variable is CO_2, which represents carbon dioxide emissions per capita. The independent variables are: EXPD represents the rate of expenditure decentralisation, REVD represents the rate of revenue decentralisation, REC represents the share of renewable energy in gross final energy consumption, GDP represents gross domestic product per capita, EI represents energy intensity, TRADE represents trade as percentage of GDP. Additionally, a logarithmic transformation is applied to the series CO_2 and GDP to stabilize the variances, avoid heteroscedasticity, and facilitate the interpretation of the coefficients to be estimated.

Table 2 presents descriptive statistics for each of these variables in 16 old and 11 new members of the EU. Each variable's mean, standard deviation, minimum and maximum values, as well as Jarque-Bera test statistics, were calculated. All of the calculations in this research were performed using the STATA 19.5 programme.

Table 2. Results of descriptive statistics

	Variable	Number of observations	Mean	Std. Dev.	Min	Max	Jarque–Bera
EU16	CO_2	304	8.054377	3.722376	3.003927	26.04298	39.0635***
	EXPD	304	28.83404	18.97624	1.03173	66.67969	6.4708**
	REVD	304	29.65883	18.94426	1.278409	66.09945	6.3044**
	REC	304	17.70343	13.61097	0.102	66.002	7.0871**
	GDP	304	34818.45	16019.51	14120	88120	3.1472
	EI	304	3.218421	0.999907	0.97	6.82	30.30***
	TRADE	304	120.3979	73.25685	45.14148	412.1772	78.12***
EU11	CO_2	209	6.448495	2.781016	3.365484	14.74312	854.9591***
	EXPD	209	23.68931	5.011379	12.1158	34.34799	17.1562***
	REVD	209	25.18479	5.301293	13.32286	36.33689	16.6698***
	REC	209	19.79475	8.582732	4.364	43.316	51.7069***
	GDP	209	11708.47	3851.429	3870	21870	260.5962***
	EI	209	4.322775	1.08467	2.12	7.43	12.66**
	TRADE	209	126.0099	32.71646	58.47006	203.929	15.84***

Source: Authors' own calculations.

The descriptive statistics indicate that the observed variables differ significantly across old and new EU countries. The average GDP in the old EU countries is three times higher than that of the new EU countries. However, in the new EU countries, the average CO_2 emissions and the rate of revenue and expenditure decentralisation are lower than in old EU countries.

For the normality metrics, we used the Jarque-Bera test to determine the data's normal distribution. The Jarque-Bera test shows that the null hypothesis may be rejected for the majority of the variables, implying that they do not follow a normal distribution. As a result, the usual ordinary least squares (OLS) is incorrect for parameter estimation when modelling these variables. To better comprehend the estimates derived from panel data, it would be preferable to use a relevant and unique nonlinear method such as quantile regression in this paper. To provide an initial overview of variable relationships, the correlation matrix is presented below.

Table 3. Pearson correlation matrix of main variables

Variables	LCO_2	EXPD	REVD	LGDP	$LGDP^2$	REC	EI	TRADE
LCO_2	1							
EXPD	0.0826*	1						
REVD	0.0532	0.9911***	1					
LGDP	0.4087***	0.2683***	0.2396***	1				
$LGDP^2$	0.1823***	−0.0517	−0.0694	−0.0594	1			
REC	−0.4111***	0.3787***	0.3690***	−0.0154	−0.0706	1		
ei	0.3046***	0.1262***	0.1122***	−0.4166***	0.1188***	0.0646	1	
trade	0.3491***	−0.3913***	−0.4100***	0.2838***	0.3989***	−0.3196***	−0.1774***	1

Source: Authors' own calculations.

The correlation matrix reveals several key relationships between variables. CO_2 emissions per capita increase with higher income levels, as shown by a positive and significant correlation with GDP per capita. Energy-intensive economies also tend to emit more, indicated by the positive relationship between energy intensity and emissions. In contrast, renewable energy consumption shows a strong negative association with CO_2 emissions, highlighting its role in improving environmental performance. Fiscal decentralization, on both the expenditure and revenue sides, has only a modest positive correlation with emissions in this simple framework, suggesting a weak direct link at the descriptive level. As expected, the two decentralization indicators are highly correlated with each other, confirming their conceptual proximity and the need to develop two separate models for the analysis. Trade openness is positively correlated with emissions and GDP, while negatively associated with renewable energy use, suggesting that more globally integrated economies may face additional environmental pressures unless supported by strong green policy frameworks. Overall, the correlation patterns indicate that higher economic activity and greater energy use are associated with higher emissions, while renewable energy plays a central role in reducing environmental impacts.

Furthermore, in econometric models, a main concern is the potential presence of multicollinearity, which occurs when there are high correlations between variables. In Table 4, multicollinearity was assessed using the Variance Inflation Factor (VIF).

Table 4. Variance Inflation Factors (VIF) for explanatory variables

	Model 1		Model 2	
Variables	VIF	1/VIF		
EXPD	1.77	0.565573	-	-
REVD	-	-	1.69	0.590855
REC	1.22	0.818401	1.21	0.827708
LGDP	1.78	0.562251	1.69	0.590234
$LGDP^2$	1.32	0.757396	1.31	0.762423
EI	1.33	0.752863	1.3	0.766838
TRADE	1.95	0.512882	1.95	0.512233
Mean VIF	1.56		1.53	

Source: Authors' own calculations.

Variance Inflation Factor (VIF) tests confirm the absence of multicollinearity, with a mean VIF of 1.56 and 1.53, well below the conventional threshold of 5.

3.2. Econometric methods

Testing for cross-sectional interdependence between countries is crucial in econometric analysis, especially when dealing with panel data. Cross-sectional interdependence between countries refers to the phenomenon where the outcomes, actions, or behaviours of one country are influenced by those of other countries in a cross-sectional dataset. A shock in one country can affect macroeconomic performance in others. Ignoring cross-sectional interdependence in econometric analysis can lead to biased and inconsistent estimates (Baltagi, 2014).

Traditional panel unit root tests, known as first-generation tests, often assume cross-sectional independence and homogeneity, which may not reflect the true dynamics. To address this limitation, second-generation tests like the Pesaran test consider cross-sectional dynamics by modelling factors that contribute to cross-sectional dependence. As a result, we used the Pesaran (2007, 2015) test to determine the presence of cross-sectional dependence (CD). Table 3 shows the empirical findings of the CD and second-generation unit root tests, which support the presence of cross-sectional dependency in the dataset and demonstrate that shocks in one country affect the other countries in the panel. After establishing CD in the data, we assessed the integrated level of variables 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).

Table 5. Results of cross-sectional and unit-root tests (trend and intercept included)

		CD-test		CADF		CIPS	
	Variable	Model 1	Model 2	Level	Difference	Level	Difference
EU16	LCO_2	43.31***	43.31***	-2.286*	-2.946***	-2.227	-4.225***
	EXPD	-	1.75*	-1.441	-2.555***	-2.700	-4.401***
	REVD	6.62***	-	-1.511	-2.868***	-3.313***	-4.151***
	REC	44.61***	44.61***	-1.887	-2.437**	-2.248	-4.034***
	$LGDP^2$	25.66***	25.66***	-2.363	-2.749**	-1.729	-2.897**
	EI	43.45***	43.45***	-2.130*	-3.638***	-2.751*	-4.731***
	TRADE	38.20***	38.20***	-2.050	-3.128***	-2.115	-3.283***
EU11	LCO_2	10.55***	10.55***	-1.718	-3.011***	-1.894	-3.901***
	EXPD	-	2.50**	-1.974	-3.162***	-2.662	-4.863***
	REVD	6.37***	-	-1.716	-2.309**	-2.366	-4 .346***
	REC	28.34***	28.34***	-1.820	-2.457	-2.467	-4.173***
	$LGDP^2$	29.94***	29.94***	-2.000	-2.009	1.265	-2.695*
	EI	29.13***	29.13***	-1.986	-2.531***	-2.698*	-4.340***
	TRADE	25.47***	25.47***	-1.684	-1.747	-0.952	-2.750**

*Notes: Null hypothesis: No cross-section dependence (correlation) in residuals. The significance level is indicated as *** for 1%, ** for 5%, and * for 10%.*

Source: Authors' own calculations.

The results of the CADF and CIPS panel unit root tests show that all variables are stationary in first difference. Once the order of integration of the variables is determined, the next step is to assess cointegration, i.e., the existence of long-run equilibrium relationships among the variables. To ensure the robustness of the results, three cointegration tests are applied. To determine if the variables move together in the long run, we used the Kao cointegration test (Kao & Chiang, 2001), Pedroni panel cointegration test (Pedroni, 1999) and the Westerlund panel cointegration test (Westerlund, 2005). The results are shown in Table 6.

Table 6. The results of the panel cointegration test

	Model 1	Model 2
Kao cointegration test		
Modified Dickey–Fuller t	1.368*	1.1548
Dickey–Fuller t	0.5787	0.3451

Augmented Dickey–Fuller t	1.9509**	1.7294**
Unadjusted modified Dickey–Fuller T	-1.1261	-1.2535
Unadjusted Dickey–Fuller t	-1.4391*	-1.5407*
Pedroni cointegration test		
Modified Phillips-Perron t	5.6435***	5.9564***
Phillips-Perron t	-2.8989**	-1.0917
Augmented Dickey-Fuller t	-2.5242**	-1.4216**
Westerlund cointegration test		
Variance ratio	-0.3007	0.418

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

Source: Authors' own calculations.

Evidence of long-run equilibrium among the variables is supported by the majority of cointegration tests. The Pedroni test consistently rejects the null hypothesis of no cointegration, and the Kao test also provides statistically significant support for cointegration, particularly through the ADF statistic. Although the Westerlund variance-ratio test does not reject the null hypothesis, the overall results predominantly indicate the presence of a stable long-run relationship in the panel. The findings of the pedroni panel cointegration test provides significant evidence of a long-term link between the variables. It may be concluded that CO_2 emissions per capita, revenue and expenditure decentralisation, renewable energy consumption, and GDP per capita all move together in the long run, implying that the variables under consideration have a stable long-term relationship. This paper employs Methods of moments quantile regression of Machado and Santos Silva (2019) to investigate the impacts of revenue and expenditure decentralisation, renewable energy consumption and GDP per capita on CO_2 emissions. Methods of moments quantile regression was selected because it allows us to examine what is the effect of fiscal decentralization on environmental performance across different levels of CO_2 emissions, revealing potential asymmetries in effects.

4. Results and discussion

The classical OLS method calculates estimates for Gaussian linear structural equation models with additive errors. However, this method only shows the conditional mean of the structural relationship, implying restricted locational shift assumptions about how covariates can alter the conditional distributions of endogenous variables. Quantile regression approaches try to broaden this perspective by offering a more thorough characterisation of the stochastic connection between variables, as well as more robust and thus more efficient estimates in some non-Gaussian scenarios (Ma and Koenker, 2006). By investigating the linkage between variables at different quantiles, quantile regression can help to better justify the conditional distribution. Furthermore, quantile regression does not require tight assumptions about normality, homoscedasticity or the lack of outliers (Johnston and DiNardo 1997). The advantage of this method is that it maps the cause of change in a regressor at various positions along the conditional distribution.

We employed the Method of moments quantile regression (MMQREG), as developed by Machado and Santos Silva (2019). Quantile regression is considered a practice-oriented approach due to its capacity to simultaneously address both heterogeneity and endogeneity through moment restrictions. As such, it is well-suited for modelling asymmetric and non-linear relationships. A key advantage of the MMQREG approach lies in its natural handling of non-crossing quantile estimates, avoiding the generation of invalid or implausible results. In contrast to classical quantile regression, which minimizes the quantile loss function (the check function), MMQREG estimates conditional quantiles by solving a set of moment conditions. This method yields robust quantile-based estimates while allowing for model flexibility and accounting for endogeneity.

MMQREG is applied and estimated in five quantiles. These include the lower (10th quantile), middle lower (25th quantile), middle (50th quantile), middle higher (75th quantile), and upper quantile (90th quantile). The empirical results of the MMQREG model for the new EU countries are presented in Table 7.

Table 7. Results of method of moments quantile regression for new EU countries

Model 1: Fiscal Decentralization on the Expenditure Side							
	Location	**Scale**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**
EXPD	0.004**	0	0.004	0.004	0.004**	0.004**	0.005**
	[0.002]	[0.001]	[0.003]	[0.002]	[0.002]	[0.002]	[0.002]
REC	-0.010***	0.002	-0.013***	-0.012***	-0.010***	-0.009***	-0.008***
	[0.003]	[0.002]	[0.005]	[0.004]	[0.003]	[0.002]	[0.003]
LGDP	0.519***	0.246***	0.12	0.288**	0.529***	0.745***	0.872***
	[0.113]	[0.054]	[0.147]	[0.122]	[0.120]	[0.132]	[0.142]
$LGDP^2$	-0.147**	0.109***	-0.323***	-0.249***	-0.142**	-0.047	0.01
	[0.060]	[0.026]	[0.076]	[0.066]	[0.062]	[0.065]	[0.068]
EI	0.174***	0.025*	0.134***	0.151***	0.175***	0.197***	0.210***
	[0.023]	[0.014]	[0.041]	[0.032]	[0.023]	[0.019]	[0.020]
TRADE	0.001	-0.001*	0.002*	0.001*	0.001	0	0
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]
Constant	1.540***	0.069	1.428***	1.475***	1.543***	1.603***	1.639***
	[0.161]	[0.098]	[0.292]	[0.232]	[0.159]	[0.121]	[0.126]

Number of obs.			209	209	209	209	209
Model 2: Fiscal Decentralization on the Revenue Side							
	Location	**Scale**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**
REVD	0.002	0.001	0.001	0.001	0.002	0.003	0.003
	[0.002]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.002]
REC	-0.011***	0.001	-0.014***	-0.012***	-0.011***	-0.010***	-0.009***
	[0.003]	[0.002]	[0.004]	[0.003]	[0.003]	[0.002]	[0.003]
LGDP	0.523***	0.276***	0.076	0.309**	0.571***	0.796***	0.976***
	[0.117]	[0.057]	[0.159]	[0.127]	[0.125]	[0.134]	[0.153]
$LGDP^2$	-0.148**	0.114***	-0.333***	-0.237***	-0.128**	-0.035	0.04
	[0.060]	[0.026]	[0.079]	[0.066]	[0.062]	[0.065]	[0.071]
EI	0.174***	0.027*	0.129***	0.152***	0.178***	0.201***	0.219***
	[0.023]	[0.014]	[0.041]	[0.031]	[0.022]	[0.019]	[0.021]
TRADE	0.001	-0.001*	0.002*	0.001*	0.001	0	0
	[0.001]	[0.000]	[0.001]	[0.001]	[0.001]	[0.000]	[0.001]
Constant	1.605***	0.059	1.509***	1.559***	1.615***	1.664***	1.703***
	[0.147]	[0.093]	[0.266]	[0.198]	[0.138]	[0.119]	[0.137]
Number of obs.			209	209	209	209	209

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

Source: Authors' own calculations.

The findings show that expenditure decentralization and GDP have a positive, statistically significant effect on CO_2 emissions, with the impact more pronounced at the middle and upper ends of the emissions distribution. This suggests that greater local public spending authority is linked to increased emissions in countries with moderate to high pollution levels. In seeking convergence with more developed countries, new EU countries appear to rely on resource-intensive growth strategies that lead to higher carbon emissions. This implies that subnational spending autonomy, without strong environmental governance or administrative capacity, may increase environmental pressures in newer EU economies. In contrast, revenue decentralization does not show significant effects across quantiles, indicating a weaker environmental role for locally retained revenues in these economies.

These results may reflect inefficiencies among municipal governments in prioritizing environmentally sustainable investments. Instead of aligning with environmental standards, local authorities may be directing resources toward infrastructure and energy production projects reliant on fossil fuels which is consistent with the "race to the bottom" hypothesis. Such behaviour can undermine long-term environmental sustainability. To mitigate these effects, stronger accountability mechanisms and regulatory oversight at the local level are necessary. Enhancing governance capacity could facilitate a shift toward a "race to the top" approach, where environmental performance becomes a competitive advantage rather than a cost to be minimized.

On the other hand, renewable energy consumption contributes to the reduction of CO_2 emissions in all quantiles, indicating that greater adoption of renewable energy contributes to lowering CO_2 emissions among new EU countries. Its effectiveness is particularly evident among countries with low to medium emission levels, reinforcing the argument that promoting the transition to renewable energy sources is a key policy mechanism in addressing environmental challenges in new EU economies.

As Harbaugh et al. (2002) argue, during the initial stages of economic development, governments and societies tend to prioritize growth over environmental protection, leading to increased reliance on fossil fuels and a corresponding rise in emissions. Therefore, to improve environmental outcomes in the new EU countries, it is essential to strengthen carbon pricing mechanisms, regulate emissions from carbon-intensive goods and services, and promote the adoption of renewable energy technologies and energy-efficient solutions.

GDP exhibits a consistently positive and statistically significant association with CO_2 emissions across most quantiles, reinforcing the persistent link between economic expansion and environmental degradation. The positive location coefficient implies that a 1% increase in GDP results in a proportional rise in emissions. The effect of GDP increases progressively across quantiles, indicating that economic growth contributes more strongly to emissions in countries with higher pollution levels. In addition, the squared term of GDP ($LGDP^2$) becomes negative and significant in several cases. These results point to the presence of an Environmental Kuznets Curve (EKC), where pollution rises with income but gradually decreases once a certain development level is reached. This turning-point effect is more pronounced at middle and upper quantiles, where emissions intensity is higher.

Energy intensity (EI) remains strongly positive and significant across all quantiles, highlighting the persistent link between fossil-fuel-driven energy consumption and higher emissions in newer EU member economies. Trade openness yields mixed coefficients, with weak and mostly insignificant effects across quantiles, suggesting limited direct environmental implications from trade in these countries.

Overall, the MMQREG results emphasize the importance of examining distributional effects beyond mean estimates. While OLS provides a general overview, the MMQREG approach reveals significant heterogeneity across the distribution of CO_2 emissions. Specifically, expenditure decentralization and GDP are associated with increased emissions across all quantiles, whereas renewable energy consumption emerge as effective mitigation instruments, particularly in higher-emitting contexts. These findings align with previous studies, including Xie et al. (2024), Ji et al. (2020), and Liu et al. (2022) which argue that fiscal decentralization contributes to increased CO_2 emissions. You et al. (2019) attribute this to a "race to the bottom" dynamic, where decentralized governments, aiming to attract high-profit enterprises, refrain from enforcing stringent environmental regulations, thereby intensifying environmental pressures.

In contrast, other studies report opposing results where fiscal decentralization leads to reduction in CO_2 emissions. This is confirmed by Cheng et al. (2020) for China, Tufail et al. (2021) for seven highly fiscally decentralized countries, Wang et al. (2022) for seventeen developed countries, and Hu et al. (2023) for OECD members. In a related study, Satrovic et al. (2024), analysing nine EU member states, find that green innovation can moderate the adverse effects of fiscal decentralization on both ecological and carbon intensity.

Figures 2 and 3 visually summarise the quantile regression results for the new EU member states, aligned with Models 1 and 2 discussed above. Figure 2 shows how expenditure decentralisation relates to CO_2 emissions across the emissions distribution, while Figure 3 presents the corresponding relationship for revenue decentralisation.

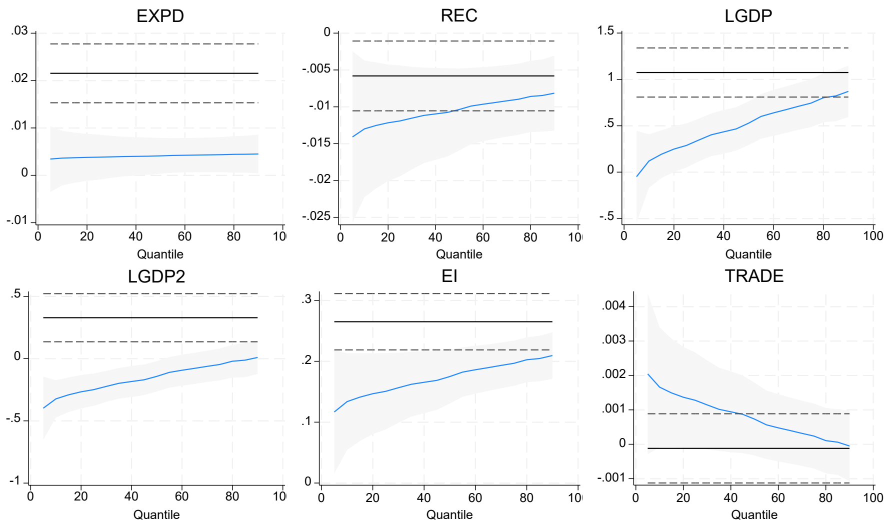

Figure 2. Graphical presentation of quantile regression results for expenditure decentralization in new EU countries

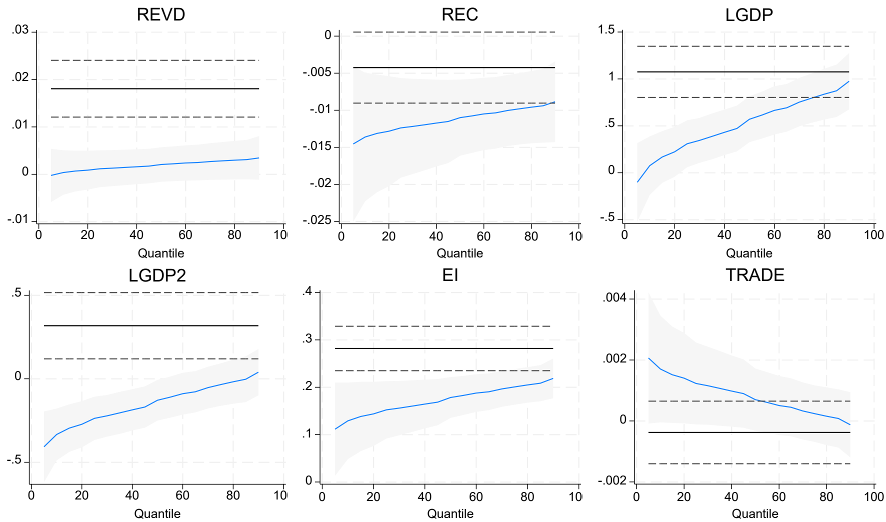

Figure 3. Graphical presentation of quantile regression results for revenue decentralization in new EU countries

Figure 2 and 3 display quantile regression graphs for per capita CO_2 emissions (horizontal axes) versus each explanatory variable. The horizontal line in each plot shows the OLS-estimated coefficient, while the dotted lines indicate the matching 95% confidence interval. The curve depicts the calculated coefficient using quantile regression, with the shaded area indicating the 95% confidence range.

Tables 8 displays the results of the fiscal decentralization and carbon emission nexus for old EU countries.

Table 8. Results of Method of moments quantile regression for old EU countries

Model 1: Fiscal Decentralization on the Expenditure Side							
	Location	**Scale**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**
EXPD	0.006**	0.001	0.004	0.005	0.006**	0.007***	0.008***
	[0.002]	[0.001]	[0.004]	[0.003]	[0.003]	[0.002]	[0.002]
REC	-0.016***	0	-0.016***	-0.016***	-0.016***	-0.016***	-0.016***
	[0.002]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.003]
LGDP	0.374***	0.097*	0.224**	0.287***	0.366***	0.464***	0.509***
	[0.092]	[0.051]	[0.103]	[0.092]	[0.092]	[0.113]	[0.132]
$LGDP^2$	0.102	-0.012	0.121	0.113	0.103	0.091	0.086

	[0.072]	[0.032]	[0.095]	[0.083]	[0.073]	[0.072]	[0.077]
EI	0.260***	0.003	0.255***	0.257***	0.260***	0.263***	0.265***
	[0.029]	[0.017]	[0.034]	[0.030]	[0.029]	[0.036]	[0.041]
TRADE	-0.001***	0	-0.001***	-0.001***	-0.001***	-0.001*	-0.001
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]
Constant	1.192***	-0.056	1.279***	1.242***	1.197***	1.139***	1.113***
	[0.190]	[0.108]	[0.228]	[0.197]	[0.189]	[0.232]	[0.266]
Number of obs.			304	304	304	304	304
Model 2: Fiscal Decentralization on the Revenue Side							
	Location	**Scale**	**Q10**	**Q25**	**Q50**	**Q75**	**Q90**
REVD	0.003**	0	0.004**	0.003**	0.003**	0.003*	0.002
	[0.001]	[0.001]	[0.002]	[0.001]	[0.001]	[0.002]	[0.002]
REC	-0.016***	0	-0.016***	-0.016***	-0.016***	-0.016***	-0.016***
	[0.002]	[0.001]	[0.002]	[0.002]	[0.002]	[0.002]	[0.003]
LGDP	0.407***	0.098*	0.257**	0.320***	0.398***	0.490***	0.544***
	[0.093]	[0.052]	[0.106]	[0.096]	[0.093]	[0.110]	[0.131]
$LGDP^2$	0.096	-0.005	0.104	0.1	0.096	0.091	0.088
	[0.075]	[0.033]	[0.101]	[0.087]	[0.076]	[0.073]	[0.077]
EI	0.260***	-0.001	0.261***	0.260***	0.260***	0.259***	0.258***
	[0.031]	[0.018]	[0.036]	[0.031]	[0.030]	[0.037]	[0.044]
TRADE	-0.001***	0	-0.001***	-0.001***	-0.001***	-0.001**	-0.001*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]	[0.001]
Constant	1.298***	0.02	1.267***	1.280***	1.296***	1.315***	1.326***
	[0.190]	[0.115]	[0.205]	[0.178]	[0.186]	[0.244]	[0.292]
Number of obs.			304	304	304	304	304

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

Source: Authors' own calculations.

The results for old EU member states show a consistent and significant role of fiscal decentralization. The coefficient estimates for expenditure decentralization and revenue decentralization are positively associated with CO_2 emissions. However, the coefficients for expenditure decentralization are small and statistically significant only in the middle and upper quantiles, implying that expenditure decentralization in more advanced

EU economies exerts a modest upward pressure on emissions. Nevertheless, the effect is weaker than in new EU members. This pattern suggests that these countries benefit from stronger institutional capacity, mature governance frameworks, and more effective environmental regulations, which help mitigate potential negative environmental effects of decentralization. In addition, quantile estimates for revenue decentralization are positive and statistically significant.

Renewable energy consumption (REC) demonstrates a strong and consistently negative effect across all quantiles in both models, with high statistical significance. This confirms the critical role of renewable energy in reducing emissions and highlights the successful integration of renewable technologies in older EU states.

Economic development also shows a robust association with emissions. The GDP coefficient (LGDP) is positive and significant across most quantiles, suggesting that economic activity continues to generate emissions despite structural shifts toward service-based industries and cleaner technologies. The estimated location effect of 0.407 implies that a 1% increase in GDP is associated with approximately a 0.4% rise in average emissions. Moreover, the impact intensifies along the emissions distribution, ranging from 0.097 at Q10 to 0.509 at Q90 in model with expenditure decentralization. This pattern underscores the increasing environmental burden of economic growth, particularly in higher-emitting countries, reinforcing the classic trade-off between economic expansion and environmental performance. However, the quadratic GDP term ($LGDP^2$) is not statistically significant, implying the absence of a clear Environmental Kuznets Curve turning point in this group. Energy intensity (EI) remains a strong and significant driver of emissions, as expected, confirming that efficiency improvements remain central to emission reduction strategies even in advanced economies.

Trade openness shows a small but statistically significant negative effect on emissions at most quantiles, suggesting that trade in old EU economies may be associated with cleaner production processes, stronger environmental standards, or greater integration into low-carbon global value chains.

In old EU countries, economic growth remains a significant contributor to CO_2 emissions across most of the distribution, while renewable energy consistently reduces emissions, confirming its central role in decarbonisation. Fiscal decentralisation shows only modest and positive effects on emissions, indicating that stronger local governance frameworks help mitigate environmental risks, although some upward pressure remains. Overall, the findings suggest that old EU economies benefit from institutional capacity and renewable energy deployment, yet continued efforts in energy efficiency and clean energy expansion are required to further decouple economic activity from carbon emissions. Figure 4 and 5 present the graphical representation of the nexus as explained above for old EU countries.

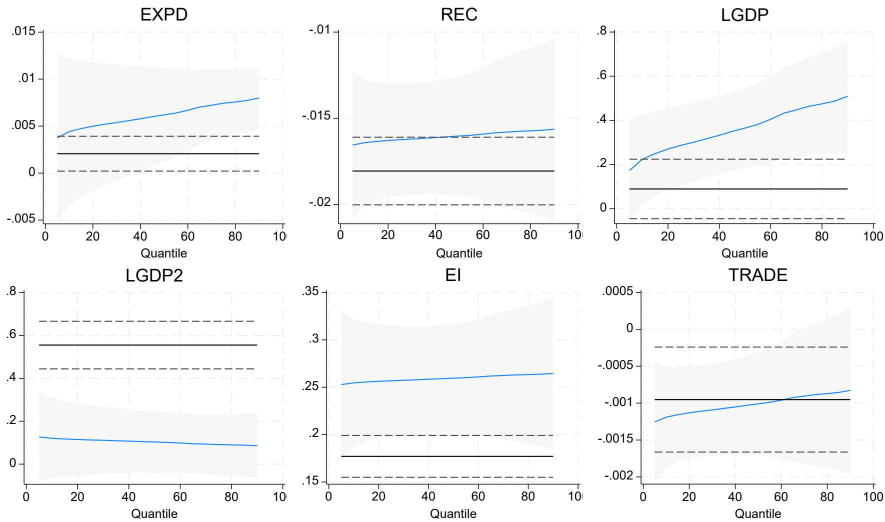

Figure 4. Graphical presentation of quantile regression results in old EU countries for Model 1 with expenditure decentralization

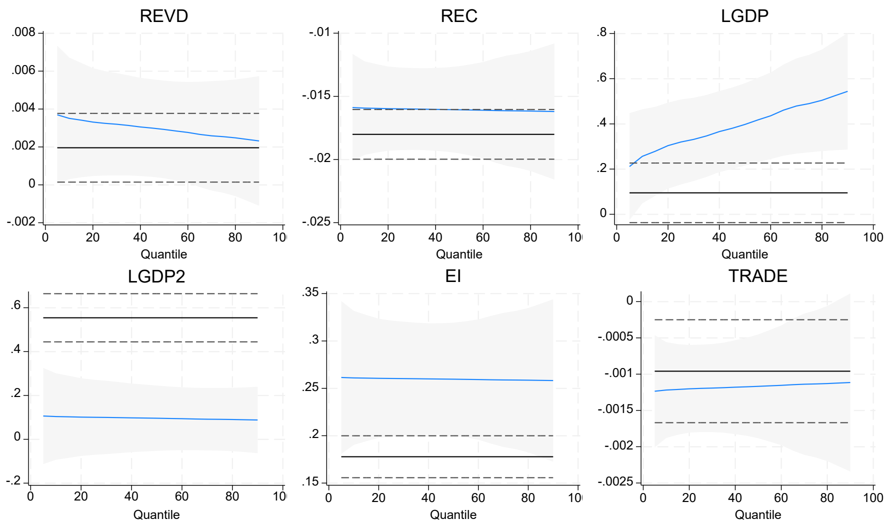

Figure 5. Graphical presentation of quantile regression results in old EU countries for Model 2 with revenue decentralization

The EU's ambition to cut greenhouse gas emissions by 55% by 2030 necessitates a tripling of efforts to reduce fossil fuel consumption and adopt alternative energy sources that enhance environmental performance and the green environment. Although it is expected that all countries will strengthen their financial institutions and enhance green financing, climate change is a pressing issue that must be addressed soon. The government should promote green initiatives by establishing regulatory and legislative frameworks that provide a transparent and dependable financing system. Furthermore, it is critical to create consumer knowledge about the importance of conserving energy and using renewable energy sources. Furthermore, consumers' financial literacy should be strengthened so that they can take use of current financial services and seek out green investments.

As a robustness check, the OLS approach with Driscoll and Kraay standard errors was employed to improve inference and estimation precision. The empirical results for old and new EU countries are presented in Table 9. It is obvious that the signs of the estimates are the same to results of MMQREG for old and new EU countries.

Table 9. Robustness check analysis via OLS approach with Driscoll and Kraay standard errors

	Old EU countries		**New EU countries**	
	Model 1	**Model 2**	**Model 1**	**Model 2**
EXPD	0.006***		0.004*	
	[0.002]		[0.002]	
REVD		0.003***		0.002
		[0.001]		[0.001]
REC	-0.016***	-0.016***	-0.010***	-0.011***
	[0.002]	[0.003]	[0.003]	[0.003]
LGDP	0.374***	0.407***	0.519***	0.523***
	[0.071]	[0.079]	[0.108]	[0.110]
$LGDP^2$	0.102	0.096	-0.147***	-0.148***
	[0.064]	[0.069]	[0.033]	[0.033]
EI	0.260***	0.260***	0.174***	0.174***
	[0.040]	[0.040]	[0.035]	[0.035]
TRADE	-0.001**	-0.001**	0.001	0.001
	[0.000]	[0.000]	[0.001]	[0.001]
cons.	1.192***	1.298***	1.540***	1.605***
	[0.228]	[0.207]	[0.217]	[0.193]
Number of obs.	304	304	209	209

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

Source: Authors' own calculations.

The results are consistent with the MMQR estimates and confirm significant asymmetries between old and new EU countries. In old EU countries, both expenditure and revenue decentralization are positively associated with CO_2 emissions, suggesting that greater fiscal autonomy may contribute to higher environmental pressure where spending responsibilities are more developed. In new EU countries, only expenditure decentralization shows a weak positive effect, while revenue decentralization is not statistically significant, indicating a more limited environmental impact of decentralization in less fiscally mature systems.

Renewable energy consumption significantly reduces emissions across all specifications, reinforcing its central role in achieving environmental goals. GDP increases emissions in both groups, but the significant negative squared GDP term in new EU countries points to an emerging Environmental Kuznets Curve pattern, where emissions begin to decline at higher income levels. Energy intensity increases emissions in all cases, while trade openness lowers emissions only in old EU economies.

Overall, the findings suggest that fiscal decentralization may heighten environmental pressures, particularly in old EU economies, while renewable energy expansion and improved energy efficiency remain crucial pathways for reducing CO_2 emissions across the Union.

To explore whether the effects differ across country groups, a pooled OLS model with interaction terms between the New EU dummy and each explanatory variable was estimated, and the results are presented in Table 10.

Table 10. Pooled OLS model with New EU countries interaction effects
Dependent variable: L**CO_2**

Variables	Model 1	Variables	Model 2
EXPD	0.0021	REVD	0.00196
New EU	−0.7215	New EU	−0.72794
EXPD × New EU	0.0195**	New EU × REVD	0.01611*
REC	−0.0181***	REC	−0.01801***
REC × New EU	0.0123	REC × New EU	0.01376
LGDP	0.0896	LGDP	0.09499
LGDP × New EU	0.9852**	LGDP × New EU	0.98035**
$LGDP^2$	0.5554*	$LGDP^2$	0.55439***
$LGDP^2$ × New EU	−0.2263	$LGDP^2$ × New EU	−0.23641
EI	0.1771***	EI	0.17784***
EI × New EU	0.088	EI × New EU	0.10403
Trade	−0.00095	Trade	−0.00096
Trade × New EU	0.00083	Trade × New EU	0.00058

Constant	1.574***	Constant	1.57089***
R^2	0.765	R^2	0.765
Root MSE	0.196	Root MSE	0.198

Source: Authors' own calculations.

The interaction model indicates that the effect of expenditure decentralization and economic growth on emissions differs between old and new EU members. Specifically, the interaction term for expenditure decentralization (EXPD × New EU) is positive and significant, suggesting decentralization increases emissions more strongly in new EU economies. GDP also shows a significantly larger positive effect in new EU members, highlighting a steeper growth–emissions trade-off. Other interaction terms are not significant, implying broadly similar effects of renewable energy, energy intensity and trade openness across EU groups.

The results for the revenue decentralization specification confirm notable differences between old and new EU countries. Revenue decentralization does not significantly affect emissions in the full sample; however, the positive and marginally significant interaction term suggests that its association with emissions is somewhat stronger among new EU countries. Renewable energy consistently reduces emissions, though its mitigating effect does not differ statistically across regions. GDP and its squared term support the EKC pattern, with new EU countries showing a significantly stronger growth-emissions link, indicating that economic expansion places greater environmental pressure in these economies. Energy intensity increases emissions across all countries, again with no meaningful regional differences. The findings imply that institutional and structural conditions in new EU members amplify the environmental effects of fiscal settings and growth dynamics.

5. Conclusion

Current public investment in local government in EU countries should be brought in line with net zero targets and there should be a stronger focus on prioritizing investment. Although significant spending is being made to achieve long-term climate targets, more can be done. By 2050, rapid decarbonization of the economy will be required to meet the 2°C target of the Paris Agreement and avert catastrophic climate change, requiring an alignment of current public investments with the net zero target. Public and private investment in renewable energy and broader efforts to improve energy efficiency also have the potential to enhance environmental performance. In addition, many countries, especially the new EU countries, need to involve sub-national levels of government in their environmental strategies and policy frameworks. Therefore, the aim of this paper was to investigate the linkage between fiscal decentralization and renewable energy in minimizing environmental pollution between 2004 and 2022. In order to obtain meaningful empirical results, a panel data analysis with a method of moment quantile regression analysis was employed. The findings show that fiscal decentralisation has heterogeneous environmental effects across EU countries. In new EU countries, greater expenditure autonomy is associated with higher CO_2 emissions, suggesting that local spending powers may reinforce polluting development pathways without strong environmental governance. In contrast, revenue decentralisation has no consistent impact. In old EU countries, decentralisation effects are positive but modest, indicating more balanced institutional frameworks. Across all models, GDP remains the main driver of emissions, while renewable energy consumption consistently reduces them. These results underscore the need for robust environmental oversight at the local level, targeted support for green investments, and continued expansion of renewable energy to ensure that decentralisation complements rather than delays the low-carbon transition. These findings suggest that decentralisation alone is not sufficient to strengthen environmental performance; rather, the design and quality of local environmental policies matter. Strengthening local capacity, directing resources toward clean energy investments, and avoiding "race-to-the-bottom" competition in environmental standards are crucial steps, particularly for newer EU members still undergoing institutional consolidation. The policy implications of this paper are as follows:

1. The local government should set up a special bureau to monitor progress on environmentally friendly projects and pollution reduction.
2. Increase the active participation of the local population in the introduction of environmental innovations to solve environmental problems at the local level.
3. Increase investment in the renewable energy sector by public and private companies at the local level.
4. Stimulate local government in budgetary policies both in revenues and expenditures to achieve CO_2 emission reduction targets.

Following the policy implications, this paper points out that in order to enhance environmental performance, especially in the new EU countries, central government should delegate its powers to local government authorities to create environmentally friendly projects. Institutional quality and high environmental standards should also be implemented to achieve the desired goals. According to the practice of the new EU countries, there are a variety of responsibilities in how countries organize support to address environmental challenges. The best solution is a shared responsibility between central and sub-national governments. This will lead to aligning green investments with green business models to improve the quality of the environment.

Like any research, this research has its limitations. The first limitation is the restriction of the sample and time period. Different results may be obtained for a longer period of time, for a larger sample of countries but also if including other macroeconomic variables. The second is the availability of data for certain variables to confirm the relationship between fiscal decentralization and environmental performance. Based on the results presented, future studies could investigate the relationship for each EU country individually and over a longer period of time. Another suggestion is to investigate the direct and indirect effects of fiscal decentralization on environmental performance. The results of the proposed analysis can lead to more meaningful and robust results for policy.

As emphasized at the outset, achieving net-zero emissions by 2050 necessitates the development of innovative governance frameworks. The findings of this paper underscore the pivotal role of fiscal decentralization as a key element of this transition. However, the results also reveal that the environmental effects of fiscal decentralization vary considerably between old and new EU countries. Specifically, while new EU countries appear to benefit more from devolved fiscal powers, particularly in terms of renewable energy adoption and reductions in CO_2 emissions, older member states may follow different trajectories, shaped by their more established governance and institutional frameworks.

In the face of the worsening climate crisis, the implementation of decentralised fiscal policies should not be seen as a political preference, but as a critical and urgent prerequisite for the promotion of effective and adaptable environmental policies. Environmental policies should be developed at both central and local government levels to avoid spillover effects on environmental issues, especially when there are significant differences between regions. Therefore, environmental regulation should be pursued in a diverse environment through the joint efforts of businesses, central governments, local governments and citizens.

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References

1. Aldieri, L., Gatto, A., & Vinci, C. P. (2022). Is there any room for renewable energy innovation in developing and transition economies? Data envelopment analysis of energy behaviour and resilience data. *Resources, Conservation and Recycling, 186*, 106587. https://doi.org/10.1016/j.resconrec.2022.106587
2. Baltagi, B. H. (2014). *The Oxford handbook of panel data*. Oxford University Press.
3. Bowman Cutter, W., & DeShazo, J. R. (2007). The environmental consequences of decentralizing the decision to decentralize. *Journal of Environmental Economics and Management, 53*(1), 32–53. https://doi.org/10.1016/j.jeem.2006.02.007
4. Carrillo-Pulgar, W. G., Vallejo-Mata, J. P., Tixi-Gallegos, K. G., Sánchez Cuesta, P. A., & RomeroAlvarado, J. (2025). Does Fiscal Decentralization Drive CO2 Emissions? A Quantile Regression Analysis. *Journal of Risk and Financial Management*, 18(5), 235. https:// doi.org/10.3390/jrfm18050235

5. Chen, X., & Liu, J. (2020). Fiscal decentralization and environmental pollution: A spatial analysis. *Discrete Dynamics in Nature and Society,* 1–10. https://doi.org/10.1155/2020/9254150
6. Chen, X., & Chang, C. P. (2020). Fiscal decentralization, environmental regulation, and pollution: A spatial investigation. *Environmental Science and Pollution Research, 4*(2), 54698–54717. https://doi.org/10.1007/s11356-022-19669-y
7. Cheng, S., Fan, W., Chen, J., Meng, F., Liu, G., Song, M., & Yang, Z. (2020). The impact of fiscal decentralization on CO2 emissions in China. *Energy, 192*, 116685. https://doi.org/10.1016/j.energy.2019.116685
8. DiPietro, W. R., & Anoruo, E. (2006). Creativity, innovation, and export performance. *Journal of Policy Modeling, 28*(2), 133–139. https://doi.org/10.1016/j.jpolmod.2005.10.001
9. European Committee of the Regions. (2019). *Resolution: The Green Deal in partnership with local and regional authorities*. https://cor.europa.eu/en/Documents/COR-2019-04351-00-00-RES-TRA-EN.pdf
10. Farzanegan, M., & Mennel, T. (2012). Fiscal decentralization and pollution: Institutions matter. *MAGKS Papers on Economics, 201222*. Philipps-Universität Marburg. https://hdl.handle.net/10419/73071
11. Fay, M., Hallegatte, S., Vogt-Schilb, A., Rozenberg, J., Narloch, U., & Kerr, T. (2015). *Decarbonizing development: Three steps to a zero-carbon future*. World Bank. https://openknowledge.worldbank.org/handle/10986/21842
12. Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics, 110*(2), 353–377. https://doi.org/10.2307/2118443
13. Harbaugh, W. T., Levinson, A., & Wilson, D. M. (2002). Reexamining the empirical evidence for an environmental Kuznets curve. *The Review of Economics and Statistics, 84*(3), 541–551. https://doi.org/10.1162/003465302320259538
14. He, Q. (2015). Fiscal decentralization and environmental pollution: Evidence from Chinese panel data. *China Economic Review, 36*, 86–100. https://doi.org/10.1016/j.chieco.2015.08.010
15. Hu, B., Guo, M., & Zhang, S. (2023). The role of fiscal decentralization and natural resources markets in environmental sustainability in OECD. *Resources Policy, 85*(PB), 103855. https://doi.org/10.1016/j.resourpol.2023.103855
16. Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics, 115*(1), 53–74. https://doi.org/10.1016/S0304-4076(03)00092-7
17. Ji, X., Umar, M., Ali, S., Ali, W., Tang, K., & Khan, Z. (2020). Does fiscal decentralization and eco-innovation promote sustainable environment? A case study of selected fiscally decentralized countries. *Sustainable Development, 29*(1), 79–88. https://doi.org/10.1002/sd.2132
18. Johnston, J., & DiNardo, J. (1997). *Econometric methods*. McGraw-Hill.
19. Kao, C., & Chiang, M.-H. (2001). On the estimation and inference of a cointegrated regression in panel data. In B. Baltagi, T. Fomby, & R. Carter Hill (Eds.), Nonstationary panels, panel cointegration, and dynamic panels Advances in econometrics (Vol. 15, pp. 179–222). Emerald Group Publishing Limited.
20. Kassouri, Y. (2022). Fiscal decentralization and public budgets for energy RD&D: A race to the bottom? *Energy Policy, 161*, 112761. https://doi.org/10.1016/j.enpol.2021.112761
21. Khan, Z., Ali, S., Dong, K., & Li, R. Y. M. (2021). How does fiscal decentralization affect CO2 emissions? The roles of institutions and human capital. *Energy Economics, 94*, 105060. https://doi.org/10.1016/j.eneco.2020.105060
22. Koenker, R. (2005). *Quantile regression*. Cambridge University Press.

23. Liu, R., Zhang, X., & Wang, P. (2022). A study on the impact of fiscal decentralization on green development from the perspective of government environmental preferences. *International Journal of Environmental Research and Public Health, 19*(16), 9964. https://doi.org/10.3390/ijerph19169964
24. Ma, L., & Koenker, R. (2006). Quantile regression methods for recursive structural equation models. *Journal of Econometrics, 134*(2), 471–506. https://doi.org/10.1016/j.jeconom.2005.07.003
25. Machado, J. A. F., & Santos Silva, J. M. C. (2019). Quantiles via moments. *Journal of Econometrics, 213*(1), 145–173. https://doi.org/10.1016/j.jeconom.2019.04.009
26. Millimet, D. L. (2003). Assessing the empirical impact of environmental federalism. *Journal of Regional Science, 43*(4), 711–733. https://doi.org/10.1111/j.0022-4146.2003.00317.x
27. Oates, W. E. (1972). *Fiscal federalism*. Harcourt, Brace, Jovanovich.
28. Pedroni, P. (1999). Critical values for cointegration tests in heterogeneous panels with multiple regressors. *Oxford Bulletin of Economics and Statistics, 61*(S1), 653–670.
29. Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics, 22*(2), 265–312. https://doi.org/10.1002/jae.951
30. Pesaran, M. H. (2015). Testing weak cross-sectional dependence in large panels. *Econometric Reviews, 34*(6–10), 1089–1117. https://doi.org/10.1080/07474938.2014.956623
31. Sadik-Zada, E. R., & Gatto, A. (2023). Civic engagement and energy transition in the Nordic-Baltic Sea Region: Parametric and nonparametric inquiries. *Socio-Economic Planning Sciences, 87*, 101347. https://doi.org/10.1016/j.seps.2022.101347
32. Satrovic, E., Zafar, M. W., & Suntraruk, P. (2024). Achieving ecological sustainability in European Union: The role of fiscal decentralization and green innovation. *Journal of Cleaner Production, 445*, 141316. https://doi.org/10.1016/j.jclepro.2024.141316
33. Shrestha, K., Vincent, R. C., & Martinez-Vazquez, J. (2025). The Impact of Fiscal Decentralization on Climate Change and the Mediating Role of Political Institutions. Andrew Young School of Policy Studies, Georgia State University. Working Paper 25-02. https://icepp.gsu.edu/files/2025/02/paper2502.pdf
34. Sun, Y. (2023). Income inequality, carbon emissions, and green development efficiency. *Environmental Science and Pollution Research, 30*(8), 21081–21091. https://doi.org/10.1007/s11356-022-23583-8
35. Tufail, M., Song, L., Adebayo, T.S., Kirikkaleli, D., Khan, S. (2021). Do fiscal decentralization and natural resources rent curb carbon emissions? Evidence from developed countries. *Environmental Science and Pollution Research*, 28, 49179–49190. https://doi.org/10.1007/s11356-021-13865-y
36. Wang, F., Rani, T., & Razzaq, A. (2022). Environmental impact of fiscal decentralization, green technology innovation and institution's efficiency in developed countries using advance panel modelling. *Energy & Environment, 34*(4), 1006–1030. https://doi.org/10.1177/0958305X221074727
37. Westerlund, J. (2005). New simple tests for panel cointegration. *Econometric Reviews, 24*, 297–316.
38. Xie, P., Xiao, W., Cai, Y., & Zhu, Z. (2024). Does decentralization improve natural resources and government efficiency? *Resources Policy, 91*, 104865. https://doi.org/10.1016/j.resourpol.2024.104865
39. Yang, S., Li, Z., & Li, J. (2020). Fiscal decentralization, preference for government innovation

and city innovation. *Chinese Management Studies, 14*(2), 391–409. https://doi.org/10.1108/CMS-12-2018-0778

40. You, D., Zhang, Y., & Yuan, B. (2019). Environmental regulation and firm eco-innovation: Evidence of moderating effects of fiscal decentralization and political competition from listed Chinese industrial companies. *Journal of Cleaner Production, 207*, 1072–1083. https://doi.org/10.1016/j.jclepro.2018.10.106
41. Zhao, B., Wang, K. L., & Xu, R. Y. (2023). Fiscal decentralization, industrial structure upgrading, and carbon emissions: Evidence from China. *Environmental Science and Pollution Research, 30*(13), 39210–39222. https://doi.org/10.1007/s11356-022-24971-w

Appendix

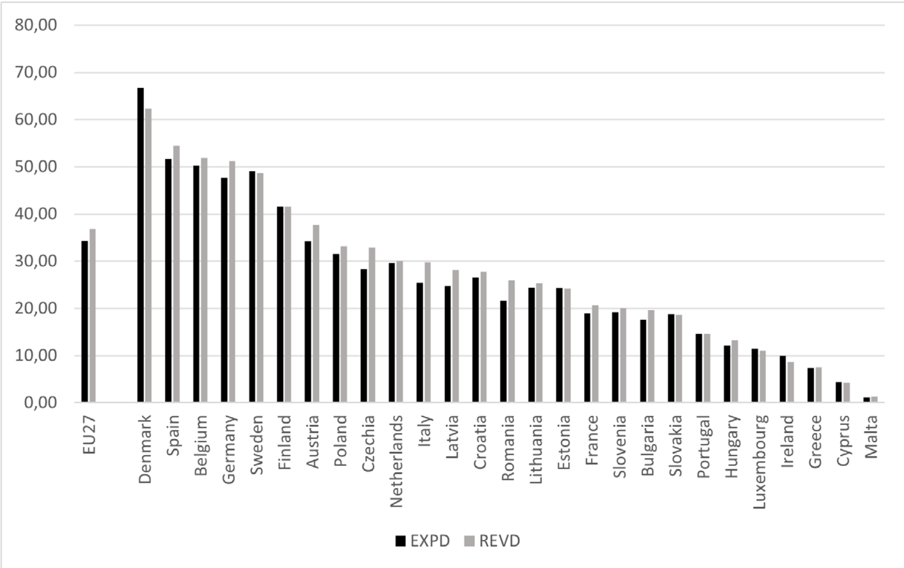

Figure 1. Expenditures and revenues decentralization in EU Countries in 2022 (in %)

Note: Decentralization of expenditures and revenues is calculated as a ratio of subnational government expenditure and revenue and total general government expenditure and revenue.

Source: Authors' calculation, based on Eurostat data

https://ec.europa.eu/eurostat/databrowser/view/gov_10a_main__custom_11476661/default/table?lang=en (accessed 15.04.2024.)