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Explanatory Factors of Carbon Dioxide Emissions in the European Union

The European Union (EU) is committed to decarbonising its economy by 2050. To that end, significant reductions in greenhouse gases from the energy and agricultural sectors are of critical importance. However, while the EU member states each pursue a different climate strategy, all member states' emissions are regulated by EU climate law. This paper investigates the factors explaining carbon dioxide (CO_2) emissions in the 27 member countries, using fully modified least squares (FMOLS) and quantile regression models. Before estimations, panel unit root and cointegration tests have been used for the period 1990-2018. The applied model examines the impact of economic growth, energy intensity, renewable energy consumption and agricultural trade on carbon dioxide emissions. Estimates have shown that the intensification of energy stimulates carbon emissions. Economic growth indicates an increase in carbon emissions. The results reveal that agricultural trade decreases carbon dioxide emissions in the EU, highlighting that intra EU trade is more environmentally friendly. Finally, the impact of renewable energy is limited to contributing to climate mitigation goals by reducing emissions.

Keywords: carbon dioxide emissions, economic growth, energy intensity, renewable energy, agricultural trade, European Union

JEL classifications: Q15, Q32

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Introduction

The Paris agreement aimed to persuade nations to significantly decrease their greenhouse gas emissions and limit global temperature increases. As a result, the European Union (EU) has committed to decarbonising its economy and becoming carbon neutral by 2050. To realise this target, a significant reduction in carbon dioxide (CO_2) emissions is needed. The EU has implemented climate acts, the European Green Deal, renewed the EU emissions trading system (ETS), and developed Fit for 55 incentives to achieve its goals. Economic development is closely associated with changes in CO_2 emissions. Higher economic development is regularly accompanied by higher energy consumption, which can lead to additional greenhouse gas emissions (GHG). A substantial part of the environmental economics literature focuses on the relationship between environmental pollution and income (Gross Domestic Product, GDP).

In recent years, several studies have been applied to explore the association between GHG and the energy industry, agricultural and forestry sectors (Burakov, 2019; Balsalobre-Lorente *et al.,* 2019) but only a limited number of studies (Mert *et al.,* 2019; Balsalobre-Lorente and Leitão, 2020) have investigated environmental pollution in the EU member states.

This paper aims to consider the determinants of CO_2 emissions in the Member States of the European Union using various panel regression models for 1990-2018. The research enriches the existing empirical literature in several ways. First, it examines economic growth, renewable energy, and energy intensity in the EU in the short and long run. Second, it explores the role of EU agricultural trade played in GHG emissions. Finally, it suggests policy recommendations for European decision makers to improve mitigation policies at the sectoral level. The paper is structured as follows. The literature review emerges in Section 2; Section 3 refers to the methodology and description of the variables used in this study. Results and discussion are to be found in Section 4. Finally, the article ends with the conclusion.

Review of the relevant literature

A wide range of literature addresses the nexus of economic growth, energy consumption, trade, and carbon emissions. However, most recent empirical studies have focused principally on country-specific, cross-country perspectives or European Union-related issues examining the Environmental Kuznets Curve (EKC). Where methodology is concerned, the authors have used panel data applied to a set of countries, a sector or different sectors, or time series.

Country-level analysis

So far as individual country-level analysis is concerned, Pata (2021) searched for the impact of economic development, globalisation, renewable and non-renewable energy consumption on CO_2 emissions, as well as the ecological footprint through EKC in the United States. A cointegration test, fully modified least squares (FMOLS), dynamic least squares (DOLS) and canonical cointegrating regression (CCR) tests were used for statistical analysis. The results of the research confirmed that the inverted U-shaped EKC relationship between economic development and environmental pollution is valid for the United States. Furthermore, globalisation and renewable energy consumption led to reducing environmental pollution. Conversely, non-renewable energy consumption causes ecological stress.

Furthermore, Burakov (2019) applied an Autoregressive Distributed Lag (ARDL) time series model for Russia, suggesting that energy consumption and the agricultural sector stimulate climate change. In their models, economic growth was in line with the assumptions of the inverted U-shaped EKC. Finally, by conducting wavelet analysis, Adebayo *et al.* (2021) confirmed that renewable energy consumption helps curb CO_2, while trade openness, technological innovation, and economic growth contribute to higher CO_2. Furthermore, renewable energy consumption has been shown to decrease CO_2 in the medium and long term in Portugal. For Pakistan, Mahmood *et al.* (2019) underlined that income, trade openness, and renewable energy motivate emissions while human capital diminishes CO_2 emissions by estimating the three-stage least squares and ridge regression. Meanwhile, Rehman *et al.* (2021) measured the asymmetric effect of CO_2 emission on expenditures, trade, FDI, and renewable energy consumption using a nonlinear ARDL and Granger causality tests on Pakistani data. The findings revealed that the different shocks of renewable energy consumption were exposed to an increase in CO_2 emission in the short term. On the other hand, positive shocks from renewable energy consumption showed an adverse relationship with CO_2 emissions. Lastly, trade showed a statistically insignificant link with environmental degradation. Turning to China, Chandio *et al.* (2020), by employing the auto-regressive distributed lag (ARDL), fully modified ordinary least squares (FMOLS), canonical cointegration regression (CCR), and Granger causality tests, point out that crop and livestock production stimulates CO_2 emissions while electric power consumption in agriculture reduces emissions in China. Complementing this, Lei *et al.* (2021) analysed the impacts of Chinese energy efficiency and renewable energy consumption on CO_2 emissions by applying nonlinear ARDL models. They suggest that a positive shock in terms of renewable energy consumption has a depressing impact on CO_2 pollutants as compared to a negative shock, as it serves to strengthen environmental quality by decreasing short-term CO_2 emissions in China. Finally, Gokmenoglu (2019) explored a similar result in China using the same econometric technique, suggesting that real income, energy consumption and agricultural development have a positive impact on CO_2 emissions.

Cross-country analysis

Among cross-country analyses, several research investigated the impacts of economic development and different types of energy consumption on carbon dioxide emission (a proxy for climate change) in both developed and developing economies. Ahmed et al. (2021) used cross-sectional augmented autoregressive distributed lag (ARDL) analysis and demonstrated that economic growth and fossil fuel consumption increased CO_2 emissions, while renewable energy helped moderating emissions in 22 OECD countries. Addressing the impacts of non-renewable energy in the G-20, Ibrahim and Ajide (2021) found that fossil fuels and imports increased, while exports and technological innovation reduced per capita carbon emissions, examined by the augmented mean group (AMG), the common correlated effect mean group (CCEMG), and the mean group (MG). In the case of developing countries, Haldar and Sethi (2021) show that institutional quality moderates energy consumption and reinforces the drop in carbon emissions. Moreover, renewable energy consumption reduces emissions in the long run. They utilised mean group (MG), augmented mean group (AMG), common correlated effects mean group (CCEMG) estimator, dynamic system General Method of Moment (GMM), panel grouped-mean FMOLS and panel Quantile Regression approach. Parajuli (2019) applied the dynamic panel model (Arellano–Bond panel GMM) for 86 countries from Africa, Asia, Latin America and Europe at various stages of development, demonstrating that energy consumption and agriculture are positively correlated with carbon dioxide emissions while forest activities reduce the level of pollution in the long run.

Investigations carried out in emerging economies were also widespread. For example, Eyuboglu and Uzar (2020) researched the impacts of agriculture and renewable energy on CO_2 emissions for seven new emerging countries (Malaysia, Indonesia, India, Kenya, Mexico, Colombia, and Poland) using panel-based vector error correction model (VECM) techniques. The authors found that agriculture increases CO_2 emissions, while renewable energy reduces CO_2 in the region studied. Furthermore, economic growth and energy consumption enhance CO_2 emissions. The results indicate that the variables produced CO_2 emissions in the long run and economic growth indicated CO_2 emissions in the short term. In the developing world, You and Kakinaka (2021) discovered the relation of renewable energy to CO_2 emissions by using the ARDL model for 31 emerging countries according to the income classification. They suggest that CO_2 emissions have negative associations with renewable energy in the long term and are more exposed to modern renewable energy sources than traditional ones. Therefore, contemporary renewable energy sources can be an effective target for environmental and energy policies in emerging countries. Zafar *et al.* (2019) have studied the renewable and non-renewable energy sector, trade openness, and its impact on CO_2 emissions using the EKC in emerging economies. Their analysis applies cross-sectional dependence, second generation panel unit root, Pedroni, Westerlund panel cointegration tests along with continuously updated fully modified (CUP-FM), continuously updated bias-corrected (CUP-BC) estimations, and the vector error correction model (VECM). They have found that renewable energy consumption negatively affects, while fossil energy consumption positively affects CO_2 emissions. In contrast, the impact of trade openness on CO_2 is unfavourable.

Country group studies

Rasoulinezhad *et al.* (2018) examined long-term causal links between economic growth, CO_2 emissions, renewable and fossil energy consumption, trade openness, financial openness for the Commonwealth of Independent States (CIS) using DOLS and FMOLS panel cointegration estimation methods. According to their findings, the use of fossil fuel is the most significant factor in increasing CO_2 emissions in the long run in these countries. Moreover, the contribution of fossil energy consumption in improving economic growth is more important than the impact of CO_2 emissions and renewable energy consumption in the long run. Balsalobre-Lorente *et al.* (2019) identified agriculture, energy use, trade openness, and mobile use as the main drivers behind environmental degradation in Brazil, Russia, India, China, and South Africa (BRICS). The authors observed the inverted U-shaped EKC pattern between income level and carbon emissions and the damaging impact of agriculture on the environment. In the case of MERCOSUR, de Souza *et al.* (2018) evaluated the impact of energy consumption and income on emissions through an EKC framework on panel data. The authors point out that the consumption of renewable energy (biogas, solar, and wind) indicates a negative impact, while the consumption of non-renewable energy positively impacts carbon dioxide emissions. The validity of the EKC hypothesis for the MERCOSUR states was also proved. Mehmood (2021) found that globalisation, economic growth, and financial inclusion increased carbon dioxide emissions. However, the consumption of renewable energy moderated the emissions in Pakistan, India, Bangladesh, and Sri Lanka, investigated using the CS-ARDL approach. Similarly to individual country cases, development-energy-trade-emission patterns were identified at the regional level.

Studies focusing on EU emissions

Finally, limited number of studies explored the economic-energy-trade-emission linkage in European Union countries. In this context, Balsalobre-Lorente and Leitão (2020) analysed the effects of renewable energy, trade, carbon dioxide emissions and international tourism on economic growth in the EU using panel fully modified least squares (FMOLS), panel dynamic least squares (DOLS) and fixed effects (FE) estimation. Results suggest that trade openness, international tourism and renewable energy encourage economic growth, but the CO_2 and the use of green technologies are also associated with economic growth. Mert *et al.* (2019) investigated the association between CO_2 emissions and GDP, the use of renewable and fossil energy, and foreign direct investment in 26 EU countries by means of panel co-integration. The results confirmed the validation of the environmental Kuznets curve and the pollution haven hypothesises for EU countries. They argue that environmental regulations do not play an essential role in the validity of pollution havens but are significant elements in the EKC in the EU. They concluded that the EU should improve green technology and energy efficiency for sustainable development but narrow the environmental regulations on FDI inflow.

Considering a comparative analysis between EU and non-EU regions, Ponce and Khan (2021) considered the connection between CO_2 emissions and renewable energy, energy efficiency, fossil fuels, economic growth, property rights in 9 developed countries (Germany, Norway, Sweden, Switzerland, Australia, Canada, Japan, New Zealand, and the US), tested by the FMOLS. The outcomes shed light on a long-term equilibrium in developed European countries (Germany, Norway, Sweden, Switzerland). Still, it is not true for developed non-European countries (Australia, Canada, Japan, New Zealand, and the US). Estimates suggest a positive link between fossil fuel consumption, GDP, property rights, and CO_2 emissions. Meanwhile, renewable energy consumption and energy efficiency negatively influenced CO_2 emissions.

Previous studies have frequently focused on factors of economic growth via EKC, renewable energy and fossil fuel consumption, energy efficiency, trade, the financial and agricultural sector in various geographical areas. The selected literature suggests that economic growth, renewable energy, trade openness, export activity, and forest area all contribute to decreasing emissions while fossil fuel consumption, agriculture and imports all stimulate air pollution. Nearly all studies confirmed the inverted U-shaped EKC curve. Taking methodologies other than VECM into consideration, panel FMOLS, DOLS, CCR, nonlinear ADRL, panel MG, AMG, CCEMG, GMM and Quantile Regression were applied, and accompanied by unit root, cointegration, and Granger causality tests. However, only a limited number of studies (Mert *et al.* 2019, Balsalobre-Lorente and Leitão 2020) have investigated the environmental issues in the EU member states while taking into consideration the impacts of agricultural trade.

Methodology and data

We started our research by verifying the properties of the variables used in this empirical study. Consequently, we used unit root tests on panel data and the Pedroni cointegration test to observe long-term cointegration between the variables. Then, we analysed the explanatory factors of carbon dioxide emission in the European Union using Panel Fully Modified Least Squares (FMOLS), and Quantile Moments Regression Estimates suggested by Machado and Silva (2019). The estimated models investigated economic development, renewable energy, energy intensity, and agricultural exports as factors offering an explanation for carbon dioxide emissions. The selected database includes balanced panel data for the 27 EU member states between 1990 and 2018. The panel regression equation (1) captures the impact of economic development (GDP per capita), the level of primary energy intesity (in megajoules per GDP), agricultural exports (measured as export value in US dollars) and renewable energy consumption as a percentage of total energy consumption. Based on the empirical literature (Burakov, 2019; Balsalobre-Lorente *et al.,* 2019), the following equation is estimated:

$$\ln(CO_2pc) = \alpha + \beta_1 \ln(EI)_{ij} + \beta_2 \ln(GDPpc)_{ij} + \\ + \beta_3 \ln(agrexport)_{ij} + \beta_4 ln(RE)_{ij} + \varepsilon_{ij} \quad (1)$$

where
i denotes the EU member state,
j is the given year,
α is the constant,
β captures estimated coefficients,
and ε is the error term.

A detailed description of the variables is presented in Table 1.

Table 1: Description of variables.

Variables	Description	Source
CO_2pc	per capita CO_2 emissions in million tons	World Bank (2022) WDI
EI	primary energy intensity level (megajoules per GDP in 2011 US dollars, Purchasing Power Parity)	World Bank (2022) WDI
GDPpc	per capita GDP in 2011 US dollars, Purchasing Power Parity	World Bank (2022) WDI
AGREXPORT	agricultural exports in thousand current U.S. dollars	World Bank (2022) WITS
RE	renewable energy consumption as a percentage of total energy consumption	World Bank (2022) WDI

Note: The intensity level of primary energy is the ratio between the energy supply and the gross domestic product measured at purchasing power parity (PPP). Intensity is an indication of how much energy is used to produce one unit of economic output. A lower ratio indicates that less energy is used to produce one unit of output.
Source: Own composition

Based on the literature review, we formulate the following hypotheses in this empirical study.

H1: Economic development by increasing energy production and consumption stimulates CO_2 emissions in the EU.

More recently, studies by Balsalobre-Lorente *et al.* (2021), Leitão *et al.* (2021) and Burakov (2019) have found that economic growth has a positive impact on carbon dioxide emissions.

H2: The increased energy intensity of primary energy consumption leads to a higher level of CO_2 emission in the EU.

The intensity of the energy captures the amount of energy used to produce one unit of economic output. A higher proportion of energy intensity indicates that more energy is used to produce one unit of output. These assumptions are supported by Burakov (2019), Ponce and Khan (2021) and Haldar and Sethi (2021).

H3: The expansion of agricultural exports decreases CO_2 emissions in the member states.

Although in general, agricultural production stimulates emissions (Chen *et al.,* 2021; *Ansari et al.,* 2020 and Yu *et al.,* 2019), trade in agricultural products, especially agricultural intra-industry trade, may have been related to cleaner energies that help reduce CO_2 emissions in the EU (Leitão and Balogh, 2020).

H4: A higher share of renewable energy consumption contributes to a decrease in air pollution in the EU.

Several researchers (Pata, 2021; Burakov, 2019; Ahmed *et al.,* 2021; Eyuboglu and Uzar, 2020 and Zafar *et al.,* 2019) have suggested that increasing renewable energy consumption contributes to climate mitigation through emissions reduction.

Results

Figure 1 shows that, in line with the reduction in CO_2 emissions, the EU has generally experienced a small decrease in fossil energy use and an increase in renewable energy consumption, while agricultural trade was also developing.

The summary statistics are shown in Table 2. Based on the mean values, we can see that agriculture exports (LnAGR_EXPORT) and income per capita (LnGDPpc) represent the highest values. In addition, the variables of agricultural exports (LnAGR_EXPORT), income per capita (LnGDPC), and renewable energy (LnRE) have the highest maximum values.

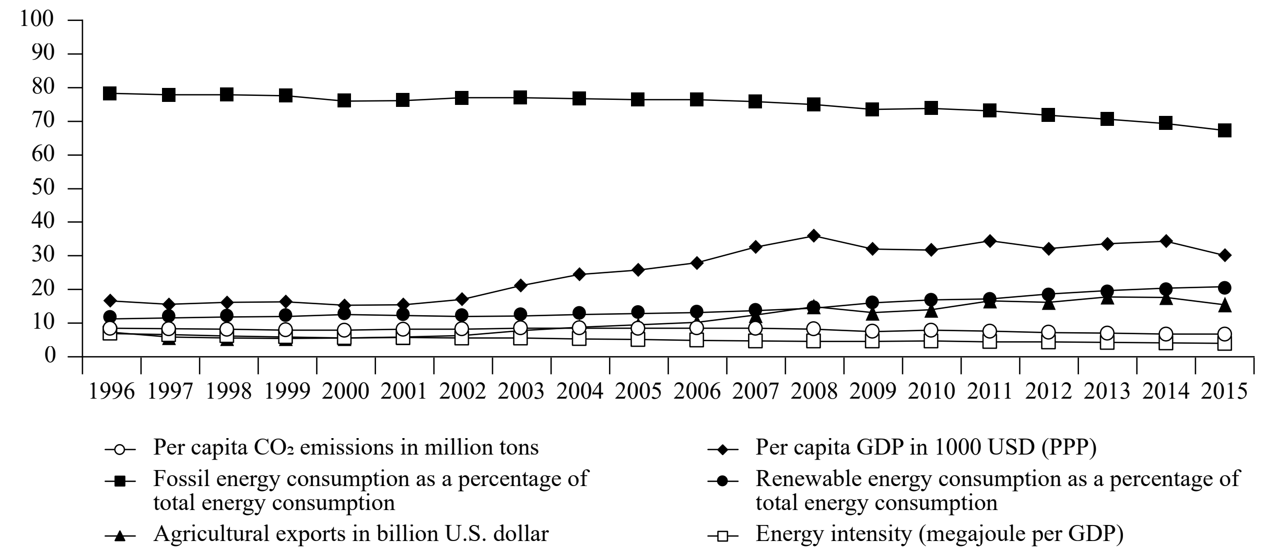

Figure 1: Evolution of indicators selected in the EU-27, mean, 1996-2015.
Source: Own composition based on World Bank (2022) data

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The Pearson correlation coefficients are given in Table 3. Variables of energy intensity (LnEI), income per capita (LnGDPC), and agricultural exports (LAGR_EXPORT) demonstrate a positive statistically significant effect on carbon dioxide emissions per capita (LCO_2pc). Furthermore, renewable energy (LnRE) is negatively correlated with per capita carbon dioxide emissions.

Table 4 presents the results obtained by the panel unit root test as well as Levin, Lin and Chu, ADF–Fisher Chi-square, Phillips-Perron, and Im–Pesaran–Shin tests to evaluate the proprieties of the variables used in this investigation. Here, we can observe that carbon dioxide emissions per capita (LnCO_2pc), energy intensity (LnEI), income per capita (LnGDPpc), renewable energy consumption (LnRE), and agricultural exports (LAGR_EXPORT) have been integrated into the first difference.

Table 2: Summary statistics.

Variable	Observation	Mean	Std. Dev.	Min	Max
Ln(CO_2pc)	737	0.869	0.172	0.429	1.438
Ln(EI)	727	0.716	0.161	0.257	1.261
Ln(GDPpc)	793	4.245	0.401	3.042	5.075
Ln(AGR_EXPORT)	609	6.536	0.797	3.952	7.949
Ln(RE)	716	0.929	0.474	-1.059	1.726

Source: Own composition based on World Bank (2022) data

Table 3: Pearson's correlation coefficients.

Variable	Ln(CO_2pc)	Ln(EI)	Ln(GDPpc)	Ln(AGR_EX-PORT)	Ln(RE)
Ln(CO_2pc)	1.000				
L(EI)	0.102*	1.000			
Ln(GDPpc)	0.399*	-0.639*	1.000		
Ln(AGR_EXPORT)	0.176*	-0.259*	0.481*	1.000	
Ln(RE)	-0.432*	0.008	-0.024	-0.043	1.000

* p<0.05.
Source: Own composition based on World Bank (2022) data

Table 4: Panel unit root tests.

Variable	Levin, Lin & Chu t		Im, Pesaran and Shin W-stat		ADF–Fisher Chi-square		PP - Fisher Chi-square	
	Null: Unit root (assumes common unit root process)		Null: Unit root (assumes an individual unit root process)					
	Statistic	p-value	Statistic	p-value	Statistic	p-value	Statistic	p-value
Ln(CO_2pc)	3.876	0.999	4.647	1.000	30.398	0.998	59.344	0.355
Ln(EI)	1.758	0.961	7.453	1.000	8.915	1.000	7.030	1.000
Ln(GDPpc)	-3.182	0.001***	1.861	0.969	26.088	0.999	23.454	1.000
Ln(RE)	0.188	0.574	3.592	0.999	67.053	0.148	74.695	0.048**
Ln(AGR_EXPORT)	-2.843	0.002***	2.138	0.984	26.246	0.999	51.449	0.573
D(Ln(CO_2pc))	-6.992	0.000***	-10.609	0.000***	227.691	0.000***	528.232	0.000***
D(Ln(EI))	-10.852	0.000***	-12.878	0.000***	267.838	0.000***	523.711	0.000***
D(Ln(GDPpc))	-13.88	0.000***	-13.179	0.000***	275.494	0.000***	324.392	0.000***
D(Ln(RE))	-9.827	0.000***	-10.144	0.000***	212.019	0.000***	386.886	0.000***
D(Ln(AGR_EXPORT))	-10.50	0.000***	-9.483	0.000***	192.724	0.000***	292.380	0.000***

*** p<0.01, ** p<0.05, * p<0.1
Source: Own composition based on World Bank (2022) data

Pedroni residual cointegration tests are reported in Table 5. Consistent with the results, we can conclude that the variables in this investigation are cointegrated in the long run.

The results of panel fully modified least squares (FMOLS) are shown in Table 6. The variable of energy intensity consumption (LnEI) is statistically significant at a 1% level and is positively correlated with carbon dioxide emissions per capita (β_1>0). Therefore, the growth in energy consumption stimulates emission of 0.318%. According to previous studies (see, e.g., Rasoulinezhad *et al*., 2018; Balsalobre-Lorente *et al*., 2019 and de Souza *et al*., 2018), this result shows that primary energy consumption stimulates the increase of carbon dioxide emissions, which validates the hypothesis formulated.

Income per capita (LnGDPpc) has a positive effect on carbon dioxide emissions and the variable is statistically significant (β_2>0). According to empirical studies by Balsalobre-Lorente *et al.* (2021), Leitão *et al.* (2021) and Burakov (2019), economic growth and their activities encourage climate changes and global warming. The empirical literature is inconclusive in relation to the coefficient of agricultural exports (LnAGR_EXPORT). Some studies found a positive impact on agricultural export (e.g. Himics *et al.,* 2018; Chen *et al.,* 2021 and Ansari *et al.,* 2020); however, the result with FMOLS showed that expanding agricultural trade decreases carbon dioxide emissions in the EU. Subsequently, renewable energy (LnRE) has a negative effect (β_4<0) on carbon dioxide emissions and is statistically significant at a level of 1%. Estimates indicate that renewable energy consumption aims to reduce greenhouse gas emissions. The works of Leitão (2021), Balsobre Lorente *et al.* (2021) and Koengkan and Fuinhas (2020) also found a negative impact between renewable energy and carbon dioxide emissions.

Table 7 illustrates the results with the method of Quantile Regression. Considering the energy intensity (LnEI), the variable is statistically significant at 1% level for three quantiles (25%, 50% and 75%). Recent studies by Pata (2021) and Eyuboglu and Uzar (2020) found the same trend. As previous studies shown (Haldar and Sethi, 2021; Ponce and Khan, 2021), a positive relationship is revealed between economic growth (LnGDPpc) and carbon dioxide emissions, demonstrating that economic growth stimulates pollution emissions. Furthermore, the coefficient of renewable energy

Table 5: Pedroni Residual Cointegration Test.

Alternative hypothesis: common AR coefficient (within-dimension)							
Panel v-Statistic		**Panel rho-Statistic**		**Panel PP-Statistic**		**Panel ADF-Statistic**	
Statistic	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**
3.456	0.000***	-0.545	0.293	-3.760	0.000***	-1.981	0.024**
-0.644	0.740	-1.044	0.148	-7.346	0.000***	-4.227	0.000***
Alternative hypothesis: individual AR coefficient (between-dimension)							
Group Rho-Statistic		**Group PP-Statistic**		**Group ADF-Statistic**			
Statistic	p-value	Statistic	p-value	Statistic	p-value		
1.5304	0.937	-7.005	0.000***	-3.780	0.000***		

*** p<0.01, ** p<0.05, * p<0.1.
Source: Own composition based on World Bank (2022) data

Table 6: Panel Fully Modified Least Squares (FMOLS).

Variables	Coefficients
Ln(EI)	0.318 ***
	(0.000)
Ln(GDPpc)	0.227***
	(0.000)
Ln(AGR_EXPORT)	-0.063**
	(0.015)
Ln(RE)	-0.138***
	(0.000)
S.E. of regression	0.003
Long-run variance	0.003
Mean dependent variable	0.871
S.D dependent variable	0.165
Sum squared residual	0.549
Observations	491

P-values in parentheses
*** p<0.01, ** p<0.05, * p<0.1.
Source: Own composition based on World Bank (2022) data

Table 7: Quantile regressions.

	25%	50%	75%
Variables	**tau 0.25**	**median**	**tau 0.75**
Ln(EI)	0.572***	0.698***	0.844***
	(0.000)	(0.000)	(0.000)
Ln(GDPpc)	0.320***	0.351***	0.423***
	(0.000)	(0.000)	(0.000)
Ln(AGR_EXPORT)	0.009	0.008	-0.055***
	(0.556)	(0.314)	(0.000)
Ln(RE)	-0.147***	-0.123***	-0.189***
	(0.000)	(0.000)	(0.000)
Constant	-0.891***	-1.045***	-0.893***
	(0.000)	(0.000)	(0.000)
Observation	520	520	520
Pseudo R-squared	0.313	0.315	0.322

P-values in parentheses
*** p<0.01, ** p<0.05, * p<0.1.
Source: Own composition based on World Bank (2022) data.

(LnRE) negatively correlated with carbon dioxide emissions was statistically significant at a level of 1%. You and Kakinaka (2021) and Rehman *et al.* (2021) as well as Ponce and Khan (2021) also had a similar result.

Discussion and Conclusions

The European Union has committed to becoming carbon neutral by 2050. To achieve this target, a significant reduction in greenhouse gas emissions is needed. This article analysed the relationship between economic growth, energy intensity, agricultural exports, and CO_2 emission in the EU-27. The research used panel data, and panel cointegration models such as Fully Modified Least Squares (FMOLS) and Quantile Regression as a methodology applied for a period of 1990 and 2018. The panel unit root tests showed that the variables used in the investigation are integrated into the first difference. Besides, the Pedroni test revealed that there was a long-term cointegrated relationship between variables. The FMOLS estimate suggests that growth in energy consumption stimulates carbon emission by 0.318% in the EU. Income per capita had a positive effect on carbon dioxide emissions indicating that economic development produces higher emission levels in line with previous analyses (Balsalobre-Lorente *et al.,* 2021; Leitão*,* 2021 and Burakov, 2019). The result of the FMOLS regression demonstrated that expanding agricultural trade decreases carbon dioxide emissions in the EU, suggesting that intra EU trade induces less emission. The estimates indicated that renewable energy consumption helps cut GHG emissions, aids the transition to a green economy and decreases environmental pollution (Leitão, 2021; Balsobre-Lorente *et al.,* 2021; Koengkan and Fuinhas, 2020).

The result of Quantile Regression revealed that energy intensity (LnEI) is statistically significant at a 1% level for three quantiles (25 %, 50 % and 75%), following Pata (2021) and Eyuboglu and Uzar (2020), who found the similar tendency. A positive relationship between economic growth and carbon dioxide emissions is explored in the EU, indicating that economic growth stimulates greenhouse gas emissions (Haldar and Sethi, 2021; Ponce and Khan, 2021). Furthermore, renewable energy aims to decrease climate change, as You and Kakinaka (2021) and Rehman *et al.* (2021) as well as Ponce and Khan (2021) pointed out. Quantile Regression estimation discovered that increasing energy intensity (LnEI) stimulates emission (coefficient was statistically significant at a 1% level for three quantiles) in line with Pata (2021) and Eyuboglu and Uzar (2020). A positive relationship between economic growth and carbon dioxide emissions is explored, indicating that economic growth stimulates greenhouse gas emissions (Haldar and Sethi, 2021; Ponce and Khan, 2021). Furthermore, renewable energy consumption aims to reduce climate change (air pollution) as You and Kakinaka (2021), Rehman *et al.* (2021) and Ponce and Khan (2021) proved. The estimates revealed that the export of agricultural products decreases carbon dioxide emissions within the EU, referring to the fact that the intra EU agricultural trade is more environmentally friendly. Finally, higher renewable energy consumption was confirmed as contributing to United Nations climate mitigation goals by reducing emissions.

The findings presented in this investigation allow us to draw conclusions associated with agricultural and trade policy, as well as a more sustainable Common Agricultural Policy. The analysis concludes that economic development and rising energy intensity are strongly associated with carbon dioxide emissions; thus, the green transition, and increasing the share of renewable energies in the energy mix are needed. However, the climate law and Common Agricultural Policy of the EU mainly puts emphasis on reducing the impacts of climate change; member states' climate policies should therefore focus on reducing growth-related emissions, slowing the increase in energy intensity, and decreasing the footprint of agricultural production and trade. In this context, reducing the use of fossil energy production (coal and gas), dependency and its consumption is crucial. Moreover, diminishing long distance agri-food trade could be the way forward for EU member countries, as has been the role of the Common Agricultural Policy. Moderating long-haul agricultural export and supporting the consumption of low-carbon food products can be another solution in the EU climate policy. The findings suggest that the effect of renewable energy adoption on carbon emissions reduction in and of itself is limited and not enough to achieve carbon neutrality; investments in green technology, R&D and greater improvements in energy efficiency are also needed across economic sectors, industry, agriculture and services. Moreover, consumption choices can also significantly influence the European Union's emissions; their promotion can be supported by sustainable food certificates and ecological products.

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