“Economic and environmental drivers of renewable energy transition in the EU”

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ECONOMIC AND ENVIRONMENTAL DRIVERS OF RENEWABLE ENERGY TRANSITION IN THE EU

Abstract

The current green agenda, the climate change, and sustainability frameworks are closely linked to the successful transition to renewable energy. The study purpose is to estimate the influence of economic and environmental drivers of renewable energy promotion in the EU-27, using the 2013–2021 data for member states. Breusch and Pagan Lagrangian multiplier test and Hausman specification test were performed to determine the proper model specification. Using random-effects GLS regression for selected data, the study found that the rise in the magnitude of the Land-Ocean Temperature Index by one unit contributes to an increase in renewable energy sources by 10-16 percentage points. The rise in natural gas prices in the EU by USD 10 per MMBtu is associated with an average growth of renewable energy sources by 2.1-2.6 percentage points and three percentage points for growth in renewable electricity. An increase in GDP per capita of USD 1,000 led to an average increase in renewable electricity by 0.2 percentage points. An increase in CO2 per capita by one ton is associated with an average decrease in renewable electricity by 0.85 percentage points. This study proves that the critical point of GDP per capita within the "economic growth/renewable energy" nexus when economic stimulus starts to decline was estimated at USD 121,227-148,623. Thus, for countries that have reached the break-even point in GDP per capita, the incentives for introducing renewable energy sources are reduced when the effect of wealth prevails over the impact of environmental awareness and responsibility.

Keywords renewable energy, drivers, factors, green transition, greenhouse gases, energy consumption, households, EU

JEL Classification Q01, O00, Q42

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INTRODUCTION

In an era of urgent environmental challenges (e.g., climate change, biodiversity loss, and resource depletion), renewable energy stands as a key pillar for achieving sustainability goals. The 2015 Paris Agreement encourages countries to increase their renewable energy capacities as part of their nationally determined contributions to reduce greenhouse gas emissions and promote sustainability. By using renewable sources like sunlight, wind, and water, countries can significantly contribute to decarbonizing the economy, reducing pollution, and mitigating the adverse impacts of fossil fuel dependence.

Renewable transition can be implemented successfully only when one completely understands its key drivers and barriers. Knowing the drivers allows policymakers to design targeted policies that directly address the factors encouraging renewable energy adoption. The synergy of economic, social, geographical, structural, and other factors contributes to the development of the renewable energy sector. However, the green transition also faces considerable barriers, including financial constraints, regulatory complexities, infrastructural limitations, and vested interests in traditional energy sectors.

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In the EU, achieving renewable energy targets necessitates a careful analysis of these influences across diverse member states, each with unique geographic and economic conditions. This complexity underlines the importance of identifying specific regional drivers and obstacles to inform strategies that are both locally adapted and aligned with EU-wide sustainability goals. It is consistent with the European Green Deal as a long-term strategy to transform the EU to be climate-neutral by 2050.

1. LITERATURE REVIEW AND HYPOTHESES

A literature review provides a comprehensive synthesis of existing research, analyzing the current state of knowledge on a particular subject while identifying gaps and areas for future investigation. Some studies investigated key drivers of renewable energy consumption. Table 1 describes critical factors affecting renewable transition across various countries/regions/organizations in different time frames. The results demonstrate that a wide range of factors (economic, social, political, or technological) potentially affect renewable energy consumption, and there needs to be more consensus among scientists regarding their influence. This variability in findings underlines the complexity of green transformations and highlights the need for further research.

Based on an overview of key publications and further comprehensive, it is possible to figure out specific research hypotheses to check.

Higher natural gas and oil prices make renewable energy sources more economically competitive. As fossil fuel prices rise, the cost gap between traditional and renewable energy narrows, encouraging investment in renewables. In addition, high natural gas and oil prices can drive the push for energy security and lead to the promotion of domestic renewable energy sources. This reduces the dependency on imported fossil fuels and enhances national energy independence.

Some research papers analyze the relationship between renewable energy generation and fossil fuel prices. For example, Li and Leung (2021) provided evidence that an increase in energy prices promotes renewable energy consumption in the EU both in the short and long run. Ben-Salha et al. (2022), using a novel ARDL approach, claimed that rising oil, coal, and natural gas prices provided more renewable energy consumption in the long run, confirming that renewable energy sources can replace traditional sources in the long term. Researchers found little evidence of statistically significant effects in the short run. Li and Lee (2022) also found a positive relationship, indicating an increase in coal price triggers a more significant influence on renewable capacity than

Table 1. Overview of key publications on the topic

Source	Countries (organizations)	Method(s)	Results
Polcyn et al. (2022)	Selected EU countries	Fixed-effects regression	RE ↑, when CO2 ↑, GDP ↑, labor force ↓, gross fixed capital formation ↓
Lin et al. (2016)	China	Johansen cointegration technique and VEC model	RE ↑, when GDP ↑, FDI ↓, trade openness ↓ (in the long run)
Kumaran et al. (2020)	Selected ASEAN countries	FMOLS and DOLS	RE↑, when GDP ↓, trade openness ↓, urbanization ↑, governmental quality ↑
Oluoch et al. (2021)	Sub Saharan African countries	ARDL model	RE ↑, when education quality ↑, GDP ↑, CO2 ↓, life expectancy ↓ (in the long run)
Sachan et al. (2023)	BRICS	Panel quantile regression	RE ↑, when environmental quality ↑, Human Development Index ↑, CO2 ↓
Chishti and Dogan (2024)	Top 10 renewable energy-consuming countries	Panel cointegration methods and ARDL model	RE ↑, when ICT ↑, globalization ↑, Human Development Index ↑, GDP ↑
Tee et al. (2021)	59 selected countries	GMM technique	RE ↑, when intellectual property rights ↑
Uzar (2023)	High-income OECD countries	Fixed-effect regression	RE ↑, when press freedom ↑, GDP↑, CO2 ↑, trade openness – no statistically significant effect
Mukhtarov et al. (2023)	Poland	Canonical Cointegrating Regression approach	RE ↑, when income ↑, corruption ↑, CO2 ↑, institutional quality ↑, trade openness – no statistically significant effect

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natural gas. Sahu et al. (2022) analyze nonlinear autoregressive distributed lag (NARDL) models to study the impact of positive and negative oil price shocks on renewable energy consumption in the United States. They proved that a rise in Brent crude prices contributes to an increase in renewables consumption in the short and long run. In general, it is expected that higher prices for fossil fuels have a direct positive influence on the promotion of renewable energy sources, increasing their economic efficiency.

Higher GDP per capita generally correlates with more significant financial capacity for investment in renewable energy infrastructure. Wealthier nations can afford to allocate significant funds toward research, development, and deployment of renewable energy technologies, driving innovation and expansion in the sector. For example, Al-Mulali et al. (2013) proved that in most investigated countries, there is a positive bi-directional long-run relationship between renewable energy consumption and GDP growth (confirming the feedback hypothesis). Amri (2017) analyzed a GDP growth consumption link in Algeria in the years 1980–2012 and discussed the unidirectional nexus between renewables development and GDP growth, capital, and non-renewable energy in the long-term period perspective. At the same time, a high GDP per capita does not guarantee that a country will prioritize renewable energy over other economic interests, such as maintaining existing fossil fuel industries or other infrastructure projects. For example, the US has a well-established fossil fuel industry, particularly oil and natural gas. States like Texas and North Dakota heavily depend on oil extraction and production for their local economies (Pacca et al., 2021). The influence of powerful lobbying groups representing oil, coal, and gas industries often results in policies favoring these traditional energy sources over renewables that inhibit the latter's development (Lantushenko & Schellhorn, 2023). Countries with higher GDP per capita have more financial resources available to invest in renewable energy infrastructure that can lead to the development of advanced technologies and large-scale renewable energy projects.

Higher CO2 per capita often indicates a heavy reliance on both economically and infrastructurally fossil fuels. This can create vital vested interests that resist the shift to renewable energy to protect existing investments and jobs in the fossil fuel industry (Tudor & Sova, 2021). Another critical point is that high CO2 per capita can signify habitual and established energy consumption patterns (Melnyk et al., 2020). Households and businesses accustomed to using fossil fuels may need more desire to change to renewable sources due to the convenience, familiarity, and perceived reliability of traditional energy.

The literature reveals several negative impacts of CO2 emissions on renewable energy consumption, including economic, policy, technological, market, and social barriers. Some research discusses how extensive subsidies for fossil fuels can undermine investments in renewable energy. Governments often subsidize fossil fuel industries to maintain economic stability and jobs, which can reduce the competitiveness of renewables (Tu et al., 2021). As seen from the previous point, countries with high CO2 emissions are likely to depend on fossil fuels with low progress in green transition. The authors analyze the influence of fossil fuel lobbying on policy decisions. The powerful fossil fuel lobby can delay or weaken regulations promoting renewable energy, maintaining the status quo of high CO2 emissions. These factors create a complex environment where high CO2 emissions can impede the adoption of renewable energy. The CO2 is directly related to environmental temperatures. A higher Land-Ocean Temperature Index often correlates with increased solar radiation, providing more sunlight for solar panels and increasing their efficiency and energy output. Another indirect impact is that rising temperatures and the associated climate impacts increase the urgency for renewable energy solutions to mitigate climate change. This can lead to more significant investment, innovation, and deployment of green energy technologies. For example, temperature changes in Poland's renewable energy sector affect both supply and demand by influencing heating and cooling needs, electricity load, and the operational conditions of renewable energy sources. The findings emphasized the role of the demand side on renewable consumption. An increase in air temperature diminishes the country's heating demand, which is beneficial for the environment and renewable development. Increasing cooling needs in hot seasons increases energy usage and indoor thermal stress (Canales et al., 2020).

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Understanding the pivotal drivers influencing renewable energy adoption across member states is essential in light of the EU's ambitious renewable energy targets.

The purpose of this study is to estimate the influence of economic and environmental drivers of renewable energy promotion in the EU-27, using the data for separate member states.

Following the key literature on the topic and the purpose of the study, such hypotheses can be specified:

H1: *The higher the natural gas and oil prices, the more economic stimulus is created for renewable energy generation.*

H2: *The higher the GDP per capita, the more economic stimulus is available for renewable energy generation. However, after some break-even points in GDP per capita, the economic incentives start to decline.*

H3: *The higher the CO2 per capita, the fewer opportunities and desires are formed for renewable energy generation and consumption by households due to the trace effect of fossil fuel usage.*

2. METHOD

The research purpose is to investigate the main drivers of renewable energy consumption that vary over time using the panel data regression method. The choice of the panel data approach is explained by its superiority over time-series and cross-section data in applying all obtainable observations for successive periods. According to Berrington et al. (2006), the primary advantage of panel data is that they reduce bias in outcomes. This study uses the panel data analysis with fixed effects (least squares dummy variable) and random effect (error components model) approaches to obtain accurate estimates of α_0 (unknown intercept) and $\beta_{1...n}$ (regressors coefficients). The robust-standard errors fixed (random)-effects estimator is applied to the model to guarantee robust results. A comprehensive panel data analysis includes unit root tests, correlation analysis, Breush and Pagan Lagrangian multiplier test, Hausman specification test, estimation (fixed or random effects), and post-estimation robustness check.

Based on the literature review and hypotheses, the following theoretical model is presented:

$$REN_{ti} = F\begin{pmatrix} LOTI_{ti,} COAP_{ti}, \ NGAP_{ti,} IDS_{ti,} \\ GDPpc_{ti,} GDPpc_{ti,} CO2\,pc_{ti,} \\ PRR_{ti,} GNIpc_{ti,} ECHpc_{ti} \end{pmatrix} \quad (1)$$

where REN_{ti} is renewable energy sources in country i at year t (%); $LOTI_{ti}$ is Land ocean temperature index; $COAP_{ti}$ = Crude oil, average(USD/bbl); $NGAP_{ti}$ = Natural gas, Europe (USD/MMBtu); IDS_{ti} = individuals with digital skills; $GDPpc_{ti}$ = GDP per capita current USD; $CO2pc_{ti}$ = CO2 emissions metric tons per capita; PRR_{ti} = personal remittances received, current international dollars, IIC_{ti} = industry including construction value-added, percent; $GNIpc_{ti}$ = GNI per capita ppp current international dollars; $ECHpc_{ti}$ = energy consumption in households.

A similar model and logic are applied for the dependent variable REEN (Renewable energy sources in electricity, percent).

To assess the drivers of development, statistical data were collected for 27 EU member states using economic, geographical, environmental, and structural indicators for 2013–2021 (latest available data). The data were taken from many trustworthy and reliable sources: World Bank, Eurostat, US EIA, and Goddard Institute for Space Studies (Kubatko et al., 2024).

The economic bloc consists of such indicators: crude oil price average (USD/bbl); natural gas prices in Europe (USD/MMBtu); GDP per capita (current USD); GNI per capita in current international dollars; personal remittances received (current USD).

The geographical bloc covers the data on the Land-Ocean Temperature Index. Within this research, the Goddard Institute for Space Studies data on climate change were used, referred to as the Land-Ocean Temperature Index (LOTI), which aggregates temperature measurements from weather stations both on land and at sea in an effort to estimate the average surface temperature of the earth. Higher levels of the Land-Ocean Temperature Index are expected to correlate with greater achievements in renewable energy generation/consumption.

The environmental bloc covers the data on CO2 emissions in metric tons per capita, energy consumption in households, renewable energy sources in the country.

A set of structural variables, such as individuals' digital skills (percentage of population), industry (including construction), and value-added (percentage of GDP), are also expected to influence renewable energy generation.

During the analysis, different software tools were applied, namely, Microsoft Excel for data collection and pre-processing and STATA 18.0 for data estimation and visualization.

3. RESULTS

The first step is to analyze the data for stationarity using a unit root test. Table 2 shows the empirical results of the Im-Pesaran-Shin (IPS) test. They indicate that the null hypothesis of having unit roots was rejected for all investigated variables, and as a result, the data are stationary.

Table 2. Im-Pesaran-Shin (IPS) test results

Variables	Adj. t- statistic	p-value	Decision
REN	11.1732	0.0000	Stationary
REEN	6.4198	0.0000	Stationary
LOTI	6.2240	0.0000	Stationary
COAP	9.2332	0.0000	Stationary
NGAP	8.9810	0.0000	Stationary
IDS	5.6459	0.0000	Stationary
GDPpc	10.1127	0.0000	Stationary
CO2pc	9.8321	0.0000	Stationary
IIC	9.0155	0.0000	Stationary
GNIpc	5.1774	0.0000	Stationary
ECHpc	13.4127	0.0000	Stationary

This panel data model analysis employs a correlation matrix to examine potential multicollinearity issues by identifying pairs of highly correlated independent variables. By analyzing the correlation coefficients between the variables, it is possible to detect if any strong linear relationships exist that might distort the regression estimates. According to the results, this econometric model has no multicollinearity issues.

Breusch and Pagan Lagrangian multiplier test was performed to select between the random-effects regression and ordinary least squares regression, and the output of the test was in favor of random-effects GLS regression. A Hausman specification test was also performed to select between the random and fixed effect models for panel data. The results of the Hausman specification test were in favor of random-effects regression.

Consequently, Table 3 presents the results for determining the key drivers of renewable energy sources promotion in the EU.

Therefore, with the growth of the land-ocean temperature index per unit, there is an average increase in renewable energy sources by 10-16 percentage points, and the estimated growth for renewable energy sources in electricity is 22 percentage points. These mean that more favorable climate conditions in the EU are an essential driver for promoting renewable energy in the EU. There is an ambitious plan for the EU to reach the aim of 42.5% renewables (compared with 22% in 2021) by 2030; the last would mean an accelerated CO2 reduction of the EU electricity supply (Simionescu et al., 2019).

Crude oil, average (USD/bbl), individuals with digital skills, and household energy consumption turned out to be statistically insignificant indicators regarding forecasting renewable energy generation trends in general and renewable electric energy in particular. The rise in the natural gas prices in the EU (USD/MMBtu) by USD 10 is associated with an average growth of renewable energy sources (percentage) by 2.1-2.6 percentage points and three percentage points for growth of renewable energy sources in electricity. This result demonstrates that a gas price increase stimulates renewable transition.

Considering the GDP per capita (current USD) as a driver of renewable energy sources, the study found positive relations. Thus, an increase of 1,000

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Table 3. Social, economic, and geographical drivers of renewable energy sources promotion in the EU during 2013–2021

Variables	Model 1 (REN) Renewable energy sources, percentage	Model 2 (REN) Renewable energy sources, percentage	Model 3 (REEN) Renewable energy sources in electricity, percent
LOTI (land-ocean temperature index)	16.12***	10.15**	22.57***
	(3.690)	(4.217)	(5.628)
COAP (Crude oil, average(USD/bbl)	0.00930	0.00355	0.00263
	(0.0170)	(0.0175)	(0.0260)
NGAP (Natural gas, Europe (USD/MMBtu)	0.270***	0.213***	0.309***
	(0.0489)	(0.0553)	(0.0746)
IDS (individuals with digital skills)	0.0938	–0.0203	0.153
	(0.200)	(0.179)	(0.305)
GDPpc (GDP per capita current USD)	9.78e–05***	–	0.000233***
	(3.27e–05)	–	(4.99e–05)
CO2pc (CO2 emissions metric tons per capita)	–0.859***	–	–1.674***
	(0.152)	–	(0.232)
IIC (industry including construction value-added, percent)	0.119	0.0318	0.264*
	(0.0921)	(0.0901)	(0.140)
PRR (personal remittances received in current international dollars)	5.61e–11	–9.52e–11	4.83e–10**
	(1.42e–10)	(1.48e–10)	(2.16e–10)
GNIpc (GNI per capita in current international dollars)	–	0.000208***	–
	–	(3.41e–05)	–
ECHpc (energy consumption in households per capita)	–	0.000814	–
	–	(0.00347)	–
Constant	–1.859	2.497	–6.548
	(12.72)	(11.79)	(19.38)
Observations	243	243	243
Number of ids	27	27	27

Note: P values in parenthesis * – 90% significance level; ** – 95% significance level; *** – 99% significance level.

dollars per capita increases the renewable energy sources in electricity by 0.2 percentage points. The obtained results are statistically significant, but the effect of economic influence on the development of renewable energy sources is not significant in terms of magnitude.

There is another issue considering the CO2 emissions in metric tons per capita, which reflects the population's attitude toward fossil fuel energy usage. The results suggest that an increase in CO2 per capita by one ton is associated with an average decrease in renewable energy sources in electricity by 0.85 percentage points. Personal remittances received (current USD), industry (including construction), and value-added (% of GDP) are statistically insignificant factors for the total generation of renewable energy; however, these indicators are important and statistically significant for the generation of renewable electricity. Renewable electricity generation often involves infrastructure-intensive projects and technological investments directly tied to industrial activity and economic productivity. Industries such as construction and manufacturing contribute significantly to deploying renewable energy technologies (e.g., solar panels, wind turbines, hydropower facilities). Meanwhile, personal remittances can influence electricity access and consumption patterns, boosting the demand for renewable electricity solutions in residential and commercial sectors. In addition, GNI per capita and PPP (current international USD) have the same statistically significant effect on renewable energy in strength and direction as GDP per capita.

3.1. Robustness check

To check the robustness of the econometric model, robust standard errors for the random estimator (as provided by STATA 18.0 software) were applied. The application of robust standard

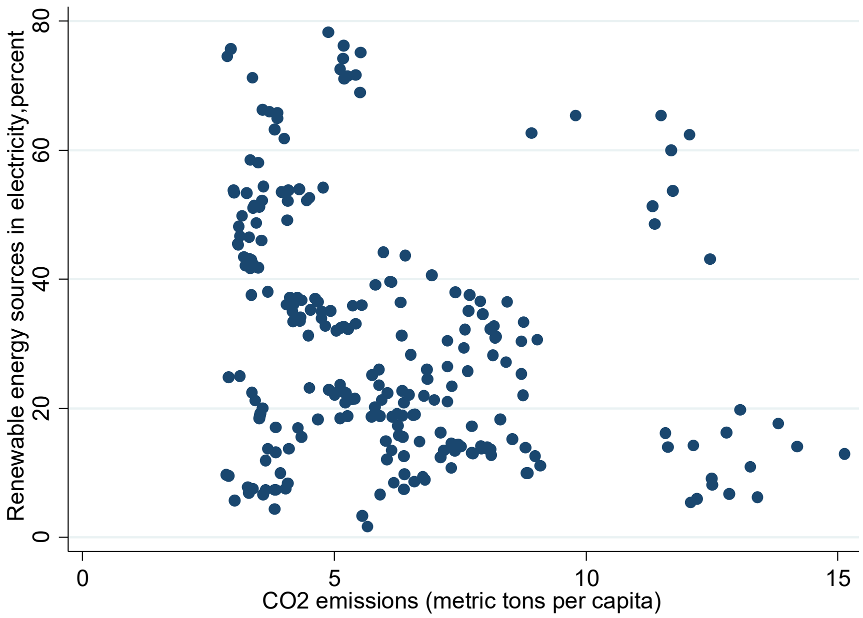

Figure 1. Fossil fuel usage in EU and renewable energy sources

errors addresses potential heteroskedasticity within data, ensuring that estimates remain reliable even if the variance of the error terms is not constant. In addition to robustness checks, the sensitivity of results to different model specifications was examined. This involved re-estimating the primary model by including or removing different independent variables. The consistency of the findings across these various specifications strengthens the confidence in the model's robustness.

Figure 1 shows real statistical data on CO2 emissions per capita in EU countries and the corresponding indicators of renewable energy development. In countries with lower CO2 indicators, the indicators of renewable energy are higher, but in fact, there is also a feedback loop when higher indicators of the introduction of renewable energy sources create conditions for reducing the indicators of CO2 per capita. The opposite situation could also occur when higher levels of fossil fuel consumption negatively affect renewable energy promotion due to the existing (sticky) energy generation system. Therefore, the higher the emission of CO2 per capita, the stronger the trace effect of fossil fuel energy usage.

The situation is different for the wealthiest EU countries, which, along with the higher GDP per capita levels, have the lowest rates of renewable energy implementation. Thus, the paper talks about the trace effect of fossil fuel usage when the most affluent population does not care about introducing more complex renewable technologies. In particular, the more affluent population in the EU does not set the development of renewable energy sources as a critical goal; as seen from Figure 2, economic incentives work only up to some critical limit in EU households.

To test the third hypothesis, it is necessary to build a separate economic concept of "economic growth – renewable energy"

$$REN_{it} = \beta_1 GDPpc_{it} + \beta_2 GDPpc^2_{it} + X_{it}\beta_i + \varepsilon_{it}, \quad (2)$$

where REN_{ti} – Renewable energy sources in country i at year t (%); REEN is Renewable energy sources in electricity, percent; $GDPpc_{ti}$ is GDP per capita current USD; X_{it} – vector of other variables; ε_{it} – model error. β_i – coefficients (parameters) reflecting the contribution of individual influencing factors on the dependent variable.

The results of the practical modeling regarding the assessment of the effect of wealth on the development of renewable energy in the EU are shown in Table 4. The same factors as in the primary model were used for the study, but indicators of the qua-

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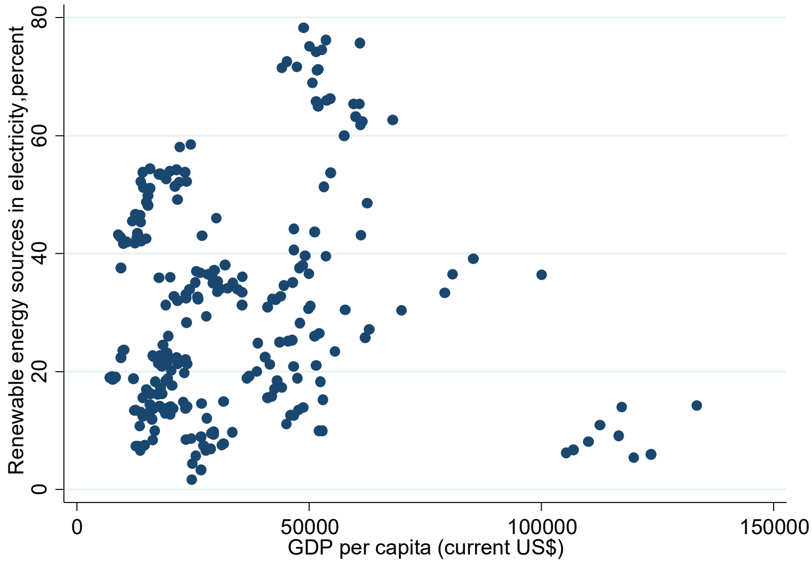

Figure 2. GDP per capita in the EU and renewable energy sources

dratic value of GDP per capita were added to assess the presence of an inverted U-shaped form of relations between GDP per capita and indicators of renewable energy ("economic growth – renewable energy").

Table 4 proves the negative and statistically significant influence of GDP per capita squared indicators, which proves the nonlinear relations between economic growth and renewable energy sources in electricity.

Table 4. Assessment of the wealth effect in the EU on stimulating the development of renewable energy, 2013–2021

Variables	Model 1 (REN) Renewable energy sources, percentage	Model 2 (REEN) Renewable energy sources in electricity, percent	Model 3 (REEN) Renewable energy sources in electricity, percent
LOTI (land-ocean temperature index)	14.34***	20.00***	–
	(3.754)	(5.750)	–
COAP (Crude oil, average(USD/bbl)	0.00226	–0.00754	–
	(0.0172)	(0.0264)	–
NGAP (Natural gas, Europe (USD/MMBtu)	0.246***	0.275***	–
	(0.0498)	(0.0763)	–
IDS (individuals with digital skills)	0.0214	0.0458	–
	(0.203)	(0.299)	–
GDPpc (GDP per capita current USD)	0.000241***	0.000446***	0.000648***
	(7.55e–05)	(0.000115)	(0.000135)
GDPpc (GDP per capita current USD squared)	–9.88e–10**	–1.48e–09**	–2.19e–09**
	(4.70e–10)	(7.20e–10)	(9.34e–10)
CO2pc (CO2 emissions metric tons per capita)	–0.857***	–1.676***	–
	(0.151)	(0.231)	–
IIC (industry including construction value-added, percent)	0.128	0.280**	–
	(0.0915)	(0.140)	–
PRR (personal remittances received in current international dollars)	0	4.06e–10*	–
	(1.43e–10)	(2.17e–10)	–
Constant	1.185	–2.123	11.96**
	(12.80)	(18.97)	(4.772)
Observations	243	243	243
Number of id	27	27	27

Note: P values in parenthesis * – 90% significance level; ** – 95% significance level; *** – 99% significance level.

The quadratic relations "economic growth – renewable energy" to estimate the break-even points for renewable energy sources in electricity would have the following form:

$$Renewable\ energy\ sources\ in\ electricity = 0.000446 \cdot GDPpc - 2.19e - 09 \cdot gGDPpc^2. \quad (3)$$

To find the critical points for model 3, it is necessary to take the first derivative and equate the expression to zero. As a result, 0.000648 – 4.38 e-09 $x = 0$.

The critical point of GDP per capita within the "economic growth – renewable energy" model when economic stimulus started to decline was estimated at the level of 148,623 USD per capita. The last is an expected maximum value of renewable energy sources reached; after reaching this economic level, the indicators of renewable energy generation could decrease.

Performing a similar calculation for model 1, the critical point turned out to be 121,227 (current USD). Thus, for countries that have reached a level of GDP per capita of more than 120 thousand dollars, the incentives for the introduction of renewable energy sources are reduced. The latter may indicate that the effect of wealth begins to prevail over the effect of environmental awareness and responsibility. Several factors can explain this trend. Firstly, individual and collective environmental consciousness, although generally higher in wealthier countries, can sometimes be offset by lifestyle choices prioritizing convenience and luxury over sustainability. This might lead to higher energy consumption overall, sometimes diminishing the relative share of renewables in the energy mix.

The scientific novelty is the detailed analysis of the wealth effect on renewable energy consumption and its potential dominance over the effect of environmental awareness and responsibility within the European Union.

4. DISCUSSION

With the growth of the population's income, the share of renewable energy grows, but at a slow pace. This result is consistent with Dabboussi and Abid (2022) and Wang et al. (2023). Most studies point out that countries with strong economic growth and higher GDP per capita levels have an increased capacity for investment in renewable energy infrastructure and technologies, possess more R&D capabilities, and can dedicate more efforts to sustainability issues (the concept of the Environmental Kuznets Curve). This study is also consistent with the finding that GDP per capita increases REC when it is above the 5,000 USD threshold (all EU economies have achieved this level) (Tudor & Sova, 2021). However, some articles have disproved the existence of the Environmental Kuznets Curve (EKC). For instance, Azam and Khan (2016) could not provide any evidence in favor of the validity of the EKC hypothesis for upper-middle-income and high-income economies. Similar results were obtained by Özokcu and Özdemir (2017), who emphasized a weak role of GDP per capita growth in the context of promoting green transformations and renewable transition.

Wealthier nations have already significantly reduced pollution and improved environmental quality through earlier investments in renewable and non-renewable energy infrastructures. As a result, the marginal benefits of further renewable energy investments might appear less compelling than their costs. It is understandable that while wealthier countries have the resources to invest in renewable energy, the complexity of economic, political, and social factors can sometimes slow down the pace of adoption (Taghizadeh-Hesary & Yoshino, 2020; Azhgaliyeva et al., 2023). This highlights the need for sustained policy interventions, public awareness campaigns, and international cooperation to ensure that the transition to renewable energy continues to progress globally, even as countries become wealthier.

Regarding the influence of fossil fuels on renewable energy, it is possible to talk about the existence of the trace effect of fossil fuel usage, and it is difficult for the relevant economic systems to adapt to renewable energy. In addition, the obtained results may indicate the existence of an oil and gas lobby, which interferes with the proper implementation of renewable energy sources. This opinion is in line with Sarwar et al. (2017). Following the results, there is a concept of a resource curse that can create significant obstacles for such econo-

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mies to become less oil-reliant and promote green transition. Tang et al. (2022) confirmed the resource curse hypothesis and suggested that one can overcome it using preferable business (e.g., fiscal) regulation for renewable projects. Some studies showed an increase in CO2 emissions may lead to a rise in the share of renewable energy since heightened awareness of the adverse impacts of significant amounts of carbon emissions often results in stricter environmental regulations and policies aimed at reducing greenhouse gases (Saidi & Omri, 2020; Doğan et al., 2021). As CO2 emissions rise, governments and international organizations are more likely to implement measures such as carbon pricing, subsidies for renewable energy projects, and mandates for cleaner energy production. These regulatory actions create financial incentives and a favorable market environment for the adoption of renewables. According to Lin (2015) and Khatibi et al. (2021), public concern over climate change can drive consumer demand for cleaner energy alternatives, pressuring companies and utilities to transition toward renewable sources.

Crude oil turned out to be a statistically insignificant indicator for forecasting renewable energy generation. The last is in contradiction with Brini et al. (2017), who underline that increasing oil prices can positively influence the renewable energy transition by making alternative energy sources more economically attractive. Following another approach, though increasing crude oil costs may not initially encourage renewable energy usage, once they reach a certain level, subsequent increases in oil prices are expected to boost renewable energy consumption numbers. According to Murshed and Tanha (2021), the anticipated real oil price threshold is circa USD 135 per barrel. In addition, this study revealed that increasing Brent oil prices do not impact the renewable electricity shares. However, the obtained result is consistent with Payne (2012), who proved the causal link between higher oil prices and higher rates of renewable energy adoption due to the specific incentive mechanism. His idea is supported by Omri and Nguyen (2014), who outlined the statistically significant impact of crude oil price fluctuations on driving the renewable transition, especially in high-income economies.

As traditional fossil fuel-based energy becomes more expensive, consumers and businesses pay more attention to cost-effective alternatives like renewables. In this context, it is also important to underline the issues of energy security (Shah et al., 2018). Doğan et al. (2023) provided results that are compatible with current findings: full-fledged sustainable transition is impossible without energy security promotion (including the renewables component). The authors also suggested that countries with low levels of energy imports are more robust, facing price fluctuations and market instabilities. The 2022 energy crisis (when natural gas achieved the critical points of 4,000 EUR per thousand m^3) boosts the desire of the EU countries to reduce natural gas dependence and diversify their energy mix. At the same time, the share of renewable energy increased sharply, and investments in promising renewable projects were provided (e.g., in 2023, the Dogger Bank project in the North Sea, potentially the world's largest offshore wind farm, was initiated). Therefore, the increase in gas prices is a factor stimulating the energy independence of EU countries and the development of their own renewable energy sources.

Higher air temperatures are associated with more sunshine, which makes more generation volume possible (Wachsmuth et al., 2013). However, some studies indicate that a significant increase in the temperatures can reduce the efficiency of PV panels, as heat can cause the semiconductor materials to become less effective at converting sunlight into electricity (Tyagi et al., 2013; Dubey et al., 2013). Wind energy studies indicate that temperature can affect air density, influencing wind turbine performance (Papież et al., 2019). Cooler temperatures typically result in denser air, which can improve the power output of wind turbines.

The promising idea for further research is to investigate the influence of behavioral factors on the renewable energy sector. Public perception, cultural attitudes toward energy consumption, and community engagement in renewable energy projects are critical aspects that can drive or de-stimulate the transition to renewable energy. Within the behavioral economics framework, scholars can apply novel methods of household/business surveys and experiments to reveal how decisions about the renewable energy sector are adopted at the micro- and macro-levels.

CONCLUSION

The purpose of this study was to estimate the influence of economic and environmental drivers of renewable energy promotion in the EU-27, using the data for separate member states. The analysis demonstrates a clear relationship between natural gas prices, economic indicators, and the adoption of renewable energy. As natural gas prices rise, renewable energy sources' relative attractiveness and competitiveness increase, leading to a higher share of renewables in both overall energy consumption and electricity generation. Furthermore, economic prosperity, as measured by GDP per capita, generally supports the growth of renewable energy. However, this effect is not constant and eventually declines beyond a certain income threshold (USD 121,227-148,623). This finding indicates that the effect of wealth begins to prevail over the effect of environmental awareness and responsibility. The higher CO2 emissions per capita correlate with reduced opportunities and motivation for renewable energy adoption, likely due to the strong reliance of economies on fossil fuels.

The paper concludes that supporting economic growth with targeted renewable energy policies is crucial. Governments and the business sector should encourage renewable energy investment and deployment in regions with growing GDP per capita, particularly before reaching the identified break-even point. Policies could include direct investments in renewable infrastructure and incentives for private sector investment in renewables. Public-private partnerships are a promising idea for the implementation of renewable projects as they combine both sectors' strengths and resources. These collaborations facilitate leveraging private sector efficiency, innovation, and capital while benefiting from public sector support, regulatory frameworks, and long-term planning capabilities (ensuring such projects are economically viable and socially and environmentally beneficial). Implementing policies to reduce CO2 emissions per capita, which may indirectly promote renewable energy adoption, is another crucial step toward green transformation. These measures could include carbon pricing, stricter emissions regulations, and promoting energy efficiency measures. For areas with high Land-Ocean Temperature Index values, governments should prioritize solar deployment (and, in some cases, wind energy projects).

The identified break-even point for GDP per capita (USD 121,227-148,623) and its diminishing effect on renewable energy adoption may not be universally applicable in various contexts. Additionally, numerous factors not fully captured in this investigation may influence the inverse relationship between CO2 emissions per capita and renewable energy adoption.

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