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How does the energy transition shape inclusive green growth in the European Union?

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Abstract

Amidst the growing issue of global warming and non-inclusiveness, inclusive green growth (IGG) has become an aspiration for all countries. Countries worldwide, including those in the European Union (EU), are transitioning from non-renewable to renewable energy to preserve the environment. However, there is currently a lack of comprehensive research investigating the nexus between energy transition and IGG. This paper aims to explore the impact of energy transition on IGG in 25 EU countries from 1995–2021. We develop composite indices for both IGG and renewable energy transition targeted to EU economies and employ advanced econometric approaches to uncover relevant associations. Results reveal that renewable energy transition hampers IGG in the short run but fosters it in the long run in the EU. Additionally, financial development and internet access enhance IGG, whereas government expenditure, inflation, and economic globalization have negative impacts. The findings suggest that EU countries should stimulate investment by public-private partnerships in renewable energy technologies and promote the use of renewable energy to make their economic growth green and inclusive.

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JEL codes: C23, N34, O44, Q30

1 Introduction

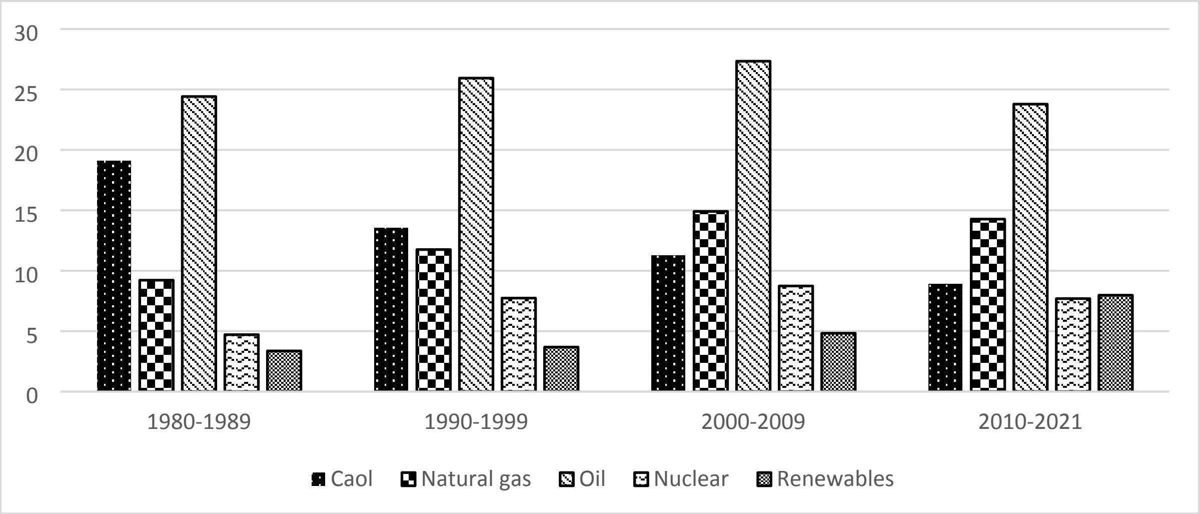
The world has been facing problems caused by global warming and climate change. Economies across the globe have been experiencing economic growth. However, the growth attended by most of these economies does not include the marginalized and vulnerable groups of society. Therefore, in the changing world economic scenario, most nations want to achieve inclusive economic growth while accounting for the growing adverse effect of climate change (Fay 2012; Li et al. 2021; Jia et al. 2023). In 2015, the United Nations (UN) adopted 17 sustainable development goals (SDGs) and ensured that the goals would be achieved by 2030 (UN 2015). Hence, inclusive green growth (IGG) is the central attraction. The term IGG was introduced in the 2012 G20 Summit under the presidency of Mexico. It refers to pursuing a path of economic growth that ensures social equity and conserves the environment (GGKP 2016; Jha, Sandhu, and Wachirapunyanont 2018). In simple words, IGG is the harmonization of the economy, environment, and society (Ofori, Gbolonyo, and Ojong 2022; Wu et al. 2024). The Global Commission on the Economy and Climate pointed out that achieving “inclusive, high-quality, and resilient” growth has become a top development agenda (Morgan 2014). The commission defines “better growth” as increasing incomes, reducing poverty, improving health, making cities more liveable, fostering resilience, encouraging faster innovation, and improving the climate by reducing greenhouse gas (GHG) emissions. The IGG is a pathway of sustainable development, and therefore, it becomes essential to delve into the factors that foster IGG and bring sustainability to all three spheres: economy, environment, and society.

Further, due to mounting environmental pressure, countries worldwide transit their energy use pattern and resort to renewable energy. According to the National Oceanic and Atmospheric Administration (Lan, Trans, and Thoning 2024), carbon dioxide (CO_2) emissions amount was 278 ppm before the industrial revolution, but they reached 316, 365, 400, and 417 ppm in 1959, 1998, 2015, and 2022, respectively. If the CO_2 emissions continue to grow at this pace, the global temperature may rise by 5–6 ℃ by the end of this century (Tollefson 2020). Therefore, decarbonizing the economy is necessary for avoiding catastrophic climate disasters (Codina and Semmler 2024). Increasing renewable energy consumption reduces the level of CO_2 emissions and makes the energy system sustainable (Alvarado et al. 2019). The special report of the Intergovernmental Panel on Climate Change (IPCC 2018) states that to limit global warming to 1.5 ℃, 70–85% of the world’s electricity must come from renewable energy by 2050. Therefore, the renewable-based energy transition is crucial for achieving the target. The enforcement of the Kyoto Protocol in 2005 is a critical effort to draw the attention of the nations on energy transition. Since then, the world has achieved commendable progress in energy transition.

In 2021, the total installed capacity of renewable electricity was 3064 gigawatts, producing about 8000 terawatt-hours of electricity (IRENA 2022). In 2022, renewable energy consumption increased by 13%, reaching about 46 exajoules (EJ). Most of this (more than 70%) came from wind and solar energy, reaching nearly 20 EJ and 13 EJ, respectively (EI 2023). Energy transition-related investment grew by 21% globally, reaching just USD 1 trillion in 2021 (BloombergNEF 2022). Renewable energy is the largest share, attracting USD 366 billion (excluding large hydropower). Recently, the 28th Conference of the Parties (COP28) of the United Nations Framework Convention on Climate Change, held in the United Arab Emirates during November–December 2023, is a crucial collective effort to accelerate the energy transition to achieve net-zero emissions by 2050. Though energy transition has achieved significant growth, the question of whether energy transition can promote IGG and bring sustainability in all three spheres needs to be answered. Our study is an endeavor towards this. In this paper, we attempt to address the research question of how energy transition influences IGG in the European Union (EU).

In the last decade, energy transition in the EU has progressed notably. According to the Energy Transition Index ranking published by the World Economic Forum (WEF 2023), seven EU countries have placed in the top ten. These countries are Sweden (1st), Denmark (2nd), Finland (4th), France (7th), Austria (8th), Netherlands (9th), Estonia (10th). Though fossil fuels have dominated the EU's energy basket, the share of renewable energy has increased admirably. Figure 1 clearly presents the EU's energy use pattern. "European Green Deal" has set the target to reduce GHG emissions by at least 55% by 2030 compared to the 1990s.

Figure 1. Periodic average of energy consumption by sources of EU



Source: Authors's construct; *Note*: Initial data retrieved from US Energy Information Association.

Moreover, The Russia-Ukraine war has disrupted the energy supply to the EU countries. Therefore, these economies must find new sources of energy that are sustainable. Henceforth, the transition to renewable energy has become more crucial in the EU. On the other hand, though the European region is economically developed, income inequality has risen from 1995–2021 (The Gini index was 28.016 in 1995 and went up to 29.416 in 2021). Additionally, the region has not achieved the desired green economy targets, as seen in Table 1. Therefore, despite the commendable progress of the energy transition in the EU, the question of whether or not the energy transition can bring inclusiveness to the growth of the EU while making it green has remained unanswered. Therefore, studying the association between energy transitions and IGG in the EU economies becomes imperative.

Table 1. Descriptive statistics of the inclusive green growth variables

	1995		2010		2019		2021	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Infant mortality rate	8.524	4.391	4.228	2.008	3.220	1.028	3.052	0.990
Income inequality	28.016	4.069	29.552	3.397	29.472	3.794	29.416	3.851
Forest Cover	34.674	16.380	36.347	16.148	36.868	16.100	36.923	16.070
Ambient PM.2.5 mortalities	697.908	346.061	520.872	317.262	414.115	292.327	409.619	288.586
Natural resources rent	0.689	0.855	0.775	0.928	0.376	0.412	0.459	0.468
Environmentally friendly technologies	9.818	7.449	14.464	5.712	9.959	3.916	11.477	3.335

Source: Authors' construct; *Note*: Initial data of 2021 for ambient PM.2.5 mortalities and environmentally friendly technologies have been extrapolated.

While numerous studies have delved into the effects of transitioning to renewable energy on economic, environmental, and societal aspects, very few have addressed its impact on IGG. Additionally, there is a noticeable absence of research investigating the relationship between renewable energy transition and IGG, specifically within the EU economies. In order to address these gaps, the study aims to explore the influence of energy transition on IGG across 25 EU economies from 1995–2001. Advanced econometric techniques, including the pooled mean group-autoregressive distributed lag model, Driscoll-Kraay standard errors method, feasible generalized least square method, panel corrected standard errors method, and Dumitrescu-Harlin causality test are employed to achieve this objective.

This study contributes to the existing literature in several ways. First, it is the first of its kind to investigate the liaison between energy transition and IGG within the EU context. Second, it devises composite indices for IGG and renewable energy transition tailored to the EU economies. Last, by employing advanced econometric techniques, this study offers methodological contributions that may inform future research endeavors.

The remainder of the paper is structured as follows: Section 2 offers a brief review of related literature, Section 3 provides the data sources and econometrics methods employed, Section 4 discusses the results, and Section 5 ends with conclusions and policy implications.

2 Related literature

Energy transition can influence IGG through the economy, environment, and society. Accordingly, we provide the literature review on three aspects: Energy transition and economic sustainability, energy transition and environmental sustainability, and energy transition and social sustainability.

2.1 Energy transition and economic sustainability

The detrimental impact of fossil fuels on the environment urges countries worldwide to shift their energy consumption to renewable energy. This leads the researchers to investigate the linkage between renewable energy transition and economic growth. Apergis and Payne (2010) explored the impact of renewable energy consumption on economic growth in 20 Organisation for Economic Co-operation and Development (OECD) countries from 1985–2005. The study confirmed the positive impact of renewable energy on economic growth for those countries. Another study by Apergis and Payne (2011) established the profound impact of renewable energy usage on economic growth for six Central American countries. For 34 OECD countries, Inglesi-Lotz (2016) affirmed that total renewable energy consumption and an increase in the share of renewable energy consumption both have a promotional effect on economic growth.

Bhattacharya et al. (2016) studied the impact of renewable energy consumption on economic growth in the top 38 renewable energy-consuming countries spanning 1991–2012. The findings showed that renewable energy enhanced the prosperity of those economies. Similarly, Rafindadi and Ozturk (2017) asserted that renewable energy consumption increased Germany's per capita GDP. Further, in a study of 103 countries, Chen, Pinar, and Stengos (2020) found that renewable energy consumption positively affected economic growth in OECD countries. However, renewable energy amplified economic growth in non-OECD and developing countries after a certain threshold period. In addition, Jan, Durrani, and Khan (2021) noticed that renewable energy spurred economic prosperity more efficiently than other sources in Pakistan. Similar kind of findings can be observed from the studies by Iqbal, Tang, and Rasool (2023), and Z. Wang et al. (2021) for BRICS countries and ten Asian countries, respectively.

However, some studies have different opinions. In a Turkish survey, Ocal and Aslan (2013) found that an increase in the share of renewable energy consumption in the total final energy consumption hampered economic growth. These findings are supported by the studies of Maji, Sulaiman, and Abdul-Rahim (2019) and Tenaw (2022) in the case of 15 West African countries and 20 Sub-Saharan countries, respectively. At the initial stage, the development of renewable energy technologies is associated with higher costs, leading to higher energy prices. This discourages people from adopting it and thus negatively affects the economy. Therefore, to get the beneficial impacts of renewable energy, the deployment of renewable energy must cross a critical threshold level.

2.2 Energy transition and environmental sustainability

Studies across different regions and periods unanimously argued that using renewable energy brings environmental sustainability. During the analysis, they used different indicators of environmental degradation, such as CO_2 emissions, ecological footprint, and carbon footprint. Gill, Viswanathan, and Hassan (2018) evaluated the influence of an increase in the share of renewable energy production on CO_2 emissions in Malaysia over the period 1970–2011. The study revealed that renewable energy reduced CO_2 emissions in Malaysia. Similar findings can be observed in a study by Murshed et al. (2021), which indicated that non-fossil fuel and hydroelectricity consumption curbed the carbon footprint in Bangladesh. Further, in a study of 15 Asian economies, Anwar et al. (2022) explained that an increase in the share of renewable energy consumption enhanced environmental quality. Afshan, Ozturk, and Yaqoob (2022) constructed a composite energy transition index and scrutinized the impact of the energy transition on ecological footprint in 27 OECD countries during 1990–2014. The study confirmed that energy transition promoted environmental sustainability by curbing ecological footprint.

In addition, Kazemzadeh (2024) explored the impact of energy transition on the environment using the ratio of renewable energy to non-renewable energy consumption and observed that energy transition reduced environmental degradation. The study further stated that the impact of energy transition is more intense on higher quantiles of CO_2 emissions. The same findings can be noticed in a study by Liao et al. (2023) for ten OECD countries. Moreover, studies by Salahodjaev et al. (2022) and Gao and Chen (2023) reported that an increase in the share of renewable electricity production augmented environmental quality in 45 Europe and Central Asia countries and 21 industrialized countries, respectively. A study by Sadiq et al. (2023) established that renewable energy mitigated environmental degradation in BRIC countries. Other studies shared the same vision (Gu and Liu 2023; Kongkuah 2024; Yang et al. 2023; Ahmad et al. 2023). Therefore, from the above discussion of literature, it can be confirmed that the transition from non-renewable to renewable energy makes the environment sustainable.

2.3 Energy transition and social sustainability

While plenty of researchers focused on finding the impact of renewable energy transition on the economy and environment, few studies delved into the social impact of renewable energy transition. Apergis and Salim (2015) studied the impact of renewable energy consumption on unemployment in a panel of 80 countries from 1990-2013. The study reported that renewable energy consumption increased unemployment for the overall panel, though the results varied across different regions. However, these findings are inconsistent with the findings of the studies by Khobai et al. (2020) and Naqvi, Wang, and Ali (2022) for South Africa and ten European countries, respectively. The studies found that renewable energy usage reduced unemployment in these economies. In addition, Ram, Aghahosseini, and Breyer (2020) performed an analytical job creation assessment for the global power sector from 2015–2050 and reported that 100% electricity generation from renewable sources by 2050 would create job opportunities from about 21 million in 2015 to nearly 35 million in 2050.

Further, Topcu and Tugcu (2020), in a study of 23 developed economies, revealed that increasing the share of renewable energy consumption reduced income inequality. Sasmaz et al. (2020) explored the impact of renewable energy on the human development index in 28 OECD countries over the period 1990–2017. The study reported an increase in the share of renewable energy improved human development in these economies. The findings are similar to the findings of the studies by Z. Wang et al. (2021) and Kaewnern et al. (2023) for BRICS countries and the top ten human development countries, respectively. In a study for India, Mamidi, Marisetty, and Thomas (2021) found that the transition to clean energy amplified household development. On the other hand, Nketia et al. (2022) and Iddrisu, Ofoeda, and Abor (2023) indicated that increasing the share of renewable energy consumption negatively affected inclusive growth for 48 African economies and 30 Sub-Saharan African (SSA) countries, respectively. Likewise, in the case of economic sustainability, the deployment of renewable energy must reach beyond a certain threshold level to attain social sustainability.

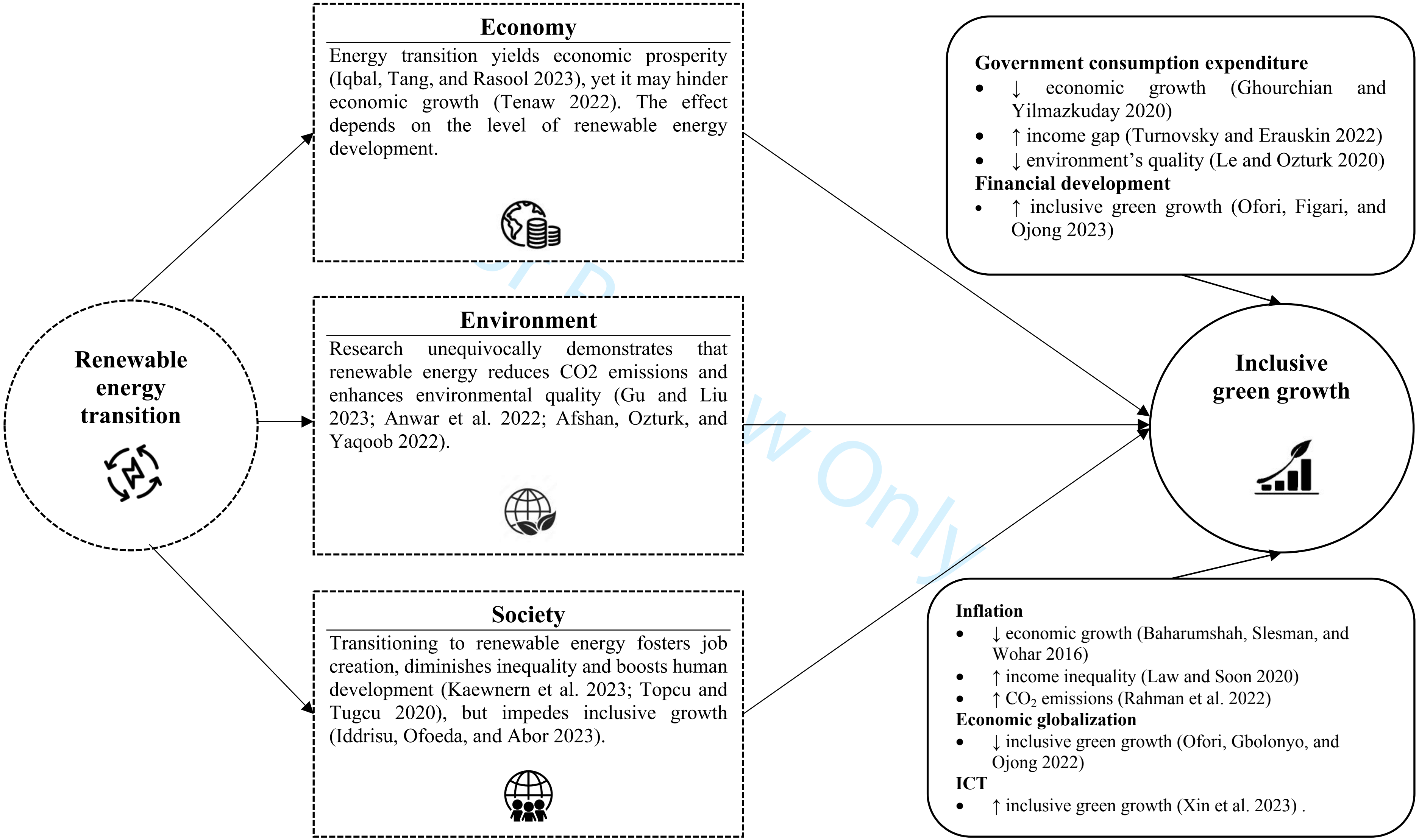
2.4 Other factors affecting IGG

Along with renewable energy transition, other variables can influence IGG directly or indirectly. Ghourchian and Yilmazkuday (2020) carried out a study on the impact of government consumption expenditure on economic growth in a group of 83 countries during 1960–2014. The findings of the study established that government consumption expenditure hampered economic growth. Further, a study by Onifade et al. (2020) also confirmed that government recurrent expenditures negatively affected economic growth in Nigeria from 1981–2017. The effect of productive government expenditure on income disparity was examined by Turnovsky and Erauskin (2022) over a sample of 80 countries spanning 1980–2015. The findings of the study revealed that government expenditure widened the income gap in those countries. Further, Le and Ozturk (2020) showed that government expenditure degraded the environmental quality by enhancing economic activities and luring more trade and investment activities in 47 emerging markets and developing economies. However, a study by Bilal et al. (2022) confirmed that government expenditures and inflation improved environmental quality in Germany spanning 1971–2016. Baharumshah, Slesman, and Wohar (2016) showed that inflation dampened economic growth in 94 developing and emerging countries from 1976–2010.

Conversely, for 79 developing countries, Uddin and Rahman (2023) reported that inflation boosted spending and investment, further stimulating economic growth. In addition, Law and Soon (2020) examined the association between inflation and income inequality for 65 developed and developing economies over the period 1987–2014. The study revealed that inflation exacerbated income inequality in those countries. A study by Rahman et al. (2022) showed that inflation increased CO_2 emissions in Pakistan. Furthermore, Ofori and Figari (2023) explored the impact of economic globalization on IGG in 23 African countries from 2000–2020. They found that economic globalization negatively affected IGG in those countries. A study by Ofori, Gbolonyo, and Ojong (2022) revealed that information and communication technologies (ICT) fostered IGG while financial deepening hampered it in 23 African countries from 2000–2020. The study further revealed that trade openness deteriorated environmental quality in those economies. Similarly, a study by Xin et al. (2023) concluded that the digital economy promoted IGG in China. However, another study by Ofori, Figari, and Ojong (2023) reported that ICT harmed IGG, whereas financial development promoted it in 20 SSA countries over the period 2000–2020. Henceforth, it can be concluded that the effect of ICT and financial development depends on the policy framework of countries. The study further concluded that foreign direct investment (FDI) and trade openness enhanced environmental degradation.

In summary, the mechanization of energy transition affecting IGG through its three dimensions is depicted in Figure 2.

Figure 2. Mechanization of energy transition affecting IGG



Economy

Energy transition yields economic prosperity (Iqbal, Tang, and Rasool 2023), yet it may hinder economic growth (Tenaw 2022). The effect depends on the level of renewable energy development.

Environment

Research unequivocally demonstrates that renewable energy reduces CO2 emissions and enhances environmental quality (Gu and Liu 2023; Anwar et al. 2022; Afshan, Ozturk, and Yaqoob 2022).

Society

Transitioning to renewable energy fosters job creation, diminishes inequality and boosts human development (Kaewnern et al. 2023; Topcu and Tugcu 2020), but impedes inclusive growth (Iddrisu, Ofoeda, and Abor 2023).

Government consumption expenditure

- ↓ economic growth (Ghourchian and Yilmazkuday 2020)
- ↑ income gap (Turnovsky and Erauskin 2022)
- ↓ environment's quality (Le and Ozturk 2020)

Financial development

- ↑ inclusive green growth (Ofori, Figari, and Ojong 2023)

Inflation

- ↓ economic growth (Baharumshah, Slesman, and Wohar 2016)
- ↑ income inequality (Law and Soon 2020)
- ↑ CO_2 emissions (Rahman et al. 2022)

Economic globalization

- ↓ inclusive green growth (Ofori, Gbolonyo, and Ojong 2022)

ICT

- ↑ inclusive green growth (Xin et al. 2023) .

Source: Authors' construct

3 Data and methods

3.1 Data

The study employs annual data from 25 EU nations[1] over the period 1995–2021. The selection of the time period and countries is based on data availability. Some data points have been interpolated and extrapolated to make the data set balanced. The outcome variable of our study is IGG. The data of IGG is not directly available. We have formulated a composite index of IGG by following the study of Ofori, Gbolonyo, and Ojong (2022). This index incorporates sustainable development's social, economic, and environmental perspectives. The definition and data sources of the variables used to formulate the index are given in Table 2.

Table 2. Description and sources of inclusive green growth variables

	Description	Source
Social sustainability		
Sanitation	Population with access to improved sanitation (% total population)	OECD
Potable water	Population with access to improved drinking water sources (% total population)	OECD
Population density	Population density, inhabitants per square kilometer	OECD
Infant mortality	Mortality rate, infant (per 1,000 live births)	WDI
Life expectancy	Life expectancy at birth, total (years)	OECD
Air transport	Air transport, registered carrier departure worldwide	WDI
Railway transport	Rail lines (total route-km)	WDI
Economic sustainability		
Income growth	GDP per capita, PPP (constant 2017 international $)	WDI
Income inequality	Gini index (0 = Lowest; 1 = Highest)	SWIID
Human capital index	Human capital index, based on years of schooling and returns to education	PWT (version 10.1)
Unemployment	Unemployment, total (% of the total labor force)	WDI
Environmental sustainability		
Agricultural land	Agricultural land (% of land area)	WDI
Forest cover	Forest area (% of land area)	WDI
Temperature	Annual temperature change	OECD
Exposure to Ambient PM.2.5	Mean population exposure to PM2.5	OECD
Ambient PM.2.5 mortalities	Mortality from exposure to ambient PM2.5	OECD
Ambient PM.2.5 welfare cost	Welfare costs of premature mortalities from exposure to ambient PM2.5, GDP equivalent	OECD
Methane emission	Agricultural methane emissions (thousand metric tons of CO_2 equivalent)	WDI
Carbon productivity	Demand-based carbon productivity, GDP per unit of energy-related CO_2 emissions (constant 2015 US dollars per kilogram)	OECD
Natural resources rent	Total natural resources rents (% of GDP)	WDI

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[1] The selected countries are Austria, Belgium, Bulgaria, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden.

Renewable energy	Renewable energy consumption (% of total final energy consumption)	EIA
Fossil fuel consumption	Fossil fuel energy consumption (% of total)	EIA
Clean fuel usage	Access to clean fuels and technologies for cooking (% of population)	WDI
Environmentally friendly technologies	Development of environment-related technologies, % all technologies	OECD

Source: Authors' construct; *Note:* WDI represents World Development Indicator; OECD represents Organisation for Economic Co-operation and Development; EIA represents Energy Information Association; SWIID represents Standardized World Income Inequality Database; PWT represents Penn World Table.

The study implements principal component analysis (PCA) following Kumar, Nagar, and Samanta (2007) to formulate the sub-indices and the main index of IGG. The detailed PCA method is given in the Appendix. The key explanatory variable of our study is the renewable energy transition (RET). Previous studies have taken different proxies of energy transition—the ratio between electricity generated by renewable energy and fossil fuels (Afonso, Marques, and Fuinhas 2021), renewable energy consumption and generation (Shahbaz et al. 2022), the share of primary energy from renewable energy sources (Dogan et al. 2022).

However, according to a report by the International Energy Agency (IEA 2019), one indicator cannot be enough to grasp the complexity of energy transition to clean energy. Therefore, we have created a composite index of RET by incorporating the indicators suggested by the IEA. Apart from this, the study includes financial development (FD), government expenditure (GE), inflation rate (IR), economic globalization (EG), and internet access (INTR) as control variables. The description and data sources of the variables (including energy transition indicators) are provided in Table 3. All the variables are transformed into natural logarithms. This will reduce the sharpness of the data and express the coefficients in terms of elasticity.

Table 3. Description and sources of energy transition indicators and control variables

	Description	Source
Energy transition indicators		
Carbon emissions	CO_2 emissions from energy (Million tonnes)	EI Stat. Rev.
Final energy carbon intensity	The ratio of energy-related carbon emissions to total final energy consumption (gCO_2 per megajoules)	IEA
Share of renewable electricity generation	The ratio of electricity generation from renewables to total electricity generation	EIA
Carbon intensity of power	Carbon intensity of power index (2000 = 100) calculated using the power generation CO_2 emissions from fuel combustion.	IEA
Energy intensity	energy consumption per GDP (1000 Btu/2015$ GDP PPP)	EIA
Renewable energy investment	Net addition to yearly renewable energy installed capacity (million kilowatts)	EIA

Control variables		
Financial development	Financial development index	IMF
Government expenditure	General government final consumption expenditure (% of GDP)	WDI
Inflation rate	Inflation, consumer prices (annual %)	WDI
Economic globalization	Economic globalization index	KOF
Internet access	Individuals using the Internet (% of the population)	WDI

Source: Authors' construct; *Note:* EIA represents Energy Information Administration; EI Stat. Rev. represents Energy Institute Statistical Review of World Energy; WDI represents World Development Indicator; OECD represents the Organisation for Economic Co-operation and Development; IMF represents the International Monetary Fund; WGI represents Worldwide Governance Indicator; KOF represents Konjunkturforschungsstelle.

3.2 Modelling

The relationship between IGG and energy transition in the presence of control variables can be expressed by the following expression:

$$IGG_{it} = f(RET, FD_{it}, GE_{it}, IR_{it}, EG_{it}, INTR_{it}) \qquad (1)$$

where all the variables are previously defined, and subscript *i* and *t* are the number of cross-sections and time periods, respectively. The logarithmic form of the relationship can be expressed in the following way:

$$LnIGG_{it} = \beta_0 + \beta_1 LnRET_{it} + \beta_2 LnFD_{it} + \beta_3 LnGE_{it} + \beta_4 LnIR_{it} + \beta_5 LnEG_{it} + \beta_6 LnINTR_{it} + u_{it} \qquad (2)$$

where β_0 is the intercept, β_i $(i = 1,2,...,6)$ represents the elasticity parameter to be estimated and u_{it} is the independent and identically distributed error term.

3.3 Econometrics Methods

Before proceeding to estimation, we need to check cross-sectional dependence (CD), which is crucial in studying panel data. Increasing globalization and trade liberalization have increased interdependence among countries, and ignorance of this may lead to misleading conclusions (Salahuddin, Gow, and Vink 2020). In this study, four CD tests - Breusch-Pagan Lagrange multiplier (LM) test, Pesaran scaled LM test, Pesaran CD test, Bias-adjusted LM test (Breusch and Pagan 1980; Pesaran 2021; Pesaran, Ullah, and Yamagata 2008)–are carried out. The results of these tests indicate the presence of CD in the data.

To check the time series properties of the variables, the cross-sectionally augmented Im-Pesaran-Shin (CIPS) unit root test (Pesaran 2007) is employed, which considers the CD problem. In order to check cointegration among the concerned variables, the study applies the Pedroni (Pedroni 2004) and the Westerlund (2005) cointegration tests.

Further, the study conducts diagnostic tests, including the variance inflation factor (VIF) test for multicollinearity, the Wooldridge test for autocorrelation, the modified Wald test for group-wise heteroskedasticity, and the Hausman (1978) test between fixed and random effect model.

The study estimates the empirical relationship among underlying variables using the pooled mean group-autoregressive distributed lag (PMG-ARDL) model proposed by Pesaran, Shin, and Smith (1999). The PMG-ARDL model provides both long-run and short-run estimates of explanatory variables and is also applicable irrespective of the order of integration of the variables, i.e., when the variables are I(0) and I(1) [but not I(2)]. It allows the short-run parameters to be different between groups while the long-run parameters are assumed to be the same between groups. This model also accounts for serial-collinearity, CD among error terms, and potential endogeneity among variables.

Following Pesaran, Shin, and Smith (1999), the PMG-ARDL model for this study can be expressed as follows:

$$\Delta LnIGG_{it} = \beta_0 + \rho_i LnIGG_{it-1} + \beta_1 LnRET_{it-1} + \beta_2 LnFD_{it-1} + \beta_3 LnGE_{it-1} + \beta_4 LnIR_{it-1} + \beta_5 LnEG_{it-1} + \beta_6 LnINTR_{it-1} + \varphi_{ij}\sum_{j=1}^{p-1} \Delta LnIGG_{it-j} + \omega_{1ij}\sum_{j=0}^{q-1} \Delta LnRET_{it-j} + \omega_{2ij}\sum_{j=0}^{q-1} \Delta LnFD_{it-j} + \omega_{3ij}\sum_{j=0}^{q-1} \Delta LnGE_{it-j} + \omega_{4ij}\sum_{j=0}^{q-1} \Delta LnIR_{it-j} + \omega_{5ij}\sum_{j=0}^{q-1} \Delta LnEG_{it-j} + \omega_{6ij}\sum_{j=0}^{q-1} \Delta LnINTR_{it-j} + u_{it} \qquad (3)$$

Equation (3) can be expressed in the error correction form as follows:

$$\Delta LnIGG_{it} = \beta_0 + \rho_i ECT_{it-1} + \varphi_{ij}\sum_{j=1}^{p-1} \Delta LnIGG_{it-j} + \omega_{1ij}\sum_{j=0}^{q-1} \Delta LnRET_{it-j} + \omega_{2ij}\sum_{j=0}^{q-1} \Delta LnFD_{it-j} + \omega_{3ij}\sum_{j=0}^{q-1} \Delta LnGE_{it-j} + \omega_{4ij}\sum_{j=0}^{q-1} \Delta LnIR_{it-j} + \omega_{5ij}\sum_{j=0}^{q-1} \Delta LnEG_{it-j} + \omega_{6ij}\sum_{j=0}^{q-1} \Delta LnINTR_{it-j} + u_{it} \qquad (4)$$

Where $ECT_{it-1} = LnIGG_{it-1} - \theta_1 LnRET_{it-1} - \theta_2 LnFD_{it-1} - \theta_3 LnGE_{it-1} - \theta_4 LnIR_{it-1} - \theta_5 LnEG_{it-1} - \theta_6 LnINTR_{it-1}$ and ρ_i is the coefficient of error correction term that indicates the speed of converging the model to long-run equilibrium after any shock in explanatory variables in the short run. Statistical significance of ρ_i ensures the existence of nonlinear cointegration among the underlying variables. Moreover, $\theta_1 (= -\frac{\beta_1}{\rho})$, $\theta_2 (= -\frac{\beta_2}{\rho})$, $\theta_3 \left(= -\frac{\beta_3}{\rho}\right)$, $\theta_4 \left(= -\frac{\beta_4}{\rho}\right)$, $\theta_5 \left(= -\frac{\beta_5}{\rho}\right)$, $and\ \theta_6 \left(= -\frac{\beta_6}{\rho}\right)$ are the long-run coefficients of LnRET, LnFD, LnGE, LnINF, LnEG, and LnINTR, respectively and $\omega_{1ij}, \omega_{2ij}, \omega_{3ij}, \omega_{4ij}, \omega_{5ij},\ and\ \omega_{6ij}$ are their short-run coefficients.

In order to check the robustness of the result obtained from PMG-ARDL, the study also employs the fixed effect model with the Driscoll-Kraay standard errors (DKSE) method introduced by Driscoll and Kraay (1998), the feasible generalized least square (FGLS) method advocated by Parks (1967), and the panel-corrected standard errors (PCSE) method pioneered by Beck and Katz (1995). These methods are robust to the presence of CD, autocorrelation, and heteroskedasticity problems (2007). Lastly, the study carries out the Dumitrescu-Harlin (D-H) causality test proposed by Dumitrescu and Hurlin (2012) to check the direction of causality among variables. The D-H causality test considers the CD problem. The D-H causality model is illustrated below:

$$y_{it} = \tau_i + \sum_{k=1}^{K} \delta_i^{(k)} y_{i,t-k} + \sum_{k=1}^{K} \lambda_i^{(k)} x_{i,t-k} + \varepsilon_{it} \tag{7}$$

where τ_i denotes the constant value, $\delta_i^{(k)}$ represents the autoregressive parameters, and $\lambda_i^{(k)}$ refers to the regression coefficients. The null and alternative hypotheses of the D-H causality test can be defined as follows:

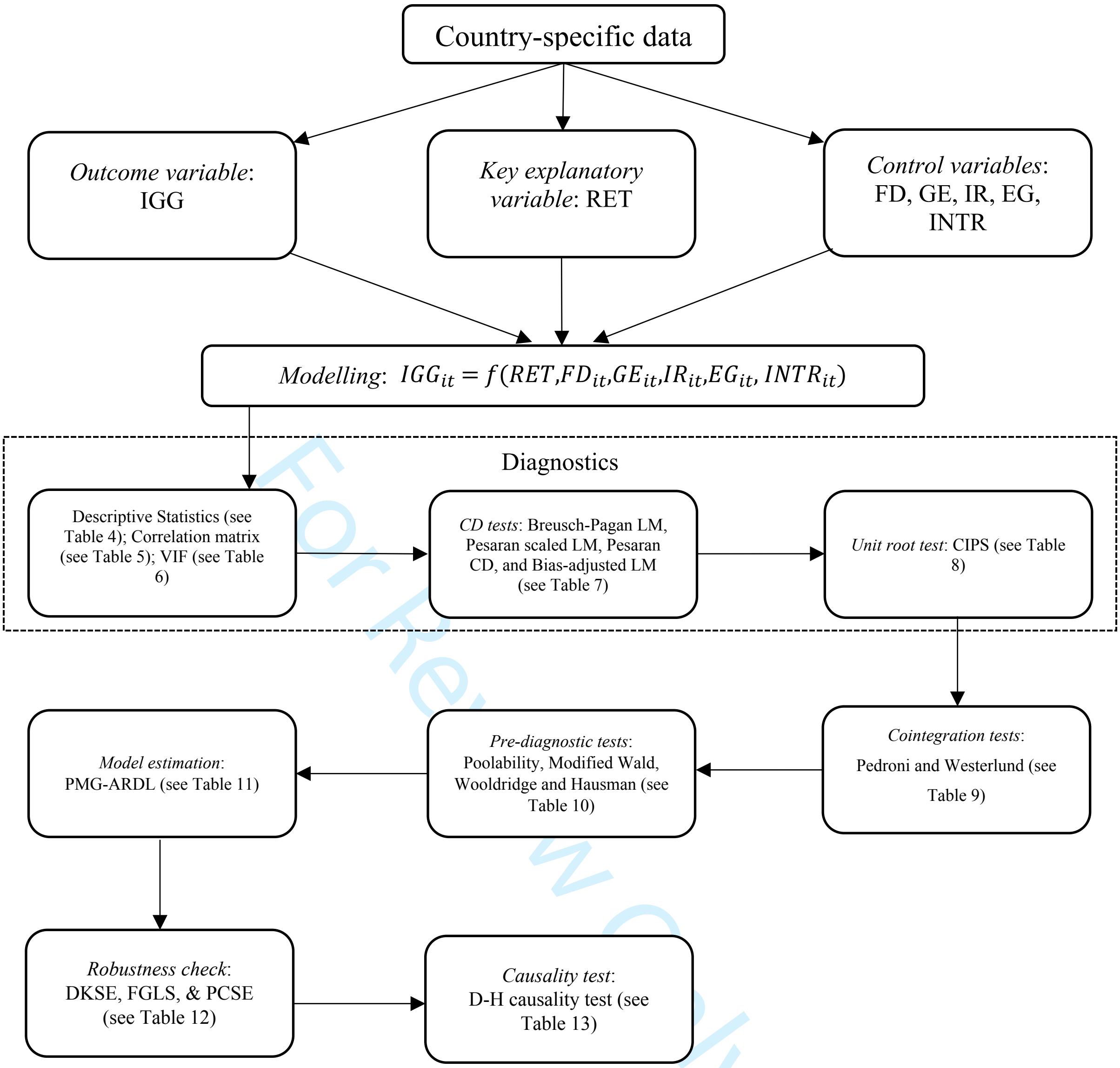
$$H_0: \lambda_i = 0 \quad \forall i = 1,2,\ldots, N \tag{8}$$

$$H_1: \left\{ \begin{matrix} \lambda_i = 0 & \forall i = 1,2,\ldots, N_1 \\ \lambda_i \neq 0 & \forall i = N_1 + 1, N_1 + 2,\ldots, N \end{matrix} \right\} \tag{9}$$

The null hypothesis indicates that there exists no causality for any cross-sectional units in the panel, whereas the alternative hypothesis implies that there exists causality for at least one cross-sectional unit in the panel.

A flowchart organizing and illustrating the steps involved in the overall framework is presented in Figure 3.

Figure 3. Flowchart of steps involved



Source: Authors' construct; *Note*: IGG represents inclusive green growth; RET represents renewable energy transition; FD represents financial development; GE expenditure represents government expenditure; IR represents inflation rate; EG represents economic globalization; INTR represents internet access; VIF represents variance inflation factors; CD represents cross-sectional dependence; LM represents Lagrange multiplier; CIPS represents cross-sectionally augmented Im-Pesaran-Shin; PMG-ARDL represents pooled mean group-autoregressive distributed lag; DKSE represents Driscoll-Kraay standard errors; FGLS represents feasible generalized least square; PCSE represents panel-corrected standard errors; D-H represents Dumitrescu-Harlin

4 Results and discussion

4.1 Descriptive statistics

The discussion starts with descriptive statistics and a correlation matrix of the concerned variables, which are given in Tables 4 and 5. It is found from the descriptive statistics that IR has the highest variation (SD = 41.683), whereas FD has the lowest (SD = 0.208). This implies that the inflation level largely varies across these countries while they are experiencing similar financial development. Further, IGG, RET, GE, and IR are positively skewed, whereas FD, EG, and INTR are negatively skewed. The Jarque-Bera statistic shows that all the variables do not follow a normal distribution except GE. The correlation matrix shows that IGG and INTR are positively correlated with IGG, whereas GE and IR are negatively correlated with it. However, FD and EG have no significant correlation with IGG. Further, the correlations between explanatory variables are not high. Therefore, the problem of severe multicollinearity can be precluded from our study, which is more evident from the VIF test (Table 6).

Table 4. Descriptive statistics of study variables

Variables	Abbreviation	Mean	Std. Dev.	Skewness	Jarque-Bera
Inclusive green growth	IGG	100.142	4.041	20.819	7083111.000***
Renewable energy transition	RET	100.000	1.575	0.445	27.190***
Financial development	FD	0.531	0.208	-0.238	46.535***
Government expenditure	GE	20.006	3.004	0.079	1.484
Inflation rate	IR	5.452	41.683	24.045	10267956.000***
Economic globalization	EG	75.822	9.818	-0.988	150.553***
Internet access	INTR	53.017	31.332	-0.378	61.920***

Source: Authors' construct; *Note*: *** denotes a 1 % significance level.

Table 5. Correlation matrix of study variables

	LnIGG	LnRET	LnFD	LnGE	LnIR	LnEG
LnRET	0.357***					
LnFD	0.042	0.124***				
LnGE	-0.093**	0.059	0.217***			
LnIR	-0.089**	-0.349***	-0.436***	-0.245***		
LnEG	0.061	0.331***	0.490***	0.166***	-0.529***	
LnINTR	0.292***	0.639***	0.395***	0.130***	-0.560***	0.647***

Source: Authors' construct; *Note*: ** and *** denote 5% and 1% significance levels, respectively.

Table 6. Variance inflation factor of explanatory variables

	VIF	1/VIF
LnINTR	2.887	0.346
LnEG	2.028	0.493
LnRET	1.767	0.566
LnIR	1.691	0.592
LnFD	1.451	0.689
LnGE	1.083	0.923
Mean VIF	1.818	

Source: Authors’ construct.

4.2 CD and CIPS unit root tests

After confirming the absence of multicollinearity problems and before proceeding with estimation, we need to check the CD and stationary properties of the variables while dealing with panel data. Tables 7 and 8 display the results of four CD tests and the CIPS unit root test, respectively. The CD test results provide evidence of the presence of CD in data for all variables. Therefore, second-generation methods are applicable to this study. Accordingly, the result of the CIPS unit root test indicates that IGG, RET, FD, IR, and INTR are stationary at level, i.e., I(0), whereas GE and EG are stationary at the first difference, i.e., I(1). Since the variables are in mixed order, i.e., I(0) and I(1), and none of the variables are I(2), the PMG-ARDL model is appropriate.

Table 7. Results of the Cross-section dependence tests of study variables

	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
LnIGG	6972.302***	272.396***	271.915***	78.184***
LnRET	5919.413***	229.412***	228.931***	76.095***
LnFD	3248.361***	120.366***	119.886***	49.257***
LnGE	1728.663***	58.325***	57.844***	17.345***
LnIR	2713.479***	98.530***	98.050***	47.973***
LnEG	4976.365***	190.912***	190.431***	64.821***
LnINTR	7726.351***	303.180***	302.699***	87.882***

Source: Authors’ construct; *Note*: *** denotes a 1 % significance level.

Table 8. Result of the CIPS unit root test of study variables

	With constant		With constant and trend	
	Level	First difference	Level	First difference
LnIGG	-3.144***	-5.100***	-3.097***	-5.172***
LnRET	-2.497***	-5.558***	-2.914***	-5.645***
LnFD	-2.560***	-5.324***	-3.201***	-5.414***
LnGE	-1.637	-4.549***	-1.905	-4.693***
LnIR	-3.158***	-4.986***	-3.129***	-5.167***
LnEG	-2.519***	-4.876***	-2.457	-4.963***
LnINTR	-3.508***	-4.795***	-3.928***	-4.653***

Source: Authors’ construct; *Note:* *** denotes a 1 % significance level.

Since all the variables are not stationary at the level, we need to check the existence of a long-run relationship among the underlying variables. For this, the Pedroni (2004) and the Westerlund (2005) cointegration tests were carried out. The results of the panel cointegration tests reported in Table 9 provide evidence for the existence of a long-run relationship among variables.

Table 9. Results of panel cointegration tests among underlying variables

	Test statistics
Pedroni cointegration test	Modified Phillips-Perron t = -0.673
	Phillips-Perron t = -2.036***
	Augmented Dickey-Fuller t = -5.668***
Westerlund cointegration test	Variance ratio = -2.1081**

Source: *Authors' construct; Note*: ** and *** denote 5% and 1% significance level, respectively.

4.3 PMG-ARDL Estimation

After finding a long-run relationship among the variables, we can now estimate the relationship. But before, pre-diagnostic checks are required. A perusal of the results of pre-diagnostic tests in Table 10 shows that data are not poolable and have autocorrelation and heteroskedastic problems. In addition, the result of the Hausman test shows the presence of a fixed effect in the model. Table 11 reports the result of the PMG-ARDL model.

Table 10. Results of pre-diagnostic tests

	Test statistics
Poolability test	F (24, 644) = 1.46*
Modified Wald	χ^2 (25) = 280000***
Wooldridge test	F (1, 24) = 54036.538***
Hausman test	χ^2 (6) = 25.75***

Source: Authors' construct; *Note*: *** denotes a 1 % significance level.

A perusal of Table 11 reveals that the coefficient of the error correction term is significant at the 5% level, and its value is negative. Therefore, it again confirms the existence of cointegration among the concerned variables. It further implies that after any shock in the explanatory variables, the system converges to equilibrium by 0.038% annually. RET has a negative short-run impact but a positive long-run impact on IGG in the selected EU economies. A 1% increase in RET results in a 0.038% decrease in IGG in the short run, whereas a 1.354% increase in IGG in the long run. The development of renewable energy technologies and plants is initially associated with higher costs. Therefore, when the economy is transitioning from non-renewable to renewable energy, it faces drawbacks and challenges (Maji, Sulaiman, and Abdul-

Rahim 2019; Tenaw 2022). However, in the long run, transitioning to renewable energy increases economic growth and makes the environment sustainable by reducing GHG emissions (Sadiq et al. 2023). The relationship has been substantiated for BRICS countries in reference to the findings from J. Wang et al. (2023). In addition, energy transition advances social sustainability by creating more job opportunities, reducing income inequality, and increasing human development (Ram, Aghahosseini, and Breyer 2020; Topcu and Tugcu 2020; Kaewnern et al. 2023). Thus, RET has a favorable impact on IGG in the long run.

Table 11. Result of the PMG-ARDL model

	Coefficient	Std. Error
Long Run Equation		
LnRET	1.354***	0.143
LnFD	0.117***	0.026
LnGE	-0.295***	0.046
LnIR	-0.020***	0.006
LnEG	-0.351***	0.050
LnINTR	0.008***	0.002
Short Run Equation		
ECT(-1)	-0.038**	0.015
D(LnIGG(-1))	0.121*	0.067
D(LnRET)	-0.007	0.025
D(LnRET(-1))	-0.054**	0.022
D(LnFD)	0.001	0.002
D(LnFD(-1))	0.002	0.002
D(LnGE)	-0.017***	0.003
D(LnGE(-1))	0.005	0.004
D(LnIR)	0.001	0.001
D(LnIR(-1))	0.002*	0.001
D(LnEG)	0.008	0.010
D(LnEG(-1))	0.009	0.007
D(LnINTR)	-0.001	0.001
D(LnINTR(-1))	0.000	0.001
C	-0.038***	0.015

Source: Authors' construct; *Note*: *, **, and *** denote 10%, 5%, and 1% significance levels, respectively.

Considering the control variables, GE hampers IGG in both the long and short run in these selected nations. A 1% increase in GE reduces IGG by 0.295% and 0.017% in the long and short run, respectively. Government consumption expenditure retards economic growth. Further, government consumption expenditure may reduce environmental quality and probably increase income disparities, ultimately detrimental to IGG. This result is consistent with studies such as those by Ghourchian and Yilmazkuday (2020), Le and Ozturk (2020), and Turnovsky and Erauskin (2022). However, inflation promotes IGG in the short run but deteriorates it in the long run. A

1% increase in IR increases IGG by 0.002% in the short run but decreases it by 0.020% in the long run. Mild inflation is good for the economy (Uddin and Rahman 2023), but sustained high inflation hampers economic growth (Baharumshah, Slesman, and Wohar 2016), widens the income gap (Law and Soon 2020), and degrades environmental quality (Rahman et al. 2022). On the other hand, FD, EG, and INTR only have significant long-run effects on IGG in these countries. A 1% increase in FD and IR inflates IGG by 0.117% and 0.008%, respectively, while a 1 % increase in EG reduces IGG by 0.351%. A developed financial system enhances investments in green projects and is crucial for bringing socio-economic justice. Further, access to information can empower individuals, which may result in greater work prospects and higher earnings. This will ultimately boost IGG and aid in reducing social inequality. On the other hand, economic integration of the EU economies with the rest of the world may fail to serve the lower stratum of society or degrade environmental quality, thus lowering IGG. These findings are akin to studies by Ofori and Figari (2023) and Xin et al. (2023).

4.4 DKSE, FGLS, and PCSE Estimations

In order to validate the findings of the PMG-ARDL model, the study employs DKSE, FGLS, and PCSE methods. These methods are consistent in the presence of autocorrelation, heteroscedasticity, and CD. Therefore, they will give robustness to the findings of the PMG-ARDL model. The results are displayed in Table 12. The impact of RET on IGG is found to be positive through all three models, which establishes the consistency of the findings of the study. This statement is also true for the control variables. According to the findings of these three methods, FD and INTR enhance IGG, while GE, IR, and EG hinder it. However, all the coefficients are statistically significant only in the FGLS method.

Table 12. Results of DKSE, FGLS, and PCSE methods

	DKSE	FGLS	PCSE
LnRET	0.594***	0.094***	0.214
	(0.102)	(0.007)	(0.190)
LnFD	0.033	0.017***	0.040**
	(0.028)	(0.001)	(0.019)
LnGE	-0.038	-0.045***	-0.072**
	(0.030)	(0.001)	(0.034)
LnIR	-0.003	-0.0009***	-0.004
	(0.003)	(0.0003)	(0.006)
LnEG	-0.090	-0.057***	-0.170***
	(0.068)	(0.003)	(0.046)
LnINTR	0.005**	0.004***	0.002
	(0.002)	(0.0002)	(0.004)

Constant	2.387 (0.296)	4.549*** (0.039)	4.603*** (0.855)
F (6, 26)	233.15***		
Wald $\chi^2(6)$ for FGLS		2408.23***	
Wald χ^2 (6) for System-GMM			16.61***

Source: Authors' construct; *Note*: ** and *** denote 5% and 1% significance levels, respectively.

4.5 D-H causality test

Model estimation does not provide any information regarding the direction of causality among the variables. Therefore, the study further carries out the D-H causality test. Table 13 exhibits the findings of the D-H causality test. The table shows that a bidirectional causality exists between RET and IGG, FD and IGG, and EG and IGG. On the other hand, a unidirectional causality runs from IR and INTR to IGG. Further, a unidirectional causality running from IGG to GE has been found.

Table 13. Result of the D-H causality (null hypotheses) test with respect to IGG

	W-Stat.	Zbar-Stat.	Direction
RET, FD, EG (bidirectional)			
LnRET ≠ LnIGG	5.190***	12.283***	LnRET ↔ LnIGG
LnIGG ≠ LnRET	5.821***	14.176***	
LnFD ≠ LnIGG	4.449***	10.060***	LnFD ↔ LnIGG
LnIGG ≠ LnFD	3.294***	6.597***	
LnEG ≠ LnIGG	7.880***	20.354***	LnEG ↔ LnIGG
LnIGG ≠ LnEG	2.357***	3.786***	
INF, INTR, GE (unidirectional)			
LnINF ≠ LnIGG	5.579***	13.452***	LnINF → LnIGG
LnIGG ≠ LnINF	1.520	1.273	
LnINTR ≠ LnIGG	8.675***	22.740***	LnINTR → LnIGG
LnIGG ≠ LnINTR	1.107	0.036	
LnGE ≠ LnIGG	1.257	0.484	LnIGG → LnGE
LnIGG ≠ LnGE	3.199***	6.311***	

Source: Authors' construct; *Note*: *** denotes a 1 % significance level. ≠ denotes no causality, whereas → and ↔ denote unidirectional and bidirectional causality, respectively.

5 Conclusion and policy implication

The objective of the study is to explore the impact of RET on IGG in 25 European economies over the period 1995-2021. The empirical analysis of the study is based on advanced econometric techniques, including the PMG-ARDL model, DKSE, FGLS, PCSE methods, and the D-H causality test. The present study is in line with previous literature (Bhattacharya et al. 2016; Topcu and Tugcu 2020; Gao and Chen 2023), exploring the impact of renewable energy transition on three aspects of sustainability—economy, society, and environment—but separately. The novelty of this study, on the other hand, lies in considering all three aspects of sustainability together and unraveling the dynamics of the nexus between RET and IGG, more so in the EU. Further, where most of the previous studies have used a single indicator of energy transition, the current study has developed a composite index that can capture the complexity of energy transition more prominently. Therefore, the study provides more comprehensive findings that will be more applicable to the context of the EU. First, the panel cointegration test results confirm the long-run relationship among the concerned variables. The PMG-ARDL model results reveal that RET diminishes IGG in the short run while augmenting it in the long run in the selected EU countries. Second, the study discovers that FD and INTR foster IGG while GE, INF, and EG decline it in the long run in these economies. Furthermore, the findings of DKSE, FGLS, and PCSE methods provide robustness to the result of the PMG-ARDL. Third, according to the result of the D-H causality test, a bidirectional causality prevails between RET and IGG, FD, and IGG, and EG and IGG. On the other hand, a unidirectional causality runs from IR and INTR to IGG and from IGG to GE has been found. Moreover, our study provides greater avenues to the UN’s SDGs as it comprehends how renewable energy transition fosters IGG (SDG 2-4, 6, 7-10, 12 and 15) in the EU.

Based on the findings, the study suggests fostering a renewable-based energy transition in the EU countries. Initially, energy transition is accompanied by higher costs and may have a negative impact on IGG. In the long run, with new renewable plants and technologies, energy transition can bring desirable sustainability to the economy, society, and environment. Therefore, these countries will have to cross the first hurdle to get the beneficial impacts of the energy transition. This can be done by channeling more investments towards renewable energy deployment (Bhattacharya et al. 2016). On the other hand, more attention should be emphasized on the EU’s manufacturing sector since the manufacturing sector is highly energy intensive and can play a crucial role in a country’s energy transition (Graevenitz and Rottner 2023). In this context, the “European Green Deal” adopted by the EU nations is a key strategy for promoting a just and inclusive transition. Therefore, EU countries should focus on making the strategy successful. The study further suggests accelerating the wide penetration of ICTs and developing the digital infrastructure throughout these economies to make their growth inclusive and green. This policy implication allies with the policy provided by Xin et al. (2023) for the Chinese cities. Further, these countries should be careful while integrating with other nations economically, as economic integration may fail to include the lower section of society and worsen environmental quality. Therefore, if these economies' policymakers want to promote IGG, they must rethink and redesign their FDI and trade policies (Ofori and Figari 2023).

Future research could explore the temporal and geographical scope beyond the study's limitations, incorporating more comprehensive data sources and alternative methodologies to validate causality relationships. A deeper analysis of sector-specific impacts and policy mechanisms could provide valuable insights for policymakers promoting IGG amidst energy transitions. Dynamic modeling techniques can capture the evolving nature of this relationship, while comparative studies across regions could enhance external validity and inform broader policy discussions on sustainable development.

Appendix

The PCA transforms highly correlated variables (indicators) into mutually orthogonal principal components (PCs), i.e., corr (P_i, P_j) = 0, where P_i and P_j are the ith and jth PCs. The PCs have the property that the first component holds the largest proportion, the second component holds the second largest proportion of total variation in all indicators, and so on. If we compute as many PCs as the number of indicators, we can fully explain the total variation of all indicators. The composite index (CI) is defined as the weighted average of all PCs: $CI = \frac{\lambda_1 P_1 + \lambda_2 P_2 + \ldots + \lambda_k P_k}{\lambda_1 + \lambda_2 + \ldots + \lambda_k}$

where $P_1, P_2, \ldots, P_k$ are the k-number of PCs and $\lambda_1 > \lambda_2 > \ldots > \lambda_k$ are the successive eigenvalues of the k × k correlation matrix of the indicators. The eigenvalues of the correlation matrix R can be computed by solving the determinant equation $|R - \lambda I| = 0$.

Corresponding to each eigenvalue (λ_i), the k×1 eigenvector can be obtained by solving the matrix equation $(R - \lambda_i I)\alpha_i = 0$. Finally, the PCs are obtained as normalized linear functions of the standardized variables:

$$\begin{array}{l} P_{1,it} = X_{it}\alpha_1 \\ P_{2,it} = X_{it}\alpha_2 \\ \quad \vdots \\ P_{k,it} = X_{it}\alpha_k \end{array}$$

where X_{it} refers to the vector of standardized variables for the ith country in t time period. However, before applying PCA, all the variables are normalized to ensure that they are positively related to the index. The following normalization method has been followed:

For negative indicators, $x_{ij} = \frac{Max(X_{ij}) - X_{ij}}{Max(X_{ij}) - Min(X_{ij})}$

For positive indicators, $x_{ij} = \frac{X_{ij} - Min(X_{ij})}{Max(X_{ij}) - Min(X_{ij})}$

where $Max(X_{ij})$ and $Min(X_{ij})$ are the maximum and minimum values of the j^{th} observation of i^{th} country. It will transform all the indicators on a scale of 0–1, where the lowest value is 0 and the highest value is 1.

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