

Economic and Social Determinants of Green Growth: An Empirical Study on Europe Union Countries

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ABSTRACT

Purpose: The aim of this study is to empirically analyze the socio-economic determinants of green growth in EU countries from a holistic perspective. Green growth is defined as the dependent variable, while per capita carbon emissions, per capita income, energy consumption, and human development are defined as independent variables. In this study, the effects of these variables on green growth were measured using annual data from the period 2010-2023.

Methodology: In order to reveal the economic and social determinants of green growth, panel data analysis methods such as fixed effects, random effects and Hausman methods were used.

Findings: It is concluded that human development has a positive and statistically significant effect on green growth, whereas per capita energy consumption has a negative impact on green growth. Green growth was found to have a positive and significant impact on per capita income, but no statistically significant effect was found between carbon emissions and green growth.

Originality: In the literature, there are very few empirical studies that address the economic and social determinants of green growth from a holistic perspective, define green growth as the dependent variable, and use Global Green Growth Index data. This study empirically reveals the determinants of green growth and offers policy recommendations for designing green growth policies.

Keywords: Green Growth, European Union Countries, Sustainable Development, Energy Consumption, Human Development Index.

JEL Codes: O13, O44, Q56.

Yeşil Büyümenin Ekonomik ve Sosyal Belirleyicileri: AB Ülkeleri Üzerine Ampirik Bir İnceleme

ÖZET

Amaç: Bu çalışmanın amacı AB ülkelerinde yeşil büyümenin sosyal ve ekonomik belirleyicilerini bütüncül bir bakış açısıyla ampirik olarak analiz etmektir. Yeşil büyüme bağımlı değişken, kişi başına karbon emisyonları, kişi başına gelir, enerji tüketimi ve insani gelişim bağımsız değişken olarak tanımlanmıştır. Çalışmada bu değişkenlerin yeşil büyüme üzerindeki etkileri 2010-2023 dönemine ait yıllık veriler esas alınarak ölçülmüştür.

Yöntem: Yeşil büyümenin ekonomik ve sosyal belirleyicilerini ortaya koyabilmek için panel veri analiz yöntemleri olan sabit etkiler, rassal etkiler ve Hausman yöntemleri kullanılmıştır.

Bulgular: İnsani gelişimin yeşil büyüme üzerindeki etkisinin olumlu ve anlamlı olduğu, kişi başına enerji tüketiminin ise yeşil büyüme üzerinde olumsuz etkiye sahip olduğu sonucuna ulaşılmıştır. Yeşil büyümenin kişi başına düşen gelirden pozitif ve anlamlı bir etkisi olduğu tespit edilmiş, karbon emisyonları ile yeşil büyüme arasında istatistiksel olarak anlamlı bir etki bulunamamıştır.

Özgünlük: Literatürde yeşil büyümenin ekonomik ve sosyal belirleyicilerini bütüncül bir bakış açısıyla ele alan, yeşil büyümeyi bağımlı değişken olarak tanımlayan ve Küresel Yeşil Büyüme İndeksi verilerini kullanan ampirik çalışmaların sayısı oldukça sınırlıdır. Çalışma, yeşil büyümenin belirleyicilerini ampirik olarak ortaya koymakta ve yeşil büyüme politikalarının tasarlanmasında politika önerileri sunmaktadır.

Anahtar Kelimeler: Yeşil Büyüme, Avrupa Birliği Ülkeleri, Sürdürülebilir Kalkınma, Enerji Tüketimi, İnsani Gelişim Endeksi.

JEL Kodları: O13, O44, Q56.

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DOI: 10.51551/verimlilik.1781877

Research Article | Submitted: 11.09.2025 | Accepted: 11.03.2026

Cite: Terzi, G. and Ak Harunoğulları, Ö. (2026). "Economic and Social Determinants of Green Growth: An Empirical Study on Europe Union Countries", *Verimlilik Dergisi*, 60(2), 631-646.

1. INTRODUCTION

In recent years, interest in green economy and green growth has increased globally. The increasing prevalence of environmental problems necessitates a move away from traditional economic models and the emergence of a green economy as an alternative economic model (Šneiderienė et al., 2020). Traditional growth models lead to resource scarcity, environmental damage, and negative impacts on human health, which helps maintain the relevance of the green growth concept. Furthermore, the transition to a green growth model is vital for adapting to climate change and reducing emissions (Naimoğlu, 2022).

The concept of green growth represents a dynamic transition from a brown economy to a green economy. Green growth is a sustainable development model that develops through eco-technological efficiency, combats poverty, ensures human well-being, and has a positive impact on social inclusion (Sarkodie et al., 2023). The lack of an accepted definition of the concept in international platforms has led to the emergence of different definitions. According to the OECD, green growth: The goal of green growth is to utilize natural capital and support growth by taking into account the carrying capacity of natural resources. According to the World Bank's definition, green growth is a growth model that uses natural resources efficiently and considers environmental pollution and degradation. The Global Green Growth Institute, on the other hand, sees green growth as a revolutionary economic model and cites the growing importance of environmental sustainability (Allen and Clouth, 2012: 36).

The most important goal of the green growth model is to improve natural resource management, increase production, and focus on the mutually reinforcing aspects of economic and environmental policy. Another goal is to seek cost-effective solutions to ensure that environmental capacity is not exceeded at the local, regional, or global scale and to ensure the transition to a green economy model. Green growth has the potential to increase productivity, utilize natural resources at their highest value, create new job opportunities, devise new environmental policies, and establish balanced macroeconomic conditions. However, there is no single green growth prescription that fits all countries. Countries will face different opportunities and challenges depending on their level of development (Kanińska, 2017: 35).

The emergence and adoption of green growth by countries is attributed to the 2008 financial crisis. The financial crisis, which originated in the US in 2008 and had devastating effects on all countries, brought about a decrease in global growth figures, unemployment, an increase in public debt, and a contraction in world trade volume. The effects of the crisis were felt not only in the economic sphere but also in the environmental and social spheres. Countries that learned from the crisis turned to green policies, which accelerated the transition to environmentally friendly economic models. Looking specifically at the EU, it is seen that the union has focused on sustainable development and green economy policies since the 1990s, supporting green investments and trying to build a carbon-free development model (Gevher and Acet, 2023). Furthermore, the EU views green growth as an alternative way to overcome financial crises. With the strategies put forth by the EU, the aim is to eliminate the conflict between economy and ecology by abandoning brown growth (Bongardt and Torres, 2010). In this context, it is observed that the EU introduced a new growth strategy in 2019 called the "European Green Deal". The European Green Deal is a roadmap and strategic plan for the EU economy to become a sustainable and green economy. The main objective of this plan is to ensure fairness during the green transformation, to leave no one behind, and to shape the roadmap accordingly by determining social, environmental and economic priorities. Within this scope, the EU sets three targets for the European Green Deal until 2050 (Eren, 2021: 142-143):

- Reducing greenhouse gas emissions to zero by 2050, the carbon-neutral continent target (environmental dimension),
- Ensuring economic growth independent of resource use (economic dimension),
- Leaving no one behind (social dimension).

However, the 2008 crisis is considered one of the most significant crises in EU history due to its impact on both economic growth and employment. In 2009, the EU experienced a 4% drop in GDP. During the same period, 10% of the population became unemployed, and planned investments faced risks due to stagnant demand and a lack of funding. In this context, taking new steps to overcome the crisis became a necessity for the Union, and the necessary strategy was adopted as "Europe 2020". The most important objectives defined in the strategy are as follows (European Commission, 2010: 14):

- A 20% reduction in greenhouse gas emissions compared to 1990,
- A 20% increase in energy efficiency,
- A 20% increase in the share of renewable energy sources in final energy consumption.

The main objective of the "Europe 2020" strategy put forward by the EU is to promote sustainable and inclusive green growth. As a result of this approach, the Union will achieve its carbon neutrality target, preventing biodiversity loss and eliminating unsustainable resource use in a world with limited resources

(European Commission, 2010: 14). A global assessment of the environmental pollution caused shows that EU countries, along with the USA, China, and Russia, are among the top four. In 2017, China's share of total global carbon emissions was 28%, while the EU's share was calculated at 10.6%. Despite this negative picture, the EU is considered an economic integration with a high level of awareness regarding ecological sensitivity and evolving environmental standards. Thanks to the synergy created by the Union, combating climate change has become one of its priority goals (Eren, 2021: 142). The EU has implemented various environmental programs, particularly between 1973 and 2020. The impact of the 1970s oil crisis on the EU and the dependence of member states on fossil fuel imports, threatening energy security, have increased the importance given to green growth. The intractable environmental problems caused by the use of fossil fuels have made it imperative for the EU to adopt a holistic approach to environmental, climate, and energy policies. In this context, the EU has developed the "2030 Climate and Energy Framework" to combat climate change. Within the framework of this strategy, member states have set targets to reduce greenhouse gas emissions and dependence on fossil fuels, and to increase energy efficiency (Kakışım, 2022). Various steps have also been taken to decarbonize the energy system and increase energy efficiency. The aim is to reduce emissions by 55% by 2030, increase the share of renewable energy in the energy mix to 40%, and reduce energy consumption costs (European Commission, 2021: 17). The EU's goal of becoming a carbon-neutral continent, the steps it has taken to transform its energy system, and its policies aimed at reducing energy costs and incentivizing sustainable investments will have positive effects on both the economic and social dimensions of green growth. EU climate change policies, such as the "European Green Deal," "Europe 2020," and the "Climate and Energy Framework 2030," are shifting the direction of fossil fuel-dependent energy investments, increasing the use of renewable energy, and this is positively impacting the green growth performance of member countries.

Green growth is seen as quite important in EU countries. The importance of green growth policies stems from their contribution to improving human well-being and creating green jobs and opportunities befitting human dignity. The plans put forward call for the active activation of state policies to achieve social and economic goals such as creating quality jobs, eradicating poverty, and ensuring comprehensive and green growth, while simultaneously combating global warming and climate change (Streimikiene, 2024: 86). From this perspective, it can be said that the main goal of green growth policies implemented by the EU is to support long-term development by ensuring both environmental sustainability and economic growth and human well-being. At this point, it is clear that sustainable development needs to be supported by certain mechanisms. The EU aims to strengthen the economy while simultaneously leaving a livable world for future generations. Adopting environmentally friendly practices that consider technological innovations instead of traditional production methods plays a crucial role in countries achieving green growth. The abandonment of fossil fuel use and investments in renewable energy, along with the recycling of waste generated from production, are closely related to green technology. The adoption of this approach by EU countries aligns with the European Green Deal and the Europe 2020 Strategy. Promoting renewable energy, increasing energy efficiency, pursuing a carbon-neutral continent goal, and green innovation constitute a multi-dimensional green growth plan for the EU. This underscores the need for a holistic approach to green growth (Kekül, 2025).

Most studies in the green growth literature focus on the relationship between economic growth and the environment, and the relationship between energy and carbon emissions. Studies that consider economic and social determinants within the same model are quite limited. This study aims to contribute to filling this gap in the literature and to address green growth not only as an environmental outcome but also as a multidimensional concept related to social welfare and social development. Studies in the existing literature generally consider variables such as per capita income, per capita carbon emissions, and energy consumption in pairs, across different periods and different country groups. Green growth is mostly expressed in terms of environmental indicators, and the social dimension is not sufficiently considered. Furthermore, the Global Green Growth Index data is rarely used in the literature. In this study, annual data for EU countries for the period 2010-2023 are analyzed using panel data methods. Unlike previous studies, green growth is defined as the dependent variable, while per capita income, per capita carbon emissions, energy consumption, and human development are defined as independent variables. The main questions of the study can be stated as follows:

- What is the impact of per capita income on green growth in EU countries?
- What is the relationship between per capita carbon emissions and green growth?
- Does human development have a statistically significant impact on green growth?
- Is there a statistically significant relationship between per capita energy consumption and green growth?

The findings indicate that human development, representing the social dimension, and per capita income, an indicator of economic well-being, play a significant role in supporting green growth. However, carbon emissions, representing the environmental dimension, do not have a statistically significant effect on green

growth. In this respect, the study offers a contemporary perspective that highlights the social dimension of green growth.

This study will begin with a literature review, focusing on empirical studies. The following section will examine green growth indicators and evaluate the performance of EU countries in the Global Green Growth Index ranking. Next, information will be provided about the dataset, model, and methodology used in the study, and the findings will be evaluated. The conclusion section will summarize the study and offer policy recommendations.

2. LITERATURE REVIEW

The literature contains very few studies that directly address green growth as a dependent variable and offer comprehensive empirical analyses. However, recent studies have focused on the relationship between green growth and numerous issues, such as financial development, economic growth, carbon emissions, eco-innovations, sustainable development, energy consumption, and environmental sustainability. Therefore, only studies related to green growth will be discussed here. Lukas (2015), in a study evaluating 60 countries, found that the Global Green Economy Index has a negative impact on economic growth but a positive impact on per capita income and poverty reduction. Akin and Akçayır (2025) examine the effects of human development and renewable energy consumption on green production in Mexico, Indonesia, South Korea, and Türkiye during the 1990-2021 period, using unit root and cointegration tests within a panel data framework and an AMG estimator that takes heterogeneity into account. The study reveals a positive and significant relationship between renewable energy and human development, and shows that increased carbon emissions have a negative impact on human development.

Fernandes et al. (2021) examined the impact of green growth on economic growth in 32 countries using OECD data between 1990 and 2013. According to the study, it is possible for green growth and economic growth to coexist. Green growth has a direct and positive impact on economic growth. Bahtiyar and Mukiyen Avcı (2025), in their study examining the dynamics of green growth in 35 OECD countries, analyzed data from 1996-2022 using the GMM dynamic panel data analysis method. According to the study's findings, the increase in per capita income leads to an increase in production-based carbon emissions, which negatively impacts both environmental pollution and green growth. Ağaoğlu (2023), using data from 1990-2019 and the Granger Causality test, investigated the applicability of green growth and non-growth policies in terms of sustainable development. The study used the Human Development Index, carbon emissions per unit of production, energy supply, and real GDP variables. The results showed that green growth policies are more applicable in achieving sustainable development. The study emphasizes that the energy and environmental indicators added to the model for green growth have a positive effect on human development, while carbon emissions per unit of production have a negative effect on human development. In the study by Khan et al. (2023a), the impact of natural resources on economic growth in G7 countries during the period 1990-2020 is measured within the framework of green growth and human development. It is shown that green growth policies and human development have a positive effect on economic growth, while the use of natural resources can weaken this positive effect. The study reveals that for sustainable development to occur, policies that increase green growth and human development must be implemented simultaneously. Liu et al. (2023), in this study, investigates the relationship between green growth and human development in China using the ARDL technique. The study concludes that human development has a positive effect on green growth. In particular, the improvement in the educational level of society leads to an increase in ecological awareness.

Taşkın et al. (2020) examine the relationship between renewable energy consumption and green growth using panel cointegration tests for OECD countries during the period 1990-2015. They emphasize that the use of renewable energy reduces carbon emissions and has a positive effect on green growth. Tawiah et al. (2021) attempted to identify the factors affecting green growth using data from 123 developed and developing countries between 2000 and 2017. Empirical results indicate that renewable energy consumption enhances green growth, while energy consumption hinders green growth. The study reveals that economic growth is positively and significantly related to green growth in developed countries. Houssini and Geng (2022) analyze Morocco's green growth efficiency between 2000 and 2018 using the TOPSIS model. While Morocco has made significant progress in its green growth performance over the years, its dependence on fossil fuels has led to increased costs. Morocco's ability to make progress in green growth depends on new strategies it will implement in this area. Zaman et al. (2016) measured the impact of green growth on sustainable development using panel cointegration analysis for the BRICS countries over the period 1975-2013. The study found that dependence on fossil fuels is the most significant obstacle to green growth. Energy diversification in BRICS countries has positive effects on economic growth.

In this study, conducted specifically in China, Sun et al. (2022) used green growth as a control variable to demonstrate the relationship between carbon emissions and economic growth. The study found a long-

term equilibrium between economic growth and carbon emissions. Green growth, in turn, plays a significant role in eliminating environmental problems and supporting sustainable development. Açıcı et al. (2023) demonstrate the effects of green growth on economic growth in EU countries using data from 2004 to 2018. The study emphasizes that green growth has a positive impact on both economic growth and per capita income.

Altıntaş (2022) used the entropy-based ELECTRE method to measure the green growth performance of G7 countries using 2019 data. The study first analyzes the values of the Global Green Growth Index dimensions to reveal the green growth performance of countries. Importance levels were determined by ranking the dimensions of the Green Growth Index. Accordingly, the order of importance was determined as follows: green opportunities, social context, conservation of natural capital, and efficient and effective sustainable energy use. In the second analysis using the ELECTRE method, Germany, France, and the UK ranked in the top three in the ranking of countries' green growth performance based on the dominance theory of net congruence and dissonance. Compared to other countries, the US's green growth success was found to lag behind other countries. Amin et al. (2025) conducted this study specifically on China. Using wavelet analysis and considering data from 1990-2018, the study found that renewable energy and green growth have a carbon emission-reducing effect. Dam et al. (2024) covered 30 OECD countries and used PMG-ARDL analysis to measure the impact of green growth and corporate quality on carbon emissions, ecological footprint, and reverse load capacity during the 1996-2020 period. The study showed that green growth has a long-term carbon emission-reducing effect and also has a positive impact on sustainability. Dogan et al. (2022) conducted a study to measure the impact of green growth and environmental taxes on carbon emissions in 25 environmentally friendly countries. Using innovative quantile regression, the study covered the period 1994-2018. The study found that green growth significantly reduces carbon emissions.

Zhao et al. (2023) examine the relationship between green growth and carbon emissions in this study using panel data regression. The study concludes that green growth reduces carbon emissions. Hussain et al. (2022) investigate the effects of green growth, energy consumption, and green technologies on environmental sustainability in high-income countries between 2000 and 2020. According to the study, green growth has a carbon emission-reducing effect. Environmental sustainability supports societal well-being, and green growth contributes to human development. Energy consumption, when supported by green policies, has positive effects on human development. A study by Hidayah et al. (2023) surprisingly concluded that carbon emissions have a positive impact on green growth. Khan et al. (2023b) investigated how green growth and eco-innovations could contribute to a more sustainable environment in EU countries between 2000 and 2020. Using panel quantile regression analysis, the study found that linear and nonlinear green growth strategies have a reducing effect on carbon emissions. However, economic growth has a positive impact on carbon emissions. This situation has important policy implications for EU countries, encouraging governments to implement green growth and renewable energy. Işık (2025) investigated the impact of green growth on sustainable development in 16 selected EU countries. The study concluded that green growth plays a critical role in achieving sustainable development.

Liang et al. (2024) conducted a study on the E-7 countries, showing that long-term positive changes in energy use have a positive and significant impact on carbon emissions, green growth, and the ecological footprint, while negative shocks have a positive and significant impact on green growth and carbon emissions. Naimoğlu (2022), in a study investigating the effect of renewable energy use on green growth, revealed that renewable energy use increases green growth and leads to a decrease in carbon emissions. Kadioğlu (2024) examined the relationship between carbon emissions and green growth in Türkiye between 1990 and 2020. According to the study, financial development and total energy production positively affect carbon emissions. This effect has a positive impact on green growth due to the increase in carbon emissions. Al-Ghamdi et al. (2024), measuring the relationship between economic growth and green growth, emphasized that carbon emissions have a negative impact on economic growth, and that as carbon emissions decrease, the potential for green growth increases.

Kuloğlu (2025) examines the relationship between green growth, financial development, innovation, and human development in developed and developing countries over the period 1990-2020. Green growth is defined as the dependent variable in the study, while the Financial Development Index, the number of patents, and the Human Development Index are defined as independent variables. The model estimated with Driscoll-Kraay standard errors reveals that financial development and innovation have a positive and significant effect on green growth in developed countries. According to the study's findings, the Human Development Index has no significant effect on green growth. Nur et al. (2025) measured the impact of energy intensity, financial development, and renewable energy on green growth in 23 OECD countries. The findings indicate that financial growth and energy intensity have a negative effect on green growth, while renewable energy use has a positive effect on green growth. Furthermore, stringent environmental policies have a supportive effect on green growth. Baniya et al. (2021) analyzes how economic growth can be greened using data from Bangladesh and Nepal for the period 1985-2016. The study finds that green growth

has limited performance in developing countries like Nepal and Bangladesh because renewable energy has not been incorporated into their energy mix. The positive impact of green growth depends on the transformation in energy consumption. Çetin et al. (2025) discuss the role that green growth can play in enabling G-7 countries to become carbon-neutral economies in this study. The study examines the relationship between green growth, carbon emissions, and energy efficiency in the period 1990-2019 using the Westerlund cointegration test and the Driscoll-Kraay estimator. According to the study's findings, green growth and energy efficiency lead to a reduction in carbon emissions. The findings suggest that policymakers need to take significant and rapid steps regarding green growth and energy efficiency to ensure environmental sustainability.

The green growth literature mainly focuses on the relationship between economic growth and environmental sustainability. However, the number of empirical studies analyzing the relationship between human development and green growth is quite limited. The relationship between the multidimensional structure of the Human Development Index and green growth has not been addressed specifically in EU countries and from a holistic perspective. Furthermore, studies that do not directly address green growth mostly offer indirect inferences about the relationship between sustainable development and green growth. These studies focus on the environmental impacts of improvements in welfare levels, transformations in energy structures, and human development. In this context, the present study provides a comprehensive perspective on green growth by combining economic, environmental, and social elements under one umbrella.

3. GREEN GROWTH INDICATORS and the GREEN GROWTH PERFORMANCE of EU COUNTRIES

A review of the green growth literature reveals a diverse range of green indicator sets and indices. The first of these is the green growth indicators developed by OECD countries to recover their economies after the 2008 crisis, which led to a global recession. In the post-crisis period, OECD countries developed a new approach that ensures not only economic growth but also environmental sustainability (OECD, 2015). The "Green Growth Strategy" was adopted in 2011. The strategy aims to create new economic opportunities, protect the rights of future generations over natural resources, and achieve sustainable development. The indicator set includes five main indicators and sub-indicators related to these indicators (OECD, 2011). The indicator groups are shown in the Figure 1.



Figure 1. Indicator groups and topics covered (OECD, 2011:12).

The Global Green Growth Institute developed the "Global Green Growth Index" to measure countries' success in transitioning to environmental sustainability and inclusive economic growth models. The index consists of the dimensions "efficient and sustainable resource use," "protection of natural capital," "green economic opportunities," and "social inclusion" (GGGI, 2019). This index was chosen for this study because it is comprehensive and allows countries to measure their performance across each dimension. The Figure 2 provides comprehensive information about the index's dimensions.

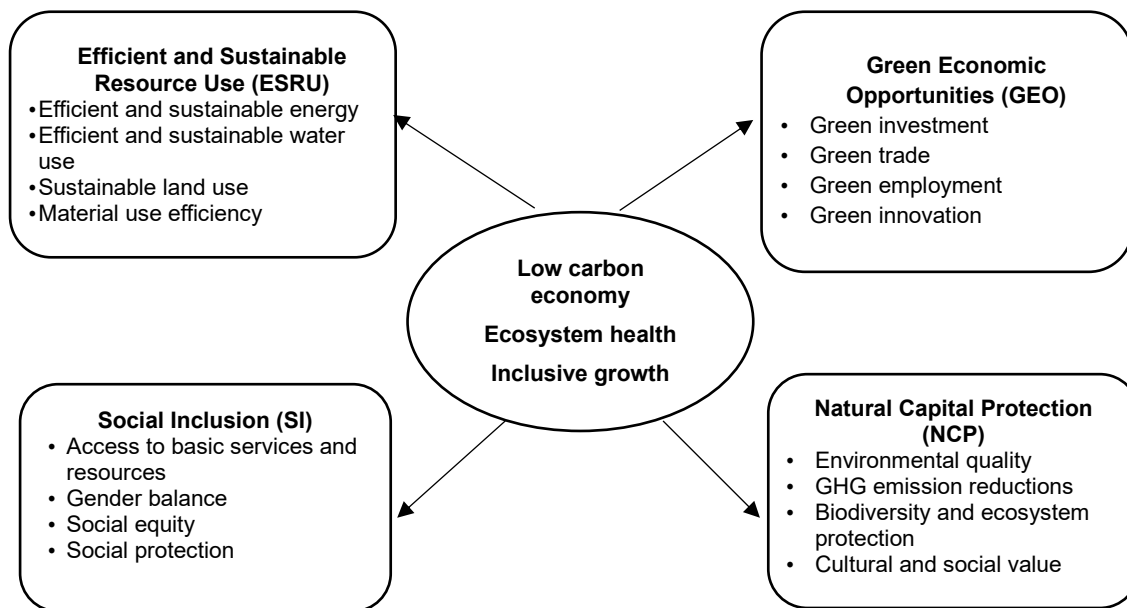


Figure 2. Conceptual framework for the Green Growth Index (Acosta, 2023: 3).

A score of 100 on the index indicates that the country has achieved the specified target. The classification ranges for the scores are determined as follows (Acosta, 2023:3):

- 81-100 are very high scores and indicate that the country has achieved or is close to achieving its goal.
- 61-80 are high scores. They represent a strategic position in achieving the goal.
- 41-60 are moderate scores.
- 21-40 represent a low score.
- 1-20 represents a very low score. Active participation is necessary to achieve the goal.

Table 1 shows the performance of countries over the years in the "Efficient and Sustainable Resource Use" dimension, which consists of "efficient and sustainable energy," "efficient and sustainable water use," "sustainable land use," and "material use efficiency." In 2010, Austria received the highest score in this dimension. Showing increasing performance over the years, it rose to 79.64 points in 2023. Belgium, Malta, Bulgaria, Cyprus, and Poland had very low scores in this dimension. In 2023, Austria, Sweden, Denmark, and Slovakia received the highest scores. The EU has made progress in the efficient and sustainable resource dimension. The "Circular Economy Action Plan" is the most fundamental reason for this success. This plan provides a basic framework for Europe to become a carbon-neutral continent and to protect biodiversity by removing pressure on natural resources. Aiming to minimize resource consumption, the Union aims to eliminate the "take-make-use-discard" approach. The success of EU countries in all dimensions has shown a slight increase over the years (Acosta, 2023: 30).

In the dimension of Protecting Natural Capital, which includes environmental quality, reduction of greenhouse gas emissions, protection of biodiversity and ecosystems, and cultural and social values, Slovakia is seen as the leading country throughout the period examined. While Croatia held a strategic position in achieving the target in the first three years of the period examined, it moved to the very high score category in subsequent years, placing second after Slovakia. Ireland, with a score between 55 and 58 between 2010-2023, showed a moderate performance and ranked last. The improvement seen in the dimension of protecting natural capital can be attributed primarily to efforts to reduce greenhouse gas emissions. Despite the success achieved in this dimension, the EU's goal of becoming a carbon-neutral continent by 2050 seems like an ambitious target. This is because the rate of carbon emission reduction has been fluctuating. In particular, the increase in emissions seen in some sectors in the post-pandemic period is negatively impacting emission reduction targets (Acosta, 2023: 30).

In the dimension of Social Inclusion, which consists of access to basic services and resources, gender balance, social equality, and social protection, countries perform better compared to other dimensions. The very high scores received by countries indicate that they have reached or are close to reaching their goals in this dimension. In 2010, Croatia received the lowest score, while Sweden received the highest. In 2023, Cyprus received the lowest score, while Finland received the highest. It is observed that EU countries received the highest scores in the dimensions of social inclusion and natural capital conservation, while in contrast to the success shown in these two dimensions, countries achieved the lowest performance in the green economic opportunities dimension. Overall, all countries showed low performance in the dimension

consisting of green investment, green trade, green employment, and green innovation. This situation is not only true for EU countries but also for other countries whose index scores were calculated. However, no EU country received a very low score between 1 and 20. In 2010, Latvia received the lowest score, while Denmark received the highest. In 2023, Malta received the lowest score, while Germany received the highest. This is especially true for Southern European countries such as Greece and Malta. Low performance in green employment and green innovation is the main reason why these countries perform less well in the green economic opportunities dimension. To achieve success in the green growth index ranking, countries should focus on the dimensions where they perform worse, such as green innovation, green trade, green jobs, and green investment (Acosta, 2023: 30).

Table 1. Green growth performance of EU countries according to the Global Green Growth Index (2010-2023)

Countries	Efficient and Sustainable Resource Use (ESRU)		Natural Capital Conservation (NCP)		Green Economic Opportunities (GEO)		Social Inclusion (SI)	
	2010	2023	2010	2023	2010	2023	2010	2023
Austria	77,22	79,64	78,80	80,41	50,07	51,48	91,87	94,59
Belgium	36,53	51,34	74,78	77,04	42,37	41,74	89,13	95,52
Bulgaria	47,58	52,62	78,25	80,54	40,50	42,29	82,48	86,73
Croatia	58,73	65,21	75,71	83,78	42,06	40,11	77,87	90,40
Cyprus	54,28	58,23	65,40	74,00	51,11	33,94	82,79	83,72
Czechia	70,76	77,42	80,66	81,96	55,02	51,31	86,98	91,27
Denmark	71,21	78,42	70,79	73,71	61,51	57,83	93,73	94,67
Estonia	61,74	65,28	76,09	77,51	47,20	44,91	89,70	91,74
Finland	65,92	70,22	71,60	72,35	50,52	52,17	94,63	95,77
France	60,69	67,60	74,84	79,14	41,56	42,49	89,86	94,07
Germany	56,88	67,16	80,88	82,97	57,38	58,66	88,24	93,44
Greece	57,38	62,87	74,17	77,84	36,76	30,05	83,92	89,44
Hungary	62,77	66,93	81,52	81,84	51,55	46,46	80,93	85,38
Ireland	57,87	61,42	55,52	58,04	41,35	33,55	85,68	89,61
Italy	62,62	65,03	77,99	80,38	42,46	45,76	87,22	91,75
Latvia	68,30	71,95	79,15	78,52	34,72	34,64	86,40	90,58
Lithuania	60,21	69,83	73,82	74,57	41,80	41,23	85,60	89,98
Luxembourg	70,80	73,96	71,91	77,64	42,49	36,75	91,60	92,79
Malta	44,51	45,62	68,77	74,23	39,84	28,41	83,52	86,91
Netherlands	54,53	59,58	71,26	73,47	51,05	50,72	94,44	94,02
Poland	53,64	59,31	74,90	75,99	43,58	43,76	80,03	90,31
Portugal	61,45	64,28	74,65	79,51	37,61	41,97	90,01	93,35
Romania	60,44	63,90	74,10	78,06	39,13	39,84	83,42	86,17
Slovakia	70,73	76,05	83,05	84,66	43,80	48,94	83,26	87,81
Slovenia	57,78	62,06	79,46	78,81	45,98	45,95	85,79	90,04
Spain	53,87	60,69	73,82	76,70	45,00	42,20	89,16	93,48
Sweden	73,81	79,49	76,11	78,43	49,28	45,22	95,14	95,59

Source: GGGI (2023).

4. DATA SET of the RESEARCH

In this study, the determinants of green growth were analyzed using a balanced panel data set covering annual data for the period 2010–2023 for 27 European Union member countries ($N = 27$, $T = 14$, $N \times T = 378$). These years were preferred in the analysis because all data for the 2010–2023 period for EU countries were available. Green growth data were compiled from the GGGI (2023), GDP per capita and carbon emissions per capita from the World Bank (2023), Human Development Index data from the UNDP (2023), and energy consumption per capita from Our World in Data (2023). Green growth was defined as the dependent variable; explanatory variables included CO₂ emissions per capita, Gross Domestic Product (GDP) per capita, Human Development Index (HDI), and energy consumption per capita.

Table 2. Variables (2010-2023 Data).

Dependent Variable	Independent Variables
Green Growth	CO ₂ Emissions per Capita GDP per capita Human Development Index (HDI) Energy Consumption Per Capita

Source: GGGI (2023), World Bank (2023), UNDP (2023), Our World in Data (2023).

The variables used in this study are based on both theoretical and empirical literature. Although these variables are frequently used in the green growth literature, the aim of this study is not to repeat them, but to reveal the economic and social dimensions of green growth. Per capita income is a variable included in the analysis to reveal the economic infrastructure of green growth. Per capita carbon emissions provide information about the environmental cost of economic growth and also reflect environmental sustainability. Human development, consisting of income, education, and health components, reflects not only economic well-being but also the level of social development. Since green growth is related not only to environmental outputs but also to people's quality of life and social well-being, human development has been defined as one of the variables in this study. Energy is considered a basic input for economic activities and provides information about the production, distribution, and consumption structure of societies (Kanianska, 2017: 35). In short, the most important factor in selecting per capita carbon emissions, per capita income, per capita energy consumption, and human development as determinants of green growth in this study is the multidimensional nature of green growth. Green growth is a concept that encompasses not only environmental but also social and economic aspects. In this research, carbon emissions represent the environmental dimension, per capita income represents the welfare dimension, and human development represents the social development dimension. Per capita energy consumption reveals the relationship between production processes and their environmental impacts. Including these four variables in the analysis helps to evaluate the dynamics of green growth from a holistic perspective.

4.1. Econometric Method and Model Selection

Although the time dimension ($T=14$) used in this study is considered limited for time series analyses, the panel data approach increases the number of observations by combining the time dimension with the cross-sectional dimension, allowing for more reliable estimations. In panel data analyses, cross-sectional dependence plays a critical role in the reliability of results, especially when similar economic and environmental conditions exist between countries, and contributes to the effective analysis of relationships between variables even in short and medium-length time dimensions. In this study, panel data analyses were performed using the R program. The plm package was used as the basis for the econometric modeling process; the pggls() function was used for the Feasible Generalized Least Squares (FGLS) method within the scope of panel regression estimations. In addition, pooled regression, fixed effects, and random effects approaches were applied through the plm() function in the estimation of panel data models. For model selection, the F-test (pFtest()), Breusch-Pagan LM test (plmtest()), and Hausman test (phtest()) were used. To test the model assumptions, the Wooldridge test for autocorrelation (pbgtest()), the Breusch-Pagan test for heteroskedasticity (bptest()), and the Pesaran CD test for cross-sectional dependence (pcdtest()) were applied.

Determining the appropriate model in panel data analysis is critical to the validity of the results. In this study, the most appropriate model was determined by applying three different tests:

F Test (Fixed Effects Necessity Test): This test tests whether the fixed effects model (FE) performs significantly better than the pooled OLS model. The results show that including fixed effects in the model provides a statistically significant improvement. This suggests that time-invariant characteristics of countries (e.g., institutional structure, geography, energy resources) could potentially have an impact on green growth.

Breusch-Pagan LM Test (Random Effects Necessity Test): This test tests the superiority of the random effects model over pooled OLS. The results show that the random effects model also offers a significant improvement over pooled OLS. This confirms that the panel feature in the data structure is strong and that the time dimension contains meaningful information.

Hausman Test (Fixed or Random?): The Hausman test, one of the most critical tests for model selection, allows comparison of fixed effects (FE) and random effects (RE) models. The test result ($p = 0.0897 < 0.10$) indicates that the fixed effects model should be preferred at the 10% significance level. This finding suggests that unobserved heterogeneity across countries (e.g., environmental management capacity, public policy preferences, cultural factors) could potentially affect green growth, and that it would be more appropriate to include these differences in the model as fixed effects.

The study first tested for cross-sectional dependence in the panel data set using the Breusch-Pagan LM test. The Breusch-Pagan LM test result ($\text{stat} = 1485.2, p < 0.001$) revealed significant dependence among countries in the panel. This suggests that countries are mutually influenced by environmental and economic developments. Therefore, it was concluded that first-generation unit root tests are inappropriate because they assume cross-sectional independence, and second-generation panel unit root tests should be preferred.

To determine the model to be used in panel data analysis, the F test, the Breusch-Pagan Lagrange Multiplier (LM) test, and the Hausman test were applied. The F and LM tests revealed the superiority of the fixed and random effects models, respectively, over pooled OLS; the Hausman test statistically confirmed the preference for the fixed effects model (Fixed Effects - FE) ($p = 0.0897 < 0.1$). This suggests that incorporating unobservable fixed differences between countries (e.g., institutional structure, environmental management capacity, access to energy resources) into the model would increase the reliability of the estimates. Therefore, the FE model was selected as the primary estimation model. Finally, a serial correlation check was performed to test the reliability of the model estimates, and necessary corrections were made.

4.2. Fixed Effects (FE) Model Findings

The FE model results reveal that GDP per capita, Human Development Index, and per capita energy consumption have a statistically significant impact on green growth. The HDI and energy consumption variables, in particular, have a strong impact on green growth. The model's estimation results are presented in Table 3.

Table 3. Fixed effects (FE) model estimates

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>t-Value</i>	<i>p-Value</i>	<i>Comment</i>
Person CO2	0.0174	0.0092	1.89	0.060	Positive impact near the border ($p < 0.10$)
GDP per capita	0.0150	0.0067	2.23	0.026	Significant positive effect ($p < 0.05$)
Human Development Index	0.3946	0.0849	4.65	< 0.001	Strong positive and meaningful impact
Energy Consumption Per Capita	-0.0641	0.0151	-4.25	< 0.001	Strong negative impact

The model's R^2 value is 0.209, and the independent variables explain approximately 21% of the variation in green growth. The limited total effect suggests that the model may contain missing variables or structural breaks. Serial correlation was confirmed in the model's error terms using Breusch-Godfrey/Wooldridge tests ($\text{stat} = 172.08$, $p < 0.001$). This means that environmental development in a country one year can affect environmental policies, investments, or the quality of growth in the following year. If the model is estimated without considering this dependency, standard errors may be calculated incorrectly, making the results misleading. Therefore, the Feasible Generalized Least Squares (FGLS) method was applied to correct for this systematic error structure.

FGLS increases the reliability of standard errors by accounting for both serial correlation and heteroskedasticity, thus strengthening the statistical robustness of the model. Therefore, the FGLS model was implemented to increase the reliability of the estimates.

4.3. FGLS Model Results

The Feasible Generalized Least Squares (FGLS) method, implemented to eliminate serial correlation and heteroscedasticity issues, has yielded more robust results. FGLS offers more robust and reliable estimates by being sensitive to the model's error structure. In analyses conducted with this method, the basic findings obtained in the fixed-effects model were largely preserved; however, the significance level and coefficient size of some variables differed. This demonstrates the effectiveness of the FGLS method in addressing the model's inherent problems. The FGLS model estimates are listed in Table 4.

Table 4. FGLS model estimates

<i>Variable</i>	<i>Coefficient</i>	<i>Std. Error</i>	<i>z-Value</i>	<i>p-Value</i>	<i>Comment</i>
Person CO2	0.0015	0.0043	0.353	0.724	Insignificant
GDP per capita	0.0131	0.0040	3.30	0.001	Significant positive
Human Development Index	0.2804	0.0487	5.76	< 0.001	Strong positive
Energy Consumption Per Capita	-0.0410	0.0060	-6.85	< 0.001	Strong negative

The R^2 value of the model is quite high ($R^2 = 0.968$), indicating that the independent variables explain green growth to a very large extent. According to these results:

- Human Development Index (HDI): It stands out as the strongest positive determinant of green growth ($\beta = 0.2804$, $p < 0.001$). This finding supports the structural relationship between sustainable development and human development.

- Energy Consumption: This variable has the most negative impact on green growth ($\beta = -0.0410$, $p < 0.001$). This finding suggests that energy resources are insufficient in terms of environmental sustainability.
- GDP per capita: Maintains its positive and significant effect ($\beta = 0.0131$, $p = 0.001$). This finding indicates a positive interaction between economic well-being and environmental sustainability.
- CO₂ Emissions: This variable had no statistically significant effect on green growth ($p = 0.724$). This result suggests that CO₂ emissions have an impact through indirect mechanisms (carbon pricing, technological innovations, environmental policies, etc.) rather than directly affecting green growth.

When comparing the results of the fixed effects model with the FGLS model estimation results, the fixed effects model has relatively low explanatory power ($R^2 = 0.209$) and its explanatory power is limited due to the presence of serial correlation in the error terms. However, FGLS estimations, which take into account serial correlation and heteroskedasticity, significantly increase the explanatory power of the model ($R^2 = 0.968$) and strengthen the statistical reliability of the coefficients. Furthermore, the signs of the principal variables remain consistent in both models.

4.4. Findings

According to the findings, economic growth and human development contribute to green growth, while energy consumption has negative effects on environmental sustainability. These results confirm previous empirical studies. Education plays a crucial role in enhancing green growth in human development. Increased educational levels in societies contribute to environmental sustainability by raising ecological awareness (Liu et al., 2023). Ağaoğlu (2023) also obtained similar findings in this study. Environmental and energy policies representing green growth have a positive impact on human development and a negative impact on carbon emissions. A study that aligns with this finding is by Khan et al. (2023a). According to this study, green growth policies and human development have a positive impact on economic growth. Furthermore, policies that promote green growth and human development should be implemented simultaneously. Hussain et al. (2022) reached similar conclusions. It is shown that green growth reduces carbon emissions, supports societal well-being, and positively impacts human development. However, a study by Lukas (2015) reveals that green growth has a negative effect on economic growth. The same study emphasizes that green growth increases per capita income and has a positive effect on poverty reduction. Furthermore, the findings of some studies indicating that CO₂ emissions are not directly effective but rather through indirect channels are consistent with the literature. A study by Al-Ghamdi (2024) shows that carbon emissions decrease as green growth increases. Bahtiyar and Mukiyen Avcı (2025) found that, according to the results of this study, an increase in per capita income increases carbon emissions, which has a negative impact on green growth. Studies by Al-Ghamdi (2024), Dam et al. (2024), Doğan et al. (2022), and Zhao et al. (2023) show that carbon emissions decrease as green growth increases. A study by Hao et al. (2021) concluded that green growth reduces carbon emissions and has a positive effect on improving environmental quality. These findings in the literature are consistent with the results of the study. However, interestingly, a study by Hidayah et al. (2023) reveals that carbon emissions have a positive effect on green growth. The negative impact of energy consumption on green growth is also supported by studies by Baniya et al (2021), Hua et al. (2022) and Lei et al. (2022). Furthermore, according to the findings of a study by Nur et al. (2025), energy intensity has a negative impact on green growth. The findings of the study by Tawiah (2021) also support the negative impact of increased energy consumption on green growth. These studies in the literature are consistent with the results of this research.

It's safe to say that this study contradicts a study by Kuloğlu (2025), which demonstrated the relationship between human development and green growth. This study found that human development was the strongest positive determinant of green growth in EU countries. Kuloğlu emphasizes that there is no significant relationship between human development and green growth. While an increase in environmental sustainability is expected with increasing human development, Kuloğlu's study suggests the opposite. Some studies suggest that despite rising welfare levels, environmental damage may increase due to unsustainable consumption habits (Naimoğlu and Shahbaz, 2025).

In this study, unlike the literature, green growth is defined as the dependent variable, Global Green Growth Index data are used, and the determinants of green growth are examined with a holistic approach. The applied econometric tests indicate that the panel data set violates traditional assumptions, and therefore, advanced panel data techniques should be used in both model selection and estimation. In particular, considering fixed effects and opting for error-sensitive methods such as FGLS made the model's findings more reliable, both theoretically and statistically. This approach allows the study to more accurately analyze not only the causal relationships among variables but also the impact of countries' institutional and structural differences on green growth.

Green growth is not only an effort to achieve environmental goals, but also a development model that achieves social welfare and economic stability in an integrated manner. The findings of this study reiterate the necessity of this holistic approach for policymakers, demonstrating the central role that human development and the energy transition play in this process. Future studies are expected to generate more in-depth policy insights through sectoral disaggregations and structural break analyses.

In conclusion, this study's findings indicate that green growth is influenced by numerous structural factors, including human development and energy consumption, as well as economic indicators. This is supported by empirical evidence. As the study demonstrates, human development is the strongest determinant of green growth. Investments in education, health, and quality of life increase environmental awareness and the adoption of sustainable technologies. The negative impact of energy consumption demonstrates that the energy resources used in countries have not yet completed the "green" transformation. Economic growth can be a supporting component of sustainable development, but the quality of green growth is more decisive. CO₂ emissions indirectly affect green growth. This underscores the importance of environmental policies, technology transfer, and efficiency-enhancing strategies. This study strongly demonstrates that green growth is a multidimensional phenomenon, with human development and energy infrastructure being particularly critical in this process. Policymakers should accelerate the energy transition for environmentally friendly growth and prioritize investments that enhance human development.

5. CONCLUSION

This study analyzes the determinants of green growth using a panel dataset covering annual data for the period 2010–2023 for 27 European Union member countries. Econometric analyses using variables such as per capita CO₂ emissions, per capita GDP, Human Development Index (HDI), and per capita energy consumption are conducted using both fixed-effects models and FGLS methods to identify the key factors shaping green growth.

According to the study's key findings, human development level stands out as the variable with the strongest and most positive impact on green growth. This demonstrates that environmental sustainability is directly linked not only to economic growth but also to human factors such as social well-being, education, health, and quality of life. GDP per capita is another variable that statistically significantly positively impacts green growth, demonstrating that economic development can contribute to sustainable growth targets if pursued in harmony with the environment. Conversely, the strong and negative impact of per capita energy consumption on green growth demonstrates that energy consumption patterns in EU countries are still far from environmentally friendly. This finding demonstrates that energy transition—especially the shift toward renewable energy sources—is critical to achieving green growth. Finally, the lack of a significant direct impact of CO₂ emissions on green growth suggests that emissions are primarily impacted through indirect mechanisms (policies, technological advancements, efficiency practices, etc.). In this context, policymakers are encouraged to increase social investments that support human development, accelerate the energy transition to renewable sources, align economic growth with environmental sustainability, and strengthen policy instruments that indirectly reduce CO₂ emissions. Furthermore, ensuring policy coordination among EU member states and developing common green growth strategies will contribute to more effectively achieving environmental and economic goals.

The EU could differentiate its green growth policies by taking into account the specific characteristics of each country. In particular, the level of development and energy infrastructure of the countries should be considered. Developed EU countries could support relatively lower-income countries in building green growth infrastructure, green technology, and renewable energy through financial incentives. Integrated policies to enhance human development should be implemented. Policies aimed at education, health, social welfare, and reducing income inequality will support environmental awareness and sustainable production and consumption behaviors. Investments in environmental education, climate change awareness, and green skills can accelerate the sustainability-based transformation of society. Taking country differences into account in the implementation of these policies will be crucial in achieving green growth.

The fact that per capita income has a positive and significant impact on green growth shows that EU countries can achieve both economic growth and environmental sustainability simultaneously. This finding demonstrates a positive interaction between economic prosperity and environmental sustainability. By integrating environmental goals into their economic growth policies, EU countries will have taken a significant step towards green growth. Empirical findings show that both energy and economic factors have an impact on green growth. This indicates that the energy transition policies outlined in the Green Deal are based on economic as well as environmental justifications. The green transformation of the energy structure must be accelerated. Policies that reduce fossil fuel dependence and encourage the use of renewable energy need to be expanded. Incentive mechanisms focused on energy efficiency will contribute to reducing environmental impacts, particularly in the residential and industrial sectors.

The nature of economic growth should be green-based. The development of fiscal and financial instruments that support green investments and clean technology initiatives will encourage environmentally sound economic growth. Sustainable infrastructure investments and circular economy practices will reduce the environmental costs of growth.

Policies that indirectly reduce emissions should be strengthened. The indirect, rather than direct, impact of CO₂ emissions requires more effective use of policy tools such as carbon pricing, emissions trading systems, green tax reforms, and environmental standards. Reducing emissions in production processes through technological innovation and digitalization should be supported.

Policy coordination should be ensured and common strategies developed within the EU. The effective implementation of harmonized and jointly implemented framework strategies across EU countries in environmental, energy, and development policies will contribute to the realization of a holistic green growth vision.

In conclusion, green growth is not merely an effort to achieve environmental goals; it is also a holistic development model that fosters both social well-being and economic stability. The findings of this study strongly support the need for multidimensional policy approaches that ensure a balance between the environment, economy, and society.

This study was conducted within the scope of EU countries, and data access limitations were encountered when creating the variables. Therefore, only the annual data for the years 2010-2023, for which data were available for all EU countries, were included in the study. The relatively limited time dimension restricts the detailed examination of long-term dynamics. However, panel data analysis largely compensates for these limitations. Future studies may compare the findings obtained in this study with longer time intervals and newly published data, or they may conduct analyses using different indices, different variables, or different econometric methods instead of the Global Green Growth Index.

Author Contributions

Günay Terzi: Literature Review, Conceptualization, Methodology, Data Curation, Writing-original draft
Öznur Ak Harunoğulları: Analysis, Modelling, Writing-review and editing.

Conflict of Interest

No potential conflict of interest was declared by the authors.

Funding

Any specific grant has not been received from funding agencies in the public, commercial, or not-for-profit sectors.

Compliance with Ethical Standards

It was declared by the authors that the tools and methods used in the study do not require the permission of the Ethics Committee.

Ethical Statement

It was declared by the authors that scientific and ethical principles have been followed in this study and all the sources used have been properly cited.



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