Determinants of Green Growth in OECD Countries: System GMM Analysis[1]

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OECD Ülkelerinde Yeşil Büyümenin Belirleyenleri: Sistem GMM Analizi[2]

Abstract

This study aims to assess the effects of renewable and non-renewable energy, green technologies, environmental taxes, political stability, foreign direct investment, trade openness, forest area, urbanisation, and population growth, as control variables, on green growth across 33 OECD countries from 2000 to 2019. Unlike previous studies, this research employs the green growth index as a measurement of green growth. The findings indicate that renewable energy, green technology, political stability, and environmental taxes positively influence green growth, whereas non-renewable energy negatively affects it.

Keywords : Green Growth, Green Technology, Renewable Energy, Non-Renewable Energy, Political Stability, GMM.

JEL Classification Codes : C23, Q44, Q56.

Öz

Bu çalışmanın amacı 33 OECD ülkesi için 2000-2019 yılları arasını temel alarak yeşil büyüme üzerinde yenilenebilir ve yenilenemez enerjinin, yeşil teknolojilerin ve kontrol değişkenleri olarak çevre vergileri, politik istikrar, yabancı sermaye yatırımları, ticari açıklık, şehirleşme, orman alanı ve nüfus artış hızı etkisini ölçmek için Sistem GMM yöntemi kullanılmıştır. Bu çalışmada literatürden farklı olarak yeşil büyüme değişkeni olarak yeşil büyüme endeksi kullanılmıştır. Elde edilen bulgulara göre yenilenebilir enerjinin, yeşil teknolojinin, politik istikrarın, çevre vergilerinin yeşil büyümeyi olumlu etkilediği, yenilenemez enerjinin ise yeşil büyümeyi olumsuz etkilediği sonucuna ulaşılmıştır.

Anahtar Sözcükler : Yeşil Büyüme, Yeşil Teknoloji, Yenilenebilir Enerji, Yenilenemez Enerji, Politik İstikrar, GMM.

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1. Introduction

Many international organisations have held conferences on these issues to discuss challenges such as climate change, global warming, ecological imbalance, environmental pollution, and greenhouse gas emissions, and have made various decisions to address these problems. Some of the most widely supported topics in these conferences include reducing carbon emissions and revising countries' growth policies. In this context, the primary focus of the Rio+20 Conference of the United Nations Environment Programme (UNEP) in 2012 was the green economy, which introduced green growth policies. Three major international organisations have played leading roles in developing the concept of green growth. Among these, UNEP defines green growth as an economy that simultaneously increases income and enhances human welfare while 'significantly reducing environmental risks and ecological scarcities' (UNEP, 2011: 16). According to the World Bank, green growth refers to resilient growth—growth that efficiently uses natural resources, is clean, minimises pollution and environmental impacts, considers natural hazards, and recognises the importance of environmental management and natural capital in preventing physical disasters (World Bank, 2012: 2).

According to the OECD, green growth is an environmentally sustainable growth model aimed at achieving sustainable development while addressing climate change, reducing poverty, and increasing national prosperity (OECD, 2012: 5). Green growth theory is endorsed by leading multilateral organisations and recommended for both national and international policies.

As Smulders et al. (2014) point out, the concept of green growth is relatively new and still somewhat uncertain, but it is constantly evolving, and the indicators used to measure it are continuously being developed (Hickel & Kallis, 2020: 2).

Historically, economic growth has increasingly been recognised as unsustainable and reliant on significant consumption of natural resources (Fernandes, 2021: 202). Many studies support the view that conventional growth, driven mainly by human activities, especially consumption levels of high-income groups, damages the environment (IPCC, 2014). Traditional approaches have argued that environmental protection would lead to an economic slowdown. However, different aspects of production, which are rarely measured in existing economic growth models, are explored within the context of green growth models (Jacobs, 2012).

Green growth theory begins with the simple observation that the natural environment is also a factor of production. Yet, both classical growth theory and historical patterns of economic growth have, in practice, largely overlooked it. The environment functions as a form of capital in three ways: it supplies resources, assimilates waste, and provides various life-sustaining 'environmental services', including climate regulation and ecosystem health (Jocobs, 2012: 11). This 'natural capital' has been undervalued in both economic theory and practice because it remains mainly unpriced and is often seen as a gift of nature.

Building on these assumptions, supporters of green growth argue that various environmental measures and policies can foster economic growth.

Green growth theory argues that current economic growth patterns are fundamentally inefficient. They misallocate resources among various factors of production, underinvest in natural capital, and overinvest in activities that harm it (Jacobs, 2012: 11).

While the concept of sustainable development originated in the environmental movement, where ideological debates about the 'limits to growth' were common, green growth emerged from the more mainstream, pragmatic community of environmental economics policymakers (Jacobs, 2012). As a fundamental aspect of sustainable development, green growth allows for economic expansion while safeguarding the environment. In this context, it is stated that the green growth approach is vital for both developed and developing countries (Dercon, 2014: 1). The benefits of green growth for countries are as follows;

- Promote sustainable, low-carbon development,
- Reducing poverty,
- Employment creation,
- Tackling climate change and biodiversity reduction,
- It has many positive impacts, such as providing access to clean water and energy (Morssy, 2012: 40).

Due to the failure to achieve the desired results in realising sustainable development goals and the inability to reduce carbon emissions to the target level, the European Union countries launched a Green Deal in 2019. The European Green Deal aims to transform the EU into an environmentally competitive economy and reduce greenhouse gas emissions by 55% compared to 1990 (Fetting, 2020: 5).

The European Green Deal offers a roadmap for nations to reach the objectives of sustainable development and green growth. Green growth is a component of sustainable development. It promotes sustainable progress by balancing the economy and the environment (OECD, 2015: 5). Many countries, especially the European Union, have embraced the green growth model and begun implementing strategies for it. Consequently, green growth is increasingly replacing traditional growth strategies worldwide.

The Global Green Growth Institute (GGGI), a new international organisation supported by numerous governments, was established to advise countries on implementation. The Green Growth Index developed by the Global Green Growth Institute is a composite index that assesses a country's performance in meeting sustainability objectives, including the Sustainable Development Goals, the Paris Climate Agreement, and the Aichi Biodiversity Targets (Global Green Growth Institute, 2020: 2).

The green growth index is determined using four core indicators along with 16 sub-indicators. Table 1 below presents these four core indicators and their sub-components.

Table: 1
Variables Used in the Calculation of the Green Growth Index

Natural Capital Protection	Efficient and Sustainable Resource Use	Green Economic Opportunities	Social Inclusion
Environmental Quality	Efficient and Sustainable Energy	Green Investments	Access to Basic Services and Resources
Greenhouse Gas Emissions Reduction	Efficient and Sustainable Water Use	Green Trade	Gender Balance
Biodiversity and Ecosystem Protection	Sustainable Land Use	Green Employment	Social Equity
Cultural and Social Value	Material Use Efficiency	Green Innovation	Social Protection

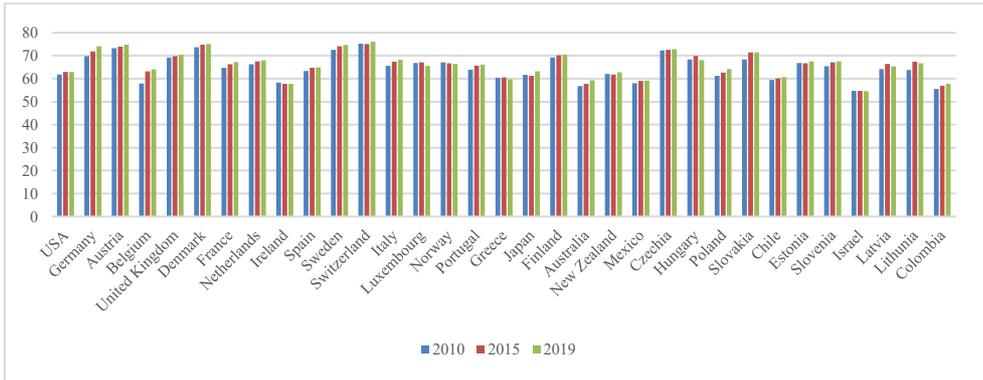Source: Global Green Growth Institute (GGGI), 2020: 3.

In the green growth index, countries score between 1 and 100 points. The meaning of these values is as follows;

- 1-20 is very low, and countries with this value must develop urgent action plans to achieve their green growth targets.
- A value between 20% and 40% is considered low, and countries with this level must establish appropriate policies to drive progress in green growth.
- A range of 40-60% is considered a moderate (medium) value, indicating that countries within this range have found a suitable balance to progress with green growth.
- A value of 60-80 is high and indicates that countries with this figure have adopted a fully strategic stance to reach the target.
- 80-100 is very high and indicates that countries with this value have fully or almost achieved their green growth targets (GGGI, 2020: 4).

The green growth index is crucial because it addresses sustainable development from environmental, economic, and social perspectives and provides insight into the green growth policies countries will adopt. Simultaneously, this index indicates progress towards a sustainable and greener economy. Chart 1 below displays the green growth index values of OECD countries between 2010 and 2019.

Chart 1 shows Colombia's lowest green growth index value in 2010, 52.2, while Austria's highest index value, 75.98, was in the 60-80 range. Austria's 2010 value of 75.98 indicates that the country is well-positioned to achieve its green growth target and that its strategy is appropriate.

Chart: 1
Green Growth Index Values of OECD Countries

Source: Created by the authors using the Global Green Growth Institute database.

In 2019, Israel recorded the lowest green growth index score of 51.57, while Austria achieved the highest with 77.74. Therefore, Israel had the lowest index scores in 2010 and 2019, and the value declined further over the ten years, raising questions about the effectiveness of the country's green growth strategy.

Green growth is the shift towards a growth model that ensures continuous economic development while simultaneously conserving natural capital, utilising it efficiently, and preventing pollution. This process also introduces constraints and opportunities within countries' current economic frameworks. Therefore, identifying the factors that influence green growth is vital for formulating and implementing effective policies and strategies. This study aims to explore the key determinants that will assist OECD countries—primarily developed nations—in identifying and applying the essential tools for their transition to a new-generation growth model, as the traditional model is increasingly regarded as environmentally unsustainable.

From this perspective, this study analyses the impact of renewable and non-renewable energy, green technologies, and environmental taxes, along with political stability, foreign direct investment, trade openness, urbanisation, and population growth rate as control variables on green growth for 33 OECD countries from 2000 to 2019. The study comprises five sections. In the introduction, the emergence of the concept and strategies of green growth and the green growth index are explained, and the values of the green growth index across OECD countries are compared. The second section summarises the existing literature on the determinants of green growth. The third section presents the data set and variables, and the following section details the methodology and the analysis's findings. The conclusion evaluates the findings and offers policy recommendations.

This study's limitation is that the dependent variable, the green growth index, dates back to 2010 and covers 2010-2019. Although our results are robust, more comprehensive outcomes can be achieved for a longer period by extending the time span and employing different variables in future research.

This study adds to the literature in two ways. First, unlike previous work, the green growth index is used as a specific green growth variable. Another contribution is that there is limited research on green growth, with most existing studies focusing primarily on carbon emissions. This study developed two models considering economic, social, and environmental factors influencing green growth. Therefore, a more comprehensive analysis of green growth was achieved. The results are expected to offer a roadmap for OECD countries.

2. Literature Review

In this section, Table 2 summarises recent studies analysing the effects of variables such as green technologies, green energy, renewable and non-renewable energy, environmental taxes on green growth, and carbon emissions. Since carbon emissions are also used as a green growth indicator in the literature, these studies are included in the summary.

Table: 2
Literature Review

Authors	Country/Countries Period	Dependent Variable	Independent Variables	Method	Conclusion
Sohag et al. (2019)	Türkiye 1980-2017	Green Growth	Technological innovation, green energy and militarisation	ARDL	They found that technological innovations and green energy increase green growth, while militarisation has a negative impact.
Wang & Shao (2019)	G-20 2001-2015	Carbon Emission	Research and development expenditure, green technologies, and education	Panel Threshold	Research and development expenditures, green technologies and education positively affect green growth.
Danish & Ulucak (2020)	BRICS 1992-2016	Green Growth	Green technologies, renewable and non-renewable energy	Westerlund Cointegration	They concluded that renewable energy and green technologies promote green growth, whereas non-renewable energy impedes it.
Hao et al. (2021)	G-7 Countries 1991-2017	Carbon Emission	Renewable energy, environmental taxes, per capita income, human capital and green growth	Panel causality test	They found that environmental taxes, renewable energy, and human capital reduce carbon emissions, while per capita income increases them.
Chien et al. (2021)	USA 1970-2015	Carbon Emission	Environmental innovation, environmental taxes, renewable energy and green growth	ARDL	They found that green growth, the square of green growth, environmental innovations, environmental taxes and renewable energy reduce carbon emissions.
Tawiah et al. (2021)	123 Developed and Developing Countries 2000-2019	Green Growth	Renewable energy, trade openness, and economic development	Random and fixed effect models panel	They concluded that trade openness negatively impacts green growth, while renewable energy and economic development positively impact it.
Cao et al. (2022)	Chinese Province 2011-2017	Green Growth	Financial development, technological innovation	Spatial Durbin Model	Technological innovations and financial development positively affect green growth.
Kuang et al. (2022)	China 1990-2018	Carbon Emission	Green technologies, renewable energy and non-renewable energy	AMG and CCE estimators	The analysis found that renewable energy and green technologies reduce carbon emissions, whereas non-renewable energy sources increase them.
Hussain et al. (2023)	High-Income Countries 2000-2022	Green Growth	Per-capita income, energy consumption, and green technologies	AMG Method	They concluded that income and green technologies increase green growth, while energy consumption decreases.
Gorji & Martek (2023)	20 Developed and 20 Developing Countries 2010-2021	Green Growth	Renewable hydroelectric power generation, solar power generation, wind power generation, renewable energy policies, and consumer price index	FGLS	They concluded that energy types other than hydroelectric power generation increase green growth, while renewable energy policies and the consumer price index are not statistically significant in green growth.
Yikun et al. (2023)	G-7 Countries 2000-2019	Impact On Sustainable Development Goals	Green growth, green technologies, governance,	ARDL	As a result of the study, they concluded that green growth, green technologies and governance increase social development.
Shang et al. (2023)	Asian Countries 2000-2021	Green Growth	Tourism, fossil energy use and renewable energy	ARDL	They concluded that fossil fuels and tourism negatively affect green growth, whereas renewable energy increases it.

Zakari et al. (2023)	Australia and the top 23 green plan economies 2008-2019	Carbon Emission	Green innovations and technological innovations	GMM	They concluded that green innovations and technological innovations reduce carbon emissions.
Wei et al. (2023)	10 Green countries in the future	Carbon Emission	Green technologies, green trade, green growth and foreign direct investment	AMG and CCE predictors	They stated that green trade, green technologies and foreign direct investments reduce carbon emissions and thus improve environmental quality.
Tawiah et al. (2024)	123 Countries 2000-2017	Green Growth	Corruption, population, foreign direct investment, forest area, trade openness and forest land	OLS	They concluded that corruption, trade openness, and population negatively affect green growth, while foreign direct investment and forest area increase it.
Huang (2024)	BRICS Countries 1990-2021	Green Growth	Globalisation, R&D expenditures, and natural resource use	GLS	The conclusion is that globalisation increases green growth when natural resources are used more.
Sharif, et al. (2024)	USA 1990-2019	Carbon Emissions, Economic Growth	Green energy, green technology	ARDL	They concluded that green technologies and green energy reduce carbon emissions, and environmental innovations increase economic growth.

Based on the literature reviewed, the studies that conclude green technology boosts green growth are Sohag et al. (2019), Danish & Ulucak (2020), Hussain et al. (2023), and Huang (2024). The studies that find renewable energy increases green growth are Sohag et al. (2019), Danish & Ulucak (2020), and Gorji & Martek (2023). The studies that suggest non-renewable energy has a negative impact on green growth are Danish & Ulucak (2020), Hussain et al. (2023), and Shang et al. (2023). Regarding carbon emissions, studies reporting that green technologies reduce them include Kuang et al. (2022), Zakari et al. (2023), and Sharif et al. (2024).

3. Data and Variables

Green growth encompasses economic, environmental, and social aspects and is shaped by various factors such as energy consumption and internationalisation (Tawiah et al., 2021). From this perspective, this study examined the impact of renewable and non-renewable energy, green technologies, environmental taxes, political stability, foreign direct investments, trade openness, forest area, urbanisation, and population growth on green growth across 33 OECD countries from 2010 to 2019 using the System GMM method. Countries like Korea, Türkiye, Canada, Costa Rica, and Iceland could not be included due to missing data. Additionally, since the green growth index has been published since 2010, the analysis begins from that year. All variables used in the study, along with their definitions, observation periods, and data sources, are presented in Table 3.

Table: 3
Variables and Sources Used in the Analysis

Variables	Defination	Observation Range	Data Source
Green Growth	Green Growth Index	2010-2019	Global Green Growth Institute (GGGI)
Non-Renewable Energy	Fossil Fuel Consumption	2010-2019	Statistical Review of World Energy
Renewable Energy	Percentage of Renewable Energy in Total Energy Use	2010-2019	World Bank
Green Technology	The ratio of environmentally developed technologies among all Technologies	2010-2019	OECD
Environmental Taxes	Environmental Taxes in GDP	2010-2019	OECD
Political Stability	Political Stability and Absence of Violence/Terrorism	2010-2019	World Bank
Foreign Direct Investments	Foreign Direct Investment, Net Inflows (% of GDP)	2010-2019	World Bank
Trade Openness	Trade as a share of GDP	2010-2019	World Bank
Forest area	Forest area (% of land area)	2010-2019	World Bank
Urbanization	Urban population (% of total population)	2010-2019	World Bank
Population Growth Rate	Annual Population Growth Rate	2010-2019	World Bank

Unlike the literature, this study employs a more comprehensive green growth index as the dependent variable. Independent variables include renewable energy, non-renewable

energy, and green technology. Since the types of renewable and non-renewable energy utilised by countries are vital for the environment, energy supply and security, and the growth policies to be implemented, these variables are incorporated into the model. The green technology variable measures the impact on economic growth from the production and use of green technologies to manufacture and supply cleaner, more environmentally friendly goods. Control variables encompass environmental taxes, political stability, FDI, trade openness, forest area, urbanisation, and population growth. It is expected that environmental taxes will enhance environmental quality and reduce pollution. Trade openness and FDI, which denote internationalisation, are analysed to understand how foreign activities influence green growth (Tawiah et al., 2021). Political stability is crucial for green growth, as the formulation and enforcement of suitable regulations in response to changing conditions often require sacrifices. Variations in the availability of forest area are anticipated to influence green growth. Population growth is included as it is likely to result in increased economic activity and consumption, environmental degradation, and threats to biodiversity (OECD, 2017: 12) due to the expansion of construction areas.

4. Methodology and Findings

This study employs the System GMM method to analyse the effects of renewable and non-renewable energy, green technologies, environmental taxes, political stability, foreign direct investments, trade openness, forest area, urbanisation, and population growth on green growth from 2010 to 2019 for OECD countries. The GMM method is a dynamic panel data analysis technique that has recently been widely utilised in research. Difference GMM and System GMM methods were developed by Holtz-Eakin, Newey, and Rosen (1988), Arellano and Bond (1991), Arellano & Bover (1995), Blundell & Bond (1998) (Roodman, 2009: 86). The GMM approach is popular because it provides reliable results when the number of countries exceeds the time periods (N>T), especially when the time span is short. Autocorrelation and endogeneity problems may also occur (Roodman, 2009: 86).

In the analysis, with 33 countries and a 10-year time interval, the GMM method is used because it satisfies the N>T condition and yields reliable results for short time intervals (10 years). The reason for choosing the System GMM method over the Difference GMM method is that the former yields more effective results (Dahir et al., 2018: 238). To verify the accuracy of the GMM results, comments should be based on the Autocorrelation test and Sargan/Hansen test results. Sargan/Hansen test results are used to determine whether the instrumental variables are valid (Roodman, 2009: 87). If the p-value exceeds 0.10, the instrumental variables are deemed exogenous and the analysis is valid.

In GMM analysis, the probability value of autocorrelation at the AR (1) level should be less than 0.05, and autocorrelation should be at Level 1. The autocorrelation at AR (2), AR (3), or AR (4) levels should be greater than 0.10, indicating no autocorrelation. Consequently, the number of lags of the instrumental variables should commence from at least that value. Two models, Model 1 and Model 2, were developed for the analysis. In both models, the natural logarithms of all variables, except the population growth rate, are used.

In Model 1 below, green growth is the dependent variable, and renewable energy (the ratio of renewable energy use to total energy consumption) and green technology (the ratio of environmentally developed technologies to all technologies) are the independent variables. Then, in models where the dependent variable is green growth and the independent variables are renewable energy and green technology fixed, the variable $\beta_4 Z$ (control variable) represents population growth rate, urbanisation rate, political stability, foreign direct investment, environmental taxes, forest areas, and trade openness. Separate equations are established for these variables.

$$\ln \text{Green Growth}_{it} = \beta_1 \text{Green Growth}_{it-1} + \beta_2 \text{Renawable Energy} + \beta_3 \text{Green Technology}_{1it} + \beta_4 Z$$
$$u_{it\ i=1,\dots\dots N\ ;\ t=1,\dots t.} \tag{1}$$

In Model 2 below, green growth is employed as the dependent variable. Non-renewable energy (fossil fuel consumption) and green technology (the proportion of environmentally developed technologies among all technologies) are used as independent variables. Subsequently, in models where the dependent variable is green growth and the independent variables include non-renewable energy and green technology fixed, the variable $\beta_4 Z$ (control variable) denotes population growth rate, urbanisation rate, political stability, foreign direct investment, environmental taxes, forest areas, and trade openness. Separate equations are established for these variables.

$$\ln \text{Green Growth}_{it} = \beta_1 \text{Green Growth}_{it-1} + \beta_2 \text{ Non-Renawable Energy} + \beta_3 \text{Green Technology}_{1it} +$$
$$\beta_4 Z\ u_{it\ i=1,\dots\dots N\ ;\ t=1,\dots t.} \tag{2}$$

Since our dependent variable, green growth, is an index, the interpretation of a variable's effect on green growth should be positive or negative. According to Model 1, renewable energy has a positive impact on green growth. This finding aligns with Gorji & Martek (2023) for 20 developed and 20 developing countries, indicating that renewable energy types boost green growth. It also matches Shang (2023) for Asian countries, which states that using renewable energy enhances green growth.

According to Model 1, green technologies also promote green growth. This finding aligns with Sohag et al. (2019) for Türkiye, which states that green technology boosts green growth. It is also consistent with Hussain et al. (2023), who found that green technologies promote green growth in high-income countries. Additionally, the analysis reveals that foreign direct investments enhance green growth. Since foreign direct investments are expected to bring new technologies to a country, utilising green technologies may positively influence green growth. Another result from the analysis is that population growth negatively impacts green growth. In their study of 123 countries, Tawiah et al. (2024) concur that population growth adversely affects green growth. The analysis further shows that urbanisation has a detrimental effect on green growth. This outcome is similar to that of Kwilinski et al. (2023) for the European Union countries and Ukraine, which states that urbanisation hampers green growth. It is also observed that forest areas have a positive effect on green growth. This aligns with Alola & Akadiri (2023) for Sweden, who noted that forest areas augment green growth. It is also comparable to Tawiah et al. (2024)'s findings for 123

countries, which indicate that increasing forest land enhances green growth. Furthermore, as seen in Table 4, political stability appears to promote green growth, as expected. This is consistent with Quamrazzaman & Karim (2024), who state that economic stability fosters green growth in OECD countries. The analysis also finds that environmental taxes contribute to green growth. This result matches Yu et al. (2023), who observed that environmental taxes promote green growth in China. Finally, the findings from Model 1 suggest that trade openness boosts green growth, aligning with Tariq et al. (2023) for developing countries, who concluded that trade openness enhances green growth.

Table: 4
Test Results of Model 1

	(1) Green Growth	(2) Green Growth	(3) Green Growth	(4) Green Growth	(5) Green Growth	(6) Green Growth	(7) Green Growth	(8) Green Growth
Green Growth	0,9299***	0,9319***	0,9198***	0,9099***	0,9176***	0,9449***	0,8561***	0,9113***
	(0,0073)	(0,0070)	(0,0150)	(0,0211)	(0,0156)	(0,0103)	(0,0239)	(0,0130)
Renewable	0,0042***	0,0042***	0,0071**	0,0113**	0,0048*	0,0052***	0,0130***	0,0077***
	(0,0015)	(0,0015)	(0,0032)	(0,0044)	(0,0024)	(0,0016)	(0,0040)	(0,0018)
Green Technology	0,0023*	0,0025**	0,0030*	0,0032***	0,0031***	0,0071***	0,0045***	0,0026**
	(0,0012)	(0,0010)	(0,0015)	(0,0011)	(0,0009)	(0,0014)	(0,0009)	(0,0011)
Foreign		0,0010***						
		(0,0004)						
Population			-0,0029**					
			(0,0012)					
Urbanization				-0,0950***				
				(0,0218)				
Forest					0,0162***			
					(0,0034)			
Politic						0,0050***		
						(0,0012)		
Trade							0,0177***	
							(0,0061)	
Enviroment								0,0029***
								(0,0007)
Constant	0,2815***	0,2676***	0,3156***	0,7544***	0,2738***	0,1817***	0,4818***	0,3469***
	(0,0298)	(0,0275)	(0,0549)	(0,1372)	(0,0576)	(0,0355)	(0,0831)	(0,0530)
Number of Observations	296	296	296	296	296	296	296	292
AR (2)	0,0635	0,0598	0,0761	0,0724	0,0711	0,0799	0,0882	0,0721
AR (3)	0,1485	0,1218	0,1879	0,2439	0,1646	0,2100	0,2235	0,3202
Hansen Test (Probability)	0,1601	0,2936	0,1148	0,1028	0,1640	0,2163	0,1172	0,2837
Number of Instruments	23	27	26	22	27	27	25	27
Country Number	33	33	33	33	33	33	33	33

*Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively. AR(2) and AR(3) statistics in the table show the probability values obtained from the second and third order autocorrelation tests, respectively, and the null hypothesis of this test is "no autocorrelation". The number of lags used for the instrumental variables is initialised to the level at which the autocorrelation problem does not exist.*

Finally, when analysing the autocorrelation test results to assess the model's accuracy, it is confirmed that the model exhibits autocorrelation at the AR (1) and AR(2) levels, but there is no autocorrelation at the AR (3) level. According to the Sargan/Hansen test results, the p-value exceeds 0.10, indicating that the instrumental variables are exogenous.

Table 5 presents the test results of Model 2. The AR(2) and AR(3) statistics in Table 5 display the probability values obtained from the second- and third-order autocorrelation tests. The null hypothesis of this test is "no autocorrelation". The number of lags used for the instrumental variables is initialised at the level where autocorrelation does not exist.

Table: 5
Test Results of Model 2

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Green Growth	Green Growth	Green Growth	Green Growth	Green Growth	Green Growth	Green Growth	Green Growth
Green Growth	0,9730***	0,9761***	0,9825***	0,9605***	0,9491***	0,9495***	0,9406***	0,9608***
	(0,0131)	(0,0074)	(0,0055)	(0,0298)	(0,0114)	(0,0135)	(0,0095)	(0,0072)
Non-renewable	-0,0091***	-0,0008*	-0,0025***	-0,0177***	-0,0191***	-0,0044***	-0,0012*	-0,0033***
	(0,0024)	(0,0005)	(0,0007)	(0,0048)	(0,0049)	(0,0010)	(0,0006)	(0,0005)
Green Technology	0,0049***	0,0015*	0,0027**	0,0018**	0,0034**	0,0060***	0,0043***	0,0032***
	(0,0014)	(0,0008)	(0,0013)	(0,0007)	(0,0015)	(0,0014)	(0,0009)	(0,0007)
Foreign		0,0084***						
		(0,0017)						
Population			-0,0034***					
			(0,0011)					
Urbanization				-0,0399				
				(0,0661)				
Forest					0,0139*			
					(0,0070)			
Politic						0,0060**		
						(0,0022)		
Trade							0,0093***	
							(0,0025)	
Enviroment								0,0022***
								(0,0007)
Constant	0,1628**	0,0664**	0,0891***	0,4464**	0,2791***	0,2015***	0,2087***	0,1796***
	(0,0596)	(0,0289)	(0,0251)	(0,1693)	(0,0416)	(0,0570)	(0,0298)	(0,0317)
Number of Observations	296	296	296	296	296	296	296	292
AR (2)	0,0620	0,0374	0,0695	0,0519	0,0591	0,0750	0,0732	0,0651
AR (3)	0,1694	0,0329	0,1315	0,1703	0,1937	0,1648	0,1163	0,2230
Hansen Test (Probability)	0,1166	0,3623	0,1109	0,1165	0,1181	0,2383	0,2413	0,1806
Number of Instruments	22	28	22	24	24	27	31	28
Number of Countries	33	33	33	33	33	33	33	33

Notes: ***, ** and * denote statistical significance at the 1%, 5% and 10%, respectively.

According to Model 2, non-renewable energy has a negative impact on green growth. This aligns with Hussain et al. (2023) for high-income countries, which also states that non-renewable energy hampers green growth. Similarly, Danish & Ulucak (2020) found that non-renewable energy negatively affects green growth in BRICS countries. Another result from Model 2 is that green technologies promote green growth, consistent with Sohag et al. (2019) for Türkiye, who found that green technology boosts green growth. Hussain et al. (2023) also report that green technologies enhance green growth in high-income countries. The analysis further indicates that foreign capital investments promote green growth, likely by introducing new technologies to host countries. Additionally, the population growth rate negatively affects green growth, suggesting that rapid population growth and unhealthy urbanisation hinder it. This aligns with findings by Kwilinski et al. (2023) for the European Union countries and Ukraine, where urbanisation negatively impacted green growth. As shown in Table 4, another finding is that forest areas have a positive influence on green growth, similar to studies by Alola & Akadiri (2023) for Sweden, which show that forest lands enhance green growth. Likewise, Tawiah, Zakari & Alvarado (2024) found that increasing forest lands boosts green growth across 123 countries. The analysis also indicates that political stability fosters green growth, consistent with Quamrazzaman & Karim (2024), who observed that economic stability promotes green growth in OECD countries. Furthermore, environmental taxes are found to increase green growth, echoing Yu et al.

(2023)'s findings for China. Lastly, trade openness appears to promote green growth, similar to the results of Tariq, Xu et al. (2023) for developing countries.

Finally, when the autocorrelation test results were examined to assess the model's accuracy, it was confirmed that the model exhibited autocorrelation at the AR(1) level. Because there was autocorrelation at the AR(2) level, autocorrelation was not present at the AR(3) level. The results of the Sargan/Hansen test showed that the probability value was greater than 0.10, indicating that the instrumental variables were exogenous.

5. Conclusion

To discuss the effects of these issues faced by countries, such as environmental pollution, climate crisis, greenhouse gas emissions, energy supply, and security, among others, international organisations have organised many conferences and made various decisions to address these challenges. One of the most widely agreed-upon issues at these conferences was the need to reduce carbon emissions and revise nations' growth policies. OECD countries, in particular, have had to modify their previously implemented growth policies to cut greenhouse gas emissions, which contribute to the climate crisis. Consequently, the shift towards environmentally sustainable, green growth policies has become essential.

While renewable energy sources have become crucial for implementing green growth policies, green technologies have also become increasingly important for reducing carbon emissions from manufacturing processes. Thanks to environmentally friendly energy and green technologies within green growth policies, these technologies and energy support the sustainable development of countries and help reduce environmental pollution.

The growing global awareness of green growth is encouraging many countries to develop green economic infrastructure focused on natural resources and environmental protection, especially during the energy transition (Danish et al., 2020). Governments need to identify the determinants of green growth and formulate policies and strategies accordingly to establish new policies and make decisions aligned with this global imperative.

From this point forward, the effects of renewable and non-renewable energy, green technologies, environmental taxes, political stability, foreign direct investments, trade openness, urbanisation, forest area, and population growth on green growth were analysed using the System GMM method for 33 OECD countries between 2010 and 2019. The analysis established two separate equations, Model 1 and Model 2. In Model 1, the control variables, which included renewable energy and green technology variables, were added to the models separately, and the analysis was performed. In Model 2, the control variables — green technology and non-renewable energy — were fixed and added to the models separately, and the analysis was performed. It can be inferred that variables such as green technology, political stability, and trade openness, which are present in both models, positively affect green growth, and therefore, the results are robust.

The analysis results indicate that renewable energy positively influences green growth. This finding aligns with the study by Gorji & Martek (2023), which shows that different types of renewable energy boost green growth in 20 developed and 20 developing countries. It also supports Shang's (2023) research, indicating that renewable energy use increases green growth in Asian countries. Besides being sustainable, renewable energy may enhance green growth through its advantages, such as being cheaper than non-renewable energy after installation costs and being more environmentally friendly, both of which positively impact green growth. A key component of green growth policy in both developed economies today and in the future is decreasing dependence on fossil fuels due to climate change and local air pollution, and shifting towards clean energy sources (Smulder et al., 2014: 432). In this context, OECD countries can promote renewable energy during production by offering tax incentives to companies that install it. Additionally, social awareness can be raised by media coverage of companies using renewable energy and encouraging wider adoption. Furthermore, environmental education can be integrated into curricula, starting from primary school, to foster understanding of limited global resources and the importance of renewable energy. The results from Model 2 in the study indicate that non-renewable energy adversely affects green growth in OECD countries. This is consistent with Hussain et al.'s (2023) findings, which reveal that non-renewable energy hampers green growth in high-income nations. Similarly, the Danish & Ulucak (2020) study shows that non-renewable energy negatively impacts green growth in BRICS countries. Since non-renewable energy emits harmful gases into the environment during use, it is expected to have a detrimental effect on green growth. OECD countries can discourage their use by imposing penalties on companies that produce non-renewable energy. Public awareness can also be fostered by civil society organisations explaining the environmental damage caused by non-renewable energy.

The analysis concluded that environmental taxes in OECD countries promote green growth. Thanks to these taxes, companies are increasingly focusing on renewable energy rather than non-renewable sources. Since companies rely on non-renewable energy sources, they are subject to environmental taxes to fund pollution control. Therefore, implementing policies that increase deterrence, such as environmental taxes, can positively impact green growth.

The analysis shows that forest areas positively influence green growth in OECD countries. Forest lands absorb harmful gases, reducing environmental pollution and supporting green growth. Currently, OECD countries can increase the number of green spaces by implementing policies that promote greenery. Additionally, OECD countries help develop environmental awareness among children by initiating a green school project and expanding the number of green spaces in schools.

The analysis concluded that political stability in OECD countries positively influences green growth. Accordingly, political stability is vital for the success of green growth policies implemented within OECD nations. Particularly in countries lacking political stability, the intended success may not be realised if new policies are enforced

repeatedly. Therefore, OECD countries should recognise that these policies must be national priorities and that success will only be achieved in the long term to promote green growth effectively.

Another analysis shows that foreign capital investments positively influence green growth in OECD countries. Foreign investment introduces new technologies into the country and boosts production. If these technologies are environmentally friendly, they can also help reduce harmful gases produced during manufacturing. Governments should promote innovation and technology-driven methods to lower emissions. Therefore, OECD countries could increase such investments by offering incentives to attract foreign direct investment in environmentally friendly technologies.

Finally, the analysis concluded that population growth and urbanisation negatively impact green growth in OECD countries. Green growth can also drive structural changes in companies' and society's behaviours, including significant reductions in unsustainable levels of production and consumption in developed nations (Jackson, 2016).

Green growth policies include initiatives to invest in alternative energy capacity. Therefore, green growth can support economic development by boosting investment and innovation, opening new opportunities for sustainable progress. Increasing green awareness encourages many countries to develop green economic infrastructure to protect natural resources and the environment, particularly during the energy transition (Fernandes et al., 2021: 2022). Green growth can facilitate the production and consumption of eco-friendly goods and services by developing green technologies and clean energy sources. It can also help countries address their economic challenges sustainably, respect the environment, and achieve financial growth by revitalising existing industries or shifting to new green sectors of industrial development.

The results' robustness is expected to provide green growth by increasing investments in green technologies and renewable energy for policymakers in OECD countries. Designing, developing and implementing green technologies can ensure the development and sustainability of companies. The higher the green growth value, the greener the country's economic growth is becoming.

Finally, given the study's limitations, the green growth index, the dependent variable, began in 2010 and was analysed from 2010 to 2019. Although the results are robust, future research could increase the sample size to provide stronger validation. Additionally, by incorporating more variables —such as green investments and carbon taxes—key indicators of green growth that could not be included due to the limited time span, a more comprehensive analysis can be performed once the data range expands.

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