Renewable Energy, Economic Growth, and an Examination Related to Wind Energy: The Case of Selected OECD Countries[†]

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Abstract- The investigation reveals a unidirectional causal link from economic growth to wind energy consumption, substantiating the "conservation hypothesis" in these OECD (Organisation for Economic Co-Operation and Development) economies, implying that wind energy usage incurs significant costs. Contrarily, the analysis shows no causal relationship between wind energy consumption and the value added from medium and advanced technology production, aligning with the "neutrality hypothesis. Country-specific analysis, however, indicates varied causal interactions between economic growth and wind energy consumption, as well as between wind energy consumption and the value added of medium and advanced technology production. These findings are pivotal for policymakers and researchers focusing on wind energy and related investments. The study underscores the need for policies that promote renewable energy investments, accelerate technological innovations, and increase public awareness. Such measures are crucial for enhancing the adoption of sustainable energy sources. The research provides valuable insights into the interconnectedness of economic growth, renewable energy consumption, and technology, offering strategic directions for advancing sustainable energy utilization.

Keywords Economic growth, wind energy, renewable energy, sustainability, OECD countries.

1. Introduction

Today, a large part of our daily lives is powered by energy. A significant portion of this energy is derived from fossil fuels, which inevitably leads to major environmental problems and rapid depletion of natural resources. This also raises significant concerns in the areas of climate change and environmental sustainability. The depletion of natural resources, coupled with increasing energy demands, highlights the importance of renewable energy. Proper management of energy resources, which are critical for the socio-economic development of nations, depends on the formulation of various energy policies. In this context, renewable energy policy initiatives have gained global attention in recent years due to their positive environmental impacts. Wind energy, evaluated in terms of both its positive

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environmental impacts and its economic dimensions, is emerging not only as a stand-alone renewable energy type, but also as a viable complementary alternative in a sustainable energy production environment.

Since the dawn of the 21st century, wind energy has undergone remarkable expansion, propelled by advancements in technology, favorable policy frameworks, and decreasing costs. Witnessing a substantial rise in the last twenty years, wind power capacity has soared by a factor of 98. This expansion is evident across both onshore and offshore wind generation sectors. This consistent growth highlights the vast untapped potential of wind energy globally, bolstered by ongoing technological innovations and cost efficiencies. For instance, from 2010 to 2020, the average production cost of onshore wind energy plummeted from $0.089 per kWh to $0.039 per kWh, marking a significant 56% decrease. Concurrently, the investment costs for offshore wind projects also experienced a substantial reduction, approximately 48%, within the same timeframe [2].

This research delves into the intricate connection between energy consumption and economic growth, exploring various theoretical models in this realm. These include the growth hypothesis, the conservation hypothesis, the feedback hypothesis, and the neutrality hypothesis [3].

The Growth Hypothesis suggests a one-way causal link where energy consumption directly influences economic growth, indicating that disruptions in energy supply can adversely affect economic progress [4].

The Conservation Hypothesis posits that economic growth leads to energy consumption, and asserts that decreasing energy use may not significantly hinder economic growth [5].

The Feedback Hypothesis advocates for a two-way causal relationship, proposing that energy consumption and economic growth are interdependent and mutually influential [6].

The Neutrality Hypothesis, on the other hand, asserts the absence of any correlation between energy consumption and economic growth [7].

This study primarily focuses on the dynamic between economic growth and wind energy consumption within OECD countries. It is driven by two key motivations: the scarcity of literature specifically addressing the relationship between economic growth and wind energy, and the absence of a technological parameter in existing models exploring this relationship.

The second section of the paper covers the empirical component of the study by providing a literature review with examples from empirical studies and detailing the methodology, analysis and findings. The third section concludes with conclusions and recommendations.

2. Literature Review

The academic landscape reveals a plethora of studies examining the nexus between renewable energy and various economic indicators. However, research specifically focusing on wind energy remains relatively scarce. While a segment of these studies links overall renewable energy consumption to metrics like GDP (Gross Domestic Product), foreign trade, labor force, and inflation, others concentrate on distinct energy types such as solar, wind, geothermal, hydroelectric, and biomass, investigating their relationships with macroeconomic variables. A prevalent methodological approach in these studies is the utilization of time series and panel data analyses. The majority of these studies indicate a notable correlation between renewable energy consumption and economic growth and development.

This body of literature is concisely summarized in the following table. The table's first section discusses the connection between various types of renewable energy consumption, including wind, and economic growth, often identifying significant relationships in both the short and long term. The second section of the table encapsulates studies that delve specifically into the relationship between wind energy consumption and economic growth, yielding diverse hypotheses and results.

Table 1. Research exploring the interconnection between renewable energy usage, wind energy consumption and economic growth

Authors	**Time**	**Country/Area**	**Method**	**Findings** Analyzing the Correlation between Renewable Energy (RE) Utilization, Wind Energy (WE) Utilization, and Economic Growth (GDP)
Sadorsky (2009)	1994-2003	18 Developing Countries	Panel Cointegration Analysis	Long-Term positive and statistically Significant Colleration between RE and GDP [8]
Apergis and Payne (2010)	1985-2005	20 OECD Countries	Panel Data Analysis	Short and Long-Term positive and bidirectional causality colleration between RE and GDP [9]
Apergis and Payne (2010)	1992-2007	13 Eurasian Countries	Heterogeneous Panel Cointegration Test, Granger Causality Test	Short and Long-Term Bidirectional Causality Colleration between RE and GDP [10]
Pao and Fu (2013)	1980-2010	Brazil	Granger Causality Test and Johansen Cointegration Test	Bidirectional causality Colleration between RE and GDP [11]
Ocal and Aslan (2013)	1990-2010	Turkey	ARDL Bound Test, Toda Yamamoto Causality Test	Unidirectional Causality relationship between RE and GDP [12]
Ohler and Fetters (2014)	1990-2008	20 OECD Countries	Panel Causality Analysis	Bidirectional causality, Long-Term positive relationship RE and GDP [13]
Inglesi-Lotz (2016)	1990-2010	34 OECD Countries	Panel Data Analysis	Positive and Significant Colleration between RE and GDP [14]
Atay (2016)	2003-2012	G-7 and G-20 Countries	Panel Data Analysis	Bidirectional relationship between WE and GDP [15]
Matei (2017)	1990-2014	34 OECD Countries	Panel Data Analysis	A positive relationship in the long term, whereas results vary in the short term depending on the typeof energysource [16]

Table 1. (continued)

Authors	**Time**	**Country/Area**	**Method**	**Findings** Analyzing the Correlation between Renewable Energy (RE) Utilization, Wind Energy (WE) Utilization, and Economic Growth (GDP)
Marinas et al. (2018)	1990-2014	10 European Union Countries in Central and Eastern Europe	Panel-ARDL Method	Bidirectional causality in both short and long term relationship between RE and GDP [17]
Ozarslan and Bayrac (2018)	1998-2014	Turkey	ARDL Bound Test Analysis	From WE to GDP Positive and significant relationship [18]
Mikulic et al. (2018)	2007-2016	Croatia	Input-Output Analysis	Positive impact of RES installations on the economy [19]
Koc and Apaydin (2020)	1991-2017	Selected G-20 Countries	Panel Data Analysis	From WE to GDP positive and significant relationship [20]
Fan and Hao (2020)	2000-2015	31 Provinces of China	Granger Causality Analysis	Long-Term and stable relationship between RE and GDP [21]
Majeed et al. (2021)	1980-2019	174 Developed and Developing Countries	Fixed Effects Model, Random Effects Model and Two-Stage GMM Estimation Approach	Positive relationship between RE and GDP [22]
Birol and Demirgil (2021)	1995-2019	EU-15 countries	Panel Cointegration and Panel Causality Analysis	Unidirectional and positive relationship from GDP to WE [23]
Doğan et al. (2022)	2016 January - 2020 November	Germany, Iceland, Italy, Japan, Mexico, New Zealand, Portugal, Turkey, United States of America (ABD)	FMOLS and DOLS Models, Dumitrescu-Hurlin Causality Test	Negative effect detected, unidirectional causality from WE to GDP [24]

3. Data and Methods

3.1. Data

Our research focuses on the effects of wind energy consumption on economic growth. The sustainability of wind energy is primarily linked to the availability and accessibility of wind energy resources. Countries with a potential for wind energy production are included in the Renewable Energy Country Attractiveness Index (RECAI), which evaluates the investment appeal and potential of renewable energy sectors on a global scale. This index focuses on various renewable energy sources such as wind, solar, biomass, and hydroelectric power, analyzing and ranking countries based on their investment environment and energy production potential in these areas. In our study, we have focused on 19 OECD countries featured in this index, which possess sustainable wind production potential. The study includes Turkey, and due to data constraints, the timeframe analyzed spans from 2008 to 2020. In this study, per capita Gross Domestic Product (GDP) in current US dollars is employed as the independent variable to signify economic growth. For the dependent variable, we use Wind Energy Consumption (WCN) in exajoules to represent renewable energy consumption, and the Value Added by Medium and High Technology Manufacturing (TUKD), expressed as a percentage of total manufacturing value added, to denote technology. Data for per capita GDP and the value added by medium and high technology manufacturing were sourced from the World Bank database, while wind energy consumption figures were derived from the BP (British Petroleum) energy statistics database.

3.2. Method

The analysis of this study was conducted in a methodological framework comprising three distinct stages. Initially, the study examined the presence of cross-sectional dependence among the variables employed in the model, as well as the homogeneity of the slope parameter. Subsequently, the stationarity of the time series was assessed through unit root tests. Based on the outcomes of the stationarity tests, cointegration analyses were carried out, followed by a panel causality test. The methodologies applied in this study are delineated below.

The model, which is developed based on prior research in the literature, is represented as follows:

$$GDP = \alpha + ß1\ WIND + ß2\ TUKD + v \quad (1)$$

Given the increased likelihood of economic shocks in one country impacting others due to the rapid changes associated with globalization, various tests for Cross-Sectional Dependency (CD) were performed to detect this phenomenon.

For the CDLM1 and CDLM2 tests, the condition $T > N$ is applied when the time dimension exceeds the horizontal dimension. Conversely, in the CDLM (Cross-sectional Dependency Lagrange Multiplier) test, $N > T$ is used when the horizontal dimension surpasses the time dimension. The null hypothesis in these cross-sectional dependence tests posits the absence of cross-sectional dependence, while the alternative hypothesis suggests the presence of cross-sectional dependency.

The results of the Breusch and Pagan (1980) LM (Lagrange Multiplier) Test, Pesaran H. M. (2004) CDLM1, CDLM2 tests, and Pesaran, Ullah, and Yamagata (2008) CD tests used to assess the cross-sectional dependence within the model are presented in Table 2 [25-27]:

Table 2. Results of Cross-Sectional Dependency Tests

Test Type	Test İst.	Olasılık
LM (Breusch, Pagan 1980)	798.849	0.000***
CDLM1 (Pesaran 2004)	36.921	0.000***
CDLM2 (Pesaran2004)	23.703	0.000***
Biased Adjusted CD (Pesaran vd. 2008)	5.236	0.000***

Note: For Cross-Sectional Dependency Tests: ***, **, * indicate cross-sectional dependence at the levels of 1%, 5%, and 10% respectively.

The test results presented in Table 2 signify the presence of cross-sectional dependence among all parameters at a 1% significance level. Consequently, changes in wind energy consumption in one country have a notable impact on other countries. Furthermore, there is interdependence observed among countries concerning the growth rate.

3.2.1 Pesaran and Yamagata (2008) panel homogeneity test

Before delving into panel data analysis, it is essential to assess whether the slope coefficients in the model exhibit homogeneity. Homogeneity here refers to the equality of variances observed in different groups. This measurement process can be carried out using the delta test (Δ), as developed by Pesaran and Yamagata (2008), drawing upon the Swamy (1970) test [28-29]. This test relies on two distinct statistics, $\tilde{\Delta}$, tailored for large samples, and $\tilde{\Delta}adj$, suitable for small samples.

According to the homogeneity test results presented in Table 3, which utilized the studies of Pesaran and Yamagata (2008), the wind energy consumption and technology slope parameters in OECD countries exhibit homogeneity. This suggests that the results derived from the panel data analysis to be applied to the sample in the study are capable of reflecting individual information about the units constituting the panel.

3.2.2 Panel unit root analysis

In the realm of panel unit root tests, a common concern revolves around the independence of panel segments. Thus, it becomes imperative to evaluate the stationarity of panels through a unit root test. Various unit root analysis methods have been devised, contingent upon whether cross-sectional dependence is considered. The literature offers a plethora of unit root tests designed to examine the stationarity status of series within panel data analyses.

Table 3. Pesaran ve Yamagata (2008) homogeneity tests results

Test Statistic	Value	Probablity
$\tilde{\Delta}$	-3.000	0.999
$\tilde{\Delta}$adj	-3.421	1.000

Note: For delta tests: ***, **, * respectively indicate heterogeneity at 1%, 5%, and 10% levels.

3.2.2.1 Pesaran (2007) panel unit root CADF (Cross sectionally augmented Dickey-Fuller) analysis

Pesaran introduces a straightforward panel unit root test that encompasses standard DF (Dickey-Fuller) or ADF (Augmented Dickey-Fuller) regressions, incorporating discrete means, lagged levels, and the first differences of individual series. These conventional panel unit root tests primarily rely on the simple averages of Extended Dickey-Fuller statistics, often referred to as Cross Sectionally Augmented Dickey-Fuller (CADF) statistics.

According to the results of the Pesaran (2007) CADF unit root test for selected OECD countries, as presented in Table 4, it is determined that the variables GDP and TUKD exhibit a unit root at the levels but become stationary when examined at their first differences [30].

Table 4. Peseran (2007) panel unit root CADF analysis results

PANEL İSTATİSTİĞİ DEĞERLERİ				
	Düzey		Birinci Fark	
Variables	Constant	Trend	Constant	Trend
GDP	-0.459	-2.730*	-2.121*	-0.899
WCN	-1.715	-1.906	-2.031	-1.748
TUKD	-2.044	7.645***	5.233***	-2.466

Note: The critical values for panel statistics in the fixed model are as follows: -2.45 (1%), -2.22 (5%), and -2.11 (10%), as detailed in Pesaran 2007, Table II(b), page 280. In the fixed and trended model, the critical values are -2.98 (1%), -2.77 (5%), and -2.64 (10%), as specified in Pesaran 2007, Table II(c), page 281. The panel statistic is computed as the average of the CADF statistics. In consulting these tables, critical values pertinent to a scenario with N=20 and T=15 have been taken into consideration. Based on the results obtained from the study, the Panel LM Bootstrap Westerlund and Edgerton (2007) cointegration analysis will be applied.

3.2.3. Panel LM Bootstrap Westerlund ve Edgerton (2007) Cointegration Analysis

The Westerlund (2007) test is a cointegration test that relies on the error correction model, providing a means to investigate cointegration relationships among two or more variables. Westerlund (2007) recommends the use of bootstrap critical values proposed by Chang (2004) in cases where series exhibit cross-sectional dependence [31]. In contexts where heterogeneity and cross-sectional dependence are present, it is crucial to consider panel bootstrap critical values and interpret analyses in light of these. The outcomes of the cointegration analysis using the Panel LM Bootstrap method developed by Westerlund and Edgerton (2007) are displayed in Table 5:

Table 5. The results of the panel LM bootstrap cointegration test

Model Type	LM Test Statistic	Asymptotic Probablity Value	Bootstrap probablity Value
Fixed Model	1.492	0.068	0.999***
Fixed& Trended Model	7.718	0.000	0.984***

Note: For Panel LM Bootstrap Cointegration Test: ***, **, * indicate cross-sectional dependence at the levels of 1%, 5%, and 10% respectively.

The data presented in Table 5, derived from the Panel LM Bootstrap cointegration test, indicate the presence of a cointegration relationship in both the trend-inclusive and trend-exclusive models. This test further elucidates a long-term association among GDP, WCN, and TUKD variables. Until this point in the analysis, unit root tests were conducted to assess the stationarity of the series. Additionally, examinations of cross-sectional dependence and homogeneity have been undertaken. These assessments were crucial in determining the appropriate methodologies for unit root, cointegration, and causality analyses within the model. Following these preliminary analyses, appropriate cointegration tests were subsequently executed. In the final phase of this study, to ascertain the causal linkages among wind energy consumption, the value addition in medium and advanced technology production, and economic growth, we will employ the Emirmahmutoğlu and Köse (2011) Panel Causality Analysis method.

3.2.4. Emirmahmutoğlu and Köse (2011) Panel Causality Analysis

This methodology, essentially a Granger Causality Test tailored for heterogeneous panel data, is rooted in the principles of the Toda-Yamamoto Granger Causality approach. Emirmahmutoğlu and Köse in 2011 enhanced this method by incorporating the bootstrap technique into the Fisher test statistic, thereby facilitating the analysis of causality within each individual cross-section as referenced in

[32]. A notable merit of this approach is its applicability irrespective of the existence of a cointegration relationship among the series.

The outcomes of the Emirmahmutoglu and Kose (2011) Panel Causality Test, employed to discern the causal interactions among the variables, are delineated in Table 6:

Table 6. Panel causality test results

Cause > Effect				
Countries	**GDP > WCN**	**WCN > GDP**	**WCN > TUKD**	**TUKD > WCN**
Belgium	3.616 (0.057)	0.149 (0.700)	32.436 (0.000) ***	11.41 (0.003) ***
Denmark	77.39 (0.000) ***	3.109 (0.211)	0.282 (0.596)	1.950 (0.163)
France	1.047 (0.593)	0.926 (0.629)	8.978 (0.011)**	0.562 (0.755)
Germany	0.439 (0.803)	1.694 (0.429)	0.652 (0.722)	9.600 (0.008) ***
Ireland	1.764 (0.414)	5.714 (0.057)*	4.988 (0.083)*	0.399 (0.819)
Portugal	0.342 (0.559)	1.098 (0.295)	5.277 (0.071)*	1.407 (0.495)
Turkey	6.294 (0.043)**	0.021 (0.990)	0.001 (0.969)	0.272 (0.602)
Australia	0.701 (0.704)	3.810 (0.149)	12.33 (0.002) ***	0.134 (0.935)
Japan	6.795 (0.033)**	2.325 (0.313)	0.840 (0.657)	0.374 (0.829)
Canada	4.119 (0.128)	15.55 (0.000)	0.627 (0.731)*	1.136 (0.567)
Austria	0.706 (0.401)	0.363 (0.547)	1.312 (0.519)	38.07 (0.000) ***
Panel	112.40 (0.063)*	45.95 (0.860)	83.20 (0.917)	80.55 (0.916)

Note: For Panel Causality Test: ***, **, * indicate cross-sectional dependence at the levels of 1%, 5%, and 10% respectively.

A scrutiny of the panel causality outcomes, as showcased in Table 6, reveals a lack of causality between wind energy consumption and the value addition in medium and advanced technology production on a panel-wide basis. Contrastingly, there is an indication of a unidirectional causal influence from economic growth to wind energy consumption in the long term, observed at a 10% significance level.

4. Conclusion and Recommendations

Upon analyzing the panel causality results displayed in Table 6, it becomes evident that within the framework of the study, wind energy consumption and the added value from medium and advanced technology production are not causally linked. This aligns with the 'neutrality hypothesis.' However, a distinct unidirectional causality is observed from economic growth to wind energy consumption at a 10% significance level over a prolonged period. This trend suggests the applicability of the 'conservation hypothesis' in the economies of the selected OECD countries. These findings are in concordance with the research of Birol and Demirgil (2021), which focused on the effects of wind energy consumption on economic growth. From this perspective, any restrictive measures or economic disturbances targeting wind energy are unlikely to adversely impact the economic growth in these countries.

An individual country analysis reveals a diverse range of causal relationships. For instance, in Belgium, the identification of a bidirectional causality between wind energy consumption and the added value from medium and advanced technology production supports the 'feedback hypothesis,' indicating a mutual influence between these two variables.

In contrast, countries like France, Ireland, Portugal, and Australia demonstrate a one-way causality from wind energy consumption to the added value of medium and advanced technology production, upholding the 'conservation hypothesis.' This implies that fluctuations in the added value from these technologies are less likely to impact wind energy consumption. These nations, in their pursuit of sustainable energy objectives, show a varied approach in policy-making, with a common trend of increasing focus on wind energy and technological advancements. Energy resources play a vital role in sustainability efforts and are of critical importance for success in this domain [33]. Nevertheless, given the looming challenges of finite resource depletion and escalating energy demands, it is imperative for policymakers in these regions to strategize for diversified renewable energy development, tailored to their specific energy potentials.

In the case of Germany and Austria, it has been noted that the value added by medium and advanced technology production exhibits a noticeable impact on wind energy consumption.

In countries like Denmark, Turkey, and Japan, variations in economic growth have been identified as influencing factors on wind energy utilization. Technological advancements in this sector, encompassing improvements in turbine efficiency, advances in energy storage technologies, and the increasing role of digitalization, are contributing to the reduction of costs and enhancing the reliability of wind energy projects. Materials such as lithium, nickel, cobalt, manganese, and graphite are critical in the development of batteries for renewable energy storage. Turkey, with its significant boron resources and the ability to produce lithium from boron waste, stands to gain both economically and strategically by investing in wind energy, potentially leading the way in global energy storage technology.

For Turkey, it is advisable to focus on infrastructure investments that link wind power plants and to develop projects that modernize and increase the flexibility of energy networks. The effectiveness of wind energy policies in Turkey also hinges on the involvement, awareness, and acceptance of the local population. Engagement with local communities and civil society organizations during the planning and execution stages of projects is crucial.

The success of wind energy initiatives is closely linked to the robustness and consistency of legislative and regulatory frameworks. Simplifying procedures for permits, environmental and social impact assessments, grid integration, and energy trading is vital for the seamless development and implementation of wind energy projects in Turkey.

To optimize wind energy policies, regular evaluations and reports by energy authorities, and the development and sharing of innovative projects based on global best practices are essential. Ongoing research and development, facilitated by collaborations between the government, private sector, and academic institutions, are pivotal in enhancing the efficacy and viability of wind energy technologies in Turkey.

Wind energy is also integral to hybrid energy systems, which mitigate fluctuations in energy production and enhance grid reliability. The integration of wind energy with other renewables, like solar power, and energy storage systems, allows for more dependable and flexible energy production. Given Turkey's substantial solar potential, strategies for hybrid energy systems should be formulated.

Policy-wise, it is imperative to create strategies that diversify renewable energy production, considering the depletion of finite natural resources and the growing energy demand. Local blockchain initiatives in the energy sector can significantly enhance energy efficiency and effectiveness. Technological innovations in the wind energy sector not only support economic growth through investments in renewable energy but also contribute to local economies through the installation and operation of wind energy projects.

Kite Energy Technology and High Altitude Wind Energy Technologies are increasingly being utilised as the best examples of wind energy technology diversity and innovation. Kite Energy Technology is predicated on harnessing strong and persistent winds at high altitudes to convert wind energy into electricity, whereas High Altitude Wind Energy similarly employs alternative aerial vehicles like balloons or kites for this conversion. Both technologies offer significant advantages, including access to high winds, low installation costs, reduced environmental impact, and portability. However, they also present challenges, including the control of atmospheric conditions, energy transmission difficulties, limited testing and application capacity, and safety concerns.

When examining these technologies within the context of 19 OECD countries included in our study, Belgium's small and densely populated coastal regions, despite spatial limitations, present suitable conditions for kite energy. Denmark, with its extensive coastline and leadership in wind energy, offers advantages for both technologies. France's broad coastal areas, especially open sea regions, are ideal for High Altitude Wind Energy.

Germany's northern coasts, with strong winds and advanced technological infrastructure, are perfect for High Altitude Wind Energy. The coastal regions of Ireland, Portugal, Australia, and Japan also provide conducive conditions for both technologies. Turkey's Aegean and Mediterranean coasts offer advantages for kite energy, particularly in rural and hard-to-reach areas, while Canada's geographical diversity, especially in coastal and mountainous regions, presents opportunities for both technologies. Austria's mountainous regions show potential for High Altitude Wind Energy.

In conclusion, these innovative energy solutions are continuously evolving and in the research phase. With further applications and developments in the future, the usage of these technologies could increase, offering more advantages. The unique geographical and climatic characteristics of each country are key factors affecting the applicability and efficiency of these technologies.

Wind energy diversification bolsters energy security by reducing reliance on fossil fuels and leveraging domestic resources, thus supporting economic growth and stability in the energy sector.

Taking all these aspects into account, wind energy consumption is poised to play a pivotal role in economic growth and the sustainability of the energy sector. Policymakers and the business community can amplify this potential by fostering investments in wind energy and establishing effective incentive mechanisms.

Nevertheless, the scarcity of studies exploring the correlation between wind energy and economic growth poses a challenge in conducting a thorough analysis of their interrelationship. Despite these constraints, incorporating technological development into this research offers a novel perspective, positioning it as a trailblazing study in the field.

For future research endeavors, accessing more extensive time-series data would allow for a deeper understanding of the internal dynamics of the countries concerned in relation to wind energy. Expanding studies to include data on R&D (Research and Development) investments, CO2 emissions, and skilled labor, employing diverse analytical techniques, could enrich the research. Given the growing relevance of renewable energy, regional analyses may become a primary focus in future studies, offering valuable insights into the dynamics of renewable energy.

In summary, when combined with technological innovation, eco-friendly policies, and sustainability, wind energy consumption emerges as a vital component in supporting economic growth. As a clean energy source, wind energy not only minimizes environmental harm but also fosters economic growth through technological progress and environmental policies. Therefore, escalating investments in the wind energy sector and making suitable policy adjustments are essential for a sustainable energy future that bolsters economic growth.

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