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Renewable Energy Policy, Governance Quality and Economic Growth: A Cross-Country Analysis

Anh Thi Ha Do[1]*

[1]Institute for Sustainable Development, National Economics University, Hanoi, Vietnam.

***Corresponding Author**
E-mail: dothihaanh.ephd4@st.neu.edu.vn

ABSTRACT

This study examines the nexus between renewable energy policies, institutional quality, and economic growth in 140 countries from 2010 to 2021 by employing the Generalized Method of Moments (GMM) estimation to address endogeneity concerns and dynamic effects. The empirical findings reveal that the pillars of renewable energy policies (energy efficiency [EE], renewable energy [RE], electricity access [EA], and clean cooking [CC]) are underdeveloped and negatively influence economic growth, highlighting investment constraints, infrastructure bottlenecks, and technological inefficiencies in the transition to sustainable energy systems. Institutional quality plays a critical role in shaping economic performance. Regulatory quality (RQ), the rule of law (RL), and economic growth are positively impacted by political stability and the lack of violence or terrorism (PS), which emphasises the significance of strong legal frameworks and a stable macroeconomic environment. However, there are drawbacks to voice and accountability (VA), governance effectiveness (GE), and control of corruption (REC), indicating that compliance costs and institutional rigidities may impede economic growth. The moderating influence of voice and accountability (VA) in reducing the negative consequences of renewable energy policies and promoting equitable and sustainable growth is one of the study's primary findings. These findings underscore the necessity for adaptive and high-quality institutional reforms, coupled with strategic renewable energy policies, to enhance governance efficiency, mitigate transition costs, and maximize long-term economic gain.

Keywords: Institutional quality, Renewable energy policy, Labor, Economic growth, Capital.

Introduction

Economic growth remains a key goal for nations, with energy playing a crucial role in production, industry, and consumption (Liu *et al*., 2022; Warsame *et al*., 2024). However, over-reliance on fossil fuels not only increases environmental pollution but also accelerates global climate change, threatening sustainable development and public health (Oh & Lee, 2004; Acheampong *et al.*, 2021; Thazha *et al*., 2023). Thus, transitioning to renewable energy is essential for reducing CO_2 emissions and achieving long-term growth.

Despite its environmental benefits (Dong *et al*., 2018; Makhoahle *et al*., 2022; Saliba *et al*., 2022), high upfront costs and low short-term returns deter many countries from prioritizing renewable energy over fossil-fueled growth (Bhuiyan *et al*., 2022; Dhanasekar *et al*., 2022). Renewable energy is still a key sign of sustainable development, nevertheless (Kahia *et al*., 2017; Graefen *et al*., 2023).

The nexus between energy and economic growth has been extensively researched over an extended period (Akarca & Long, 1980; Wilhelmy *et al*., 2022). Several studies have confirmed a causal relationship between energy consumption and economic growth. However, the impact of renewable energy remains controversial (Dong *et al*., 2018; Kulkarni *et al*., 2023). While some studies indicate that renewable energy promotes economic growth (Paramati *et al*., 2016;

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Sarkodie & Adams, 2018; Bhuiyan *et al*., 2022; Pavlova, 2024) find that renewable energy does not hinder growth; however, its impact on developed countries remains unclear.

Mahjabeen *et al*. (2020) and Fernandes *et al*. (2022) emphasized that institutional stability significantly influences the relationship between renewable energy and economic growth. Both renewable and non-renewable energy sources affect economic productivity and CO_2 emissions. However, the adverse effects of renewable energy sources are far fewer than those of fossil fuels. Simultaneously, robust institutions facilitate economic development and mitigate the adverse environmental effects.

Although many studies have analyzed the relationship between energy and economic growth, most have not considered the moderating role of institutional quality in this relationship. Institutional quality can significantly influence the effectiveness of renewable energy policy implementation and affect investment efficiency, access to capital, transparency in resource management, and the extent to which the private sector is encouraged to participate in the clean energy industry, thereby promoting sustainable economic growth.

This study incorporates institutional and economic factors into a Cobb-Douglas framework, modeling growth as a function of capital, labor, sustainable energy policy, and institutional quality. Energy policies include renewable energy, efficiency, electricity access, and clean cooking, while institutional quality is assessed via six governance pillars.

Aiming to inform policy design suited to national contexts, the study explores the direct and moderated effects of sustainable energy policies on growth, offering empirical insights for aligning energy reform with institutional improvements to optimize economic development.

Literature Review

The Cobb-Douglas production function is frequently employed in economics to illustrate the link between inputs, specifically capital (K), labor (L), and total output (Y). This function is defined as follows:

$$y = A \cdot K^{\alpha} \cdot L^{\beta} \quad (1)$$

The Cobb-Douglas function helps analyze returns to scale, assessing the role of technology and production factors in economic growth.

Renewable Energy

Mahjabeen *et al*. (2020) asserted that renewable energy sources, including solar, wind, tidal, waste, and biomass, are environmentally sustainable and economically viable owing to their capacity to alleviate climate change and enhance energy security (Kamran, 2018; Tareen *et al*., 2018; Shaheen *et al*., 2023). According to Acheampong *et al*. (2021), Maneea *et al*. (2024) renewable energy is the optimal alternative to fossil fuels. However, the cost of adoption remains high and is affected by factors such as economic weight, economic growth, and institutional quality. Li and Leung (2021) demonstrate a bidirectional causal relationship between renewable energy and economic growth. The authors employ Regulatory Indicators for Sustainable Energy (RISE) to measure the impact of renewable energy on economic growth, including the pillars of electricity access, clean cooking, renewable energy, and energy efficiency.

Institutional Quality

According to Alonso and Garcimartín (2013) and AlHussain *et al*. (2022) institutions play an important role in shaping social behavior and promoting sustainable development. The AJR (2005) identifies institutions as a root cause of economic growth due to their role in securing property rights and promoting human capital investment. Bhattacharya *et al*. (2017) further emphasize that strong institutions aid in crafting sustainable development policies. The World Governance Indicators (WGI) are used to measure institutional quality, including six indicators: Voice and Accountability, Political Stability and Absence of Violence/Terrorism, Governance Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

This study finds that institutional quality fosters renewable energy development and sustainable growth. To reflect this, the Cobb-Douglas production function is extended beyond capital (K) and labor (L) to incorporate institutional quality (WGI) and renewable energy policy (RISE), offering a more comprehensive framework for analyzing the drivers of economic growth:

$$y = A \cdot K^{\alpha} \cdot L^{\beta} \cdot WGI^{\gamma} \cdot RISE^{\delta} \quad (2)$$

The conceptual framework is illustrated in **Figure 1**. This extension allows for a deeper analysis of the impact of non-traditional factors such as the institutional environment and sustainable development policies, thereby supporting more effective economic policymaking.

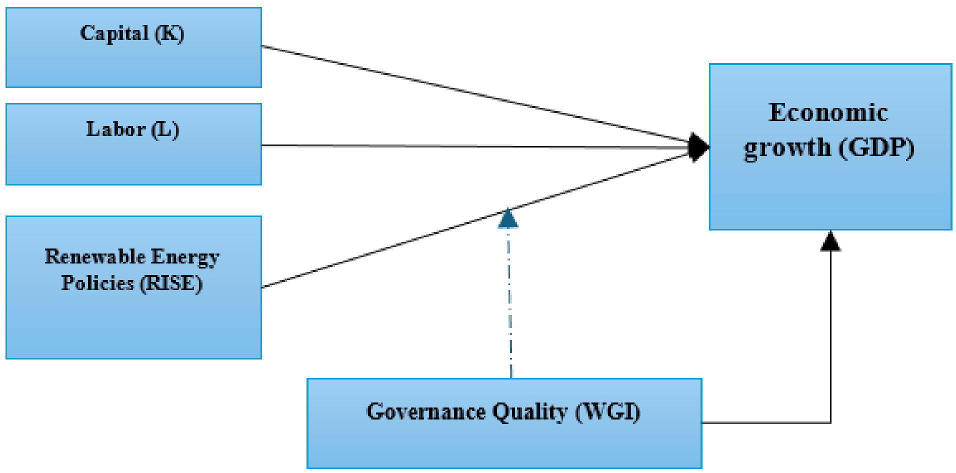

Figure 1. Conceptual Framework

Research Hypotheses

The Impact of Capital and Labor on Economic Growth

According to the World Bank (1991), Malcangi *et al*. (2023) economic growth reflects an increase in key economic indicators, particularly gross domestic product relative to population. Blanchard (2000) also defined GDP in two ways: (1) GDP is the value of final goods and services produced in the economy in a certain period, calculated by the final consumption portion, and (2) GDP is the total value added to the economy in the same period.

Neoclassical growth theory highlights capital and labor as core production inputs, with technological progress being essential for sustained growth (Bulusu *et al*., 2023; Warsame *et al*., 2024). Bulut and Muratoglu (2018) confirm the significant role of both capital and labor in determining output.

The Cobb-Douglas production function is widely used in economics to describe the relationship between inputs, such as capital (K), labor (L), and total output (Y). Thus, we propose the following hypothesis:

Hypothesis 1: Capital has a positive impact on economic growth

Hypothesis 2: Labor has a positive impact on economic growth

Institutional Quality and Economic Growth

Institutional quality significantly affects the energy–growth nexus, particularly through political stability, regime type, and democracy level. Under high-quality political regimes, energy consumption more strongly drives economic growth (Adams *et al*., 2016a; 2016b). Adams *et al*. (2016a) argued that democracy moderates the relationship between energy consumption and economic growth, and further research (Adams *et al*., 2018; Pisano *et al*., 2023; Bolay *et al*., 2024) has revealed that democratic countries have higher economic growth than authoritarian countries.

Azam *et al*. (2023) and Dipalma *et al*. (2022) emphasize that that institutional alignment—economic freedom and political stability—is vital for integrating renewable energy into economic systems, ensuring long-term prosperity. Similarly, Mahjabeen *et al*. (2020), Marian *et al*. (2023) highlight institutional stability as essential for protecting environmental quality and enabling the transition to renewables.

Furthermore, research by Sarkodie and Adams (2018), Adams and Klobodu (2017), and Azam *et al*. (2023) and Fiodorova *et al*. (2022) indicate that strong institutions and political systems foster economic growth and environmental quality. The combined use of renewable and nonrenewable energy, along with sound policies, technological innovation, and institutional stability, supports the long-term development of renewable energy.

The World Governance Indicators (WGI), developed by the World Bank, assess institutional quality through six pillars that reflect the effectiveness and environment of public institutions. The six component indicators of the WGI include the following:

- *Voice and accountability (VA): Assesses the level of freedom of speech, freedom of the press, democratic electoral rights, and government accountability.*
- *Political Stability and Absence of Violence/Terrorism (PS) reflect the level of political stability and national security, a factor that attracts investment and promotes development.*
- *Government Effectiveness (GE): Assesses the quality of public services, professionalism of civil servants, and the effectiveness of policy implementation.*
- *Regulatory Quality (RQ): Measures the ability to issue and enforce transparent regulations, promote development, and protect property rights.*
- *Rule of Law (RL) reflects the level of compliance with the law and the protection of property rights, creating a foundation for stability and growth.*
- *Control of Corruption (REC): This assesses the level of corruption in government agencies, with high scores reflecting both citizen and investor transparency and trust.*

Voice and accountability (VA) are key to strengthening institutional quality, promoting governance, and driving sustainable growth. Kaufmann *et al*. (2010) indicate that VA helps increase transparency and reduce corruption, whereas Rodrik (2000) finds that democracies with strong accountability achieve better growth outcomes. Also note that VA improves the predictability of legal and economic systems, facilitating trade and investment. By involving citizens and businesses in policymaking, VA ensures economic policies are more grounded and effective. It also strengthens oversight of public resource use, reducing waste in large-scale investments. Ultimately, VA both directly and indirectly shapes economic growth by fostering inclusive participation and competitiveness.

Based on these pillars, we propose the following hypotheses to examine their impact on economic growth.

Hypothesis 3: Higher voice and accountability (VA) have a positive impact on economic growth.

Hypothesis H3a: Energy efficiency (EE) improves economic growth more strongly through increased voice and accountability (VA).

Hypothesis H3b: Renewable energy (RE) utilization rate improves economic growth more strongly through increased voice and accountability (VA).

Hypothesis H3c: Voice and accountability (VA) promote economic growth through expanding electricity access (EA).

Hypothesis H3d: Voice and accountability (VA) positively impact economic growth through promoting clean cooking (CC).

Hypothesis 4: Political stability and the absence of violence/terrorism (PS) have a positive impact on economic growth.

Hypothesis 5: Governance effectiveness (GE) has a positive impact on economic growth.

Hypothesis 6: Regulatory quality (RQ) has a positive impact on economic growth.

Hypothesis 7: The Rule of Law (RL) has a positive impact on economic growth.

Hypothesis 8: Control of corruption (REC) has a positive impact on economic growth.

Renewable Energy Policy and Economic Growth

Renewable Energy Policy

Renewable energy sources—such as solar, wind, tides, waste, and biomass—are eco-friendly and cost-effective alternatives that help mitigate climate change, reduce pollution, enhance energy security, and alleviate poverty, especially in remote areas (Kamran, 2018; Tareen *et al*., 2018; Mahjabeen *et al*., 2020). They have become key drivers of economic growth (Xiong *et al*., 2014; Bhuiyan *et al*., 2022; Dongmo *et al*., 2023).

Acheampong *et al*. (2021) note that renewable energy is a strategic substitute for fossil fuels, though its adoption faces hurdles like high costs and dependency on national wealth, development stage, political will, and institutional quality. A bidirectional causality between renewable energy and economic growth has been observed (Li & Leung, 2021).

The energy–growth nexus has been widely studied, with some confirming that both renewable and nonrenewable energy drive growth (Doytch & Narayan, 2021; Patil, 2022), while others argue that economic growth leads to higher energy demand (Magazzino *et al*., 2021), suggesting a bidirectional relationship.

However, overconsumption of energy can degrade the environment and worsen climate change (Mirza & Kanwal, 2017; Khan *et al*., 2020). Chein and Hu (2007) identified labor, capital, and energy as core growth inputs, with GDP as output. Increasing the use of renewable energy not only improves economic efficiency but also reduces environmental pollution and promotes economic growth (Paramati *et al*., 2016).

Warsame *et al*. (2024) and Hasanov *et al*. (2017) confirm energy's critical role in growth. However, there are several perspectives in the literature. Acheampong *et al*. (2021) demonstrate that low renewable shares may hinder growth. Bulut and Muratoglu (2018) suggest increasing renewable use to reduce trade deficits. In contrast, Mahjabeen *et al*. (2020) found that renewable energy has a significant positive impact on economic growth.

The Role of the Sustainable Energy Management Index

Regulatory indicators for sustainable energy (RISE) have been developed and published by the World Bank (2020). This set of indicators assesses countries' sustainable energy policies and regulatory frameworks to support the implementation of the United Nations Sustainable Development Goal No. 7 (SDG7) on access to clean, modern, reliable, and sustainable energy. The RISE consists of four main pillars.

Electricity Access (EA): Assessing the level of electricity access and policies to support expanding access to electricity.

Clean Cooking (CC): Assesses policies and initiatives that support the transition from traditional fuels (e.g., coal and firewood) to cleaner cooking solutions.

Renewable Energy (RE): Evaluates policies to encourage the development of renewable energy, such as solar power, wind power, and hydropower.

Energy Efficiency (EE): Assesses policy measures to improve energy efficiency.

Therefore, the author proposes the following hypothesis regarding the impact of the four pillars of RISE on economic growth.

Hypothesis 9: The higher the energy efficiency (EE) ratio, the more positive the impact on economic growth.

Hypothesis 10: The higher the rate of renewable energy (RE) usage, the more positive the impact on economic growth.

Hypothesis 11: The higher the electricity access rate (EA), the more positive the impact on economic growth.

Hypothesis 12: The higher the clean cooking (CC) rate, the more positive the impact on economic growth.

By reviewing domestic and foreign research, this study proposes a theoretical framework to assess the level of influence of various factors on economic growth, especially those related to renewable energy policies and institutional quality **(Figure 2)**.

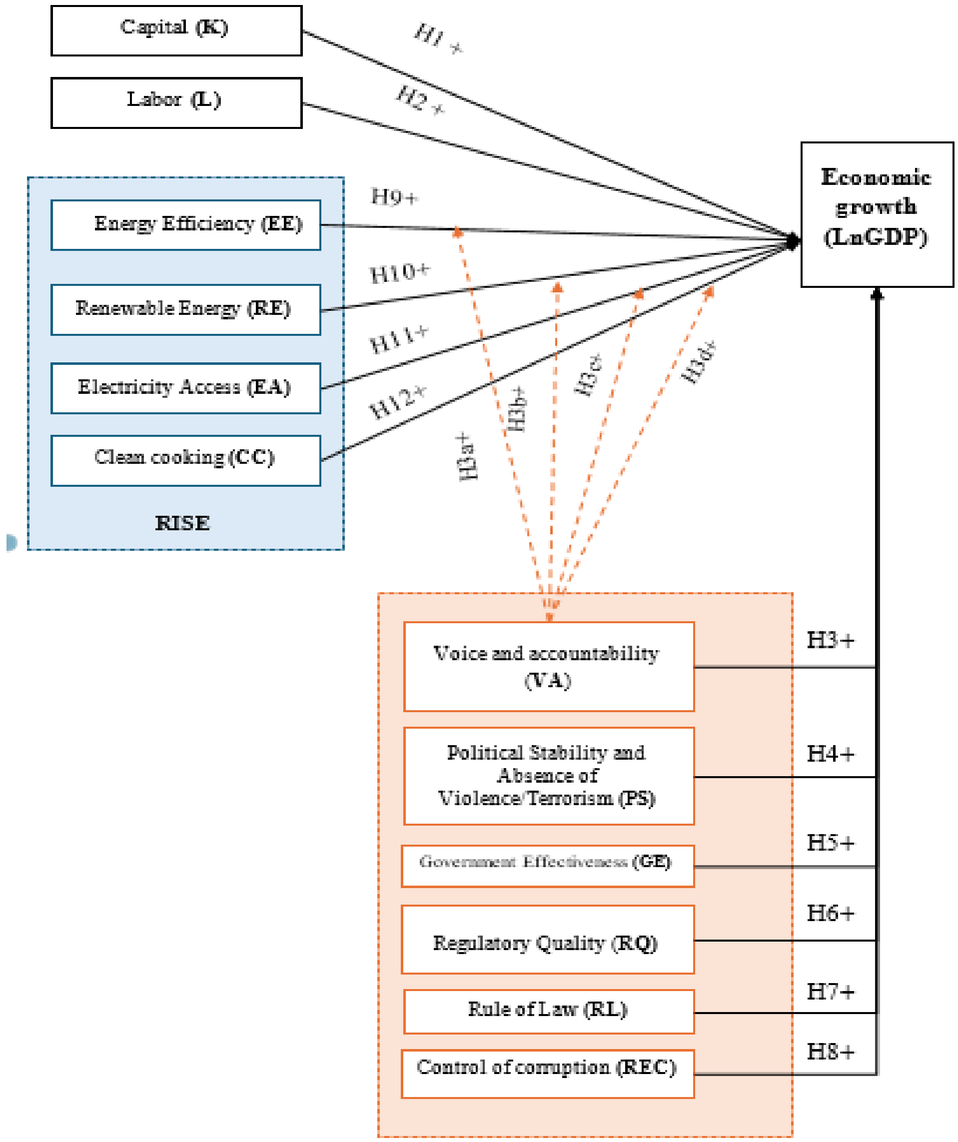

Figure 2. Theoretical Framework

Materials and Methods

Data

Secondary data on the economic growth of 140 countries were collected from the World Bank for 2010 – 2021. Among the countries selected for this study, this period had the most complete statistical data.
The natural logarithm of GDP calculates economic growth.
The Sustainable Energy Management Index - RISE is scored on a scale of 0 to 100.
The WGI indicators were scored on a scale ranging from -2.5 (low) to +2.5 (high), with higher scores reflecting better governance quality. The WGI is an important tool for assessing the institutional environment of countries, serving research and policymaking for socio-economic development.

Estimated Method

This study applied panel data regression methods, including ordinary least squares regression models (pooled OLS), fixed effects models (FEM), and random effects models (REM). In addition to handling endogeneity and potential bias, this study uses the Generalized Method of Moments (GMM) estimation model. In addition, diagnostic tests such as the Hausman test and the Arellano-Bond test are applied to select the most suitable model, ensuring the consistency and efficiency of the estimates.

Results and Discussion

Descriptive Statistics

The data in **Table 1** indicate that economic variables, including capital (K) and labor (L), exhibit large disparities in scale among countries, highlighting inequality in developmental capacity. The components of Energy Policy, namely Energy Efficiency (EE), Renewable Energy (RE), Energy Access (EA), and Climate Change (CC), exhibited mean values of 29.83 ± 24.12, 35.02 ± 25.42, 29.53 ± 20.71, 32.62 ± 29.88, respectively, indicating large dispersion and highlighting disparities in clean energy access and energy efficiency across developed and developing countries. This large dispersion indicates uneven energy efficiency, reflecting differences in the level of technological modernization and energy-saving policies. Some countries rely heavily on renewable energy, whereas others rely on traditional energy sources (coal, wood, and fossil fuels). The data also reflect inequalities in access to electricity, particularly in rural and low-income countries.

In terms of institutional quality, indicators such as VA, PS, GE, RQ, RL, and REC had negative mean values, indicating that many countries face challenges in governance effectiveness, transparency, and corruption control. This reflects low levels of democracy and transparency, especially in developing countries, along with political instability and difficulty in enforcing effective legal regulations. Corruption remains widespread, thus reducing the effectiveness of economic policies and hindering sustainable growth.

Table 1. Descriptive statistics.

Variable	Number of observations	Medium	Standard deviation	Lowest	Highest
LnGDP	1,645	8,495	1,442	5,574	11,396
K	1,436	1.54E+11	5.91E+11	1.52E+08	6.56E+12
L	1,666	1414957	4616409	1912.626	5.07E+07
EE	1,645	29,831	24,122	0.126	87,389
RE	1,656	35,025	25,424	0.333	93,935
EA	635	29,526	20,716	0.911	89,597
CC	1,680	-0.200	1,061	-1.998	2,992
VA	1,680	-0.196	1,032	-2.857	1,956
PS	1,680	-0.293	0.978	-3.838	1,942
GE	1,680	-0.118	1,029	-2.998	2,285
RQ	1,680	-0.076	1,036	-2.978	2,860
RL	1,680	-0.188	1,036	-2.858	2,816
REC	1,679	32,623	29,884	0.000	97,030

The values of the regression models are very high (OLS = 0.9962, REM = 0.9991, FEM = 0.9993), indicating that these models explain most of the GDP variation **(Table 2)**. The Hausman test results (p-value = 0.0000) indicate that the FEM model is more suitable than the REM model.

The Arellano-Bond test for first-order autocorrelation (AR(1)) has a p-value = 0.011 (<0.05), indicating the existence of first-order autocorrelation, which is normal in GMM models. The Arellano-Bond test for second-order autocorrelation (AR(2)) has a p-value of 0.221 (>0.05), indicating the absence of second-order autocorrelation, ensuring the validity of the model. The Hansen test had a p-value of 0.425 (>0.05), confirming the validity of the instrumental variables used in the model. Therefore, the GMM model is considered the most reliable and suitable and is selected to estimate the impact of factors on economic growth.

Table 2. Estimation results of choosing the optimal regression model to evaluate the impact of factors on economic growth.

Variable symbol (LnGDP)	Variable name explanation	Regression coefficient			
		OLS model	REM model	FEM model	GMM Model
(Column 1)	*(Column 2)*	*(Column 3)*	*(Column 4)*	*(Column 5)*	*(Column 6)*
LnGDP $_{t-1}$	GDP growth with 1-year lag	0.9879***	0.9841***	0.8269***	0.9506***
K	Capital	1,181e-13**	1,536e-13**	2,972e-13**	1,981e-12***
L	Labor	-1,655e-09	-2.224e-09*	-6,254e-09**	-1,967e-08***
EE	Energy efficiency	-0.0001	-0.0002	0.0001	-0.0019***
RE	Renewable Energy	-0.00012	-0.0002	-0.0001	-0.0021***
EA	Access to electricity	0.0001	0.00002	0.0002	0.0005*
CC	Clean cooking	-0.0112*	-0.0033	0.0112	0.0228
VA	Voice and accountability	-0.0302**	-0.0290**	-0.0278*	0.1184***
PS	Political stability and absence of violence/terrorism	0.0049	0.0042	0.0083	0.0185**
GE	Management efficiency	0.0061	-0.0007	-0.0064	-0.0142
RQ	Quality of legal regulations	0.0047	0.0060	0.0018	0.0231
RL	Rule of law	0.0001	0.0009	0.0073	0.0647***
REC	Control corruption	-0.0003**	-0.0003**	-0.0003**	-0.0008***
c.EE#c VA	When there is a VA regulator	-0.0005*	-0.0004	-0.0006**	-0.0042***
c.RE#c. VA	When there is a VA regulator	0.0005**	0.0004*	-0.0006**	-0.0026***
c.EA#c VA	When there is a VA regulator	0.0001	0.0002	0.0004**	0.0020***
c.CC#c. VA	When there is a VA regulator	-0.0284***	-0.0264***	-0.0231**	0.1175***
Cons		0.1306***	0.1650***	1,2915***	0.5048***
	R^2	**0.9962**	**0.9991**	**0.9983**	
	F (35, 398)			**3.97**	
	Prob> F	**0.0000**	**0.0000**	**0.0000**	
	Breusch–Pagan test				
	Arellano-Bond test for AR (1) in first differences				**0.011**
	Arellano-Bond test for AR (2) in first differences				**0.221**
	Hansen test excluding group:				**0.425**

Note: (*): significant at 10%; (**): significant at 5%; (***): significant at 1%

Overview of the Six GMM Models

Table 3 presents the results of estimating the impact of factors on economic growth (LnGDP) through six GMM models to compare and analyze the influence mechanisms of economic, energy, and institutional factors, supporting policy decision-making based on empirical evidence. In which:

GMM1 – GMM4 models: Focus on basic economic variables (K, L), institutional quality (WGI), and each pillar of RISE (EE, RE, EA, CC), and examine the moderating role of VA (Voice and Accountability) on these pillars to assess the change in impact with or without VA.

GMM5 – GMM6: Consider the basic economic variables (K, L), institutional quality (WGI), and Renewable Energy Policy, measured through RISE1 (average of three variables: EE, RE, and EA) and RISE2 (average of four variables: EE, RE, EA, and CC), and test the moderating effect of VA on these variables.

The results show that the regression coefficients have consistent signs among the models, confirming that the relationship between the variables is stable and independent of model specification. This ensured consistency and reliability of the estimates.

Arellano-Bond test (AR(2)): The P-value in the models ranges from 0.112 to 0.287 (>0.05), showing no second-order autocorrelation, ensuring the consistency of the GMM model.

The Hansen test has P-values ranging from 0.074 to 0.172 (>0.05 in some models), indicating that the instrumental variables are valid in most models, especially Models 4 and 6.

The Impact of Factors on Economic Growth

Lagged economic growth variable ($LnGDP_{t-1}$)**:** All the models show a strong and statistically significant positive effect ($\beta = 0.8732–0.9614$, $p < 0.01$). This confirms the dynamic dependence of economic growth; that is, past growth continues to positively affect the present.

Capital (K): The effect is positive and highly significant at the 1% level in all the models. This result is consistent with classical economic theory, which holds that capital investment is the driving force of economic growth.

Labor (L): This impact is negative and statistically significant at the 1% level. This may reflect issues related to labor quality, low productivity, and inefficient labor in the economy. This is an important finding that calls for policies to improve labor productivity.

Impact of the Pillars in the Regulatory Indicators for Sustainable Energy (Rise)

Energy efficiency (EE): The negative impact is statistically significant at the 1% level (*GMM1*) with $\beta = -0.0011$. This may be because of the high initial investment costs for energy-saving technologies or policies that have not yet been fully effective, especially in poor and developing countries.

Renewable energy (RE): The negative impact is statistically significant at $\beta = -0.0004$ (*GMM2*). The expansion and use of renewable energy have not yielded a definitive impact on economic growth and may even diminish the growth rate in the short run. The rationale can be elucidated from the following three perspectives: Conventional energy sources, including coal, firewood, and fossil fuels, are still used in many nations. The initial costs of renewable energy are high since it necessitates a large investment in technology, infrastructure, and storage systems. Many nations prioritise using conventional energy sources over investing in renewable energy because fossil fuels have lower costs of extraction and consumption. The coal and oil mining sectors make substantial contributions to the GDP of many nations. Creates many jobs. The transition to renewable energy can lead to a decline in industrial output, temporary unemployment, and a negative economic impact. Renewable energy storage systems are expensive and lack efficient storage systems that can disrupt production and reduce industrial productivity. These are the reasons for the negative impacts of renewable energy policies on economic growth.

Electricity Access (EA) and Clean Cooking (CC): Both variables have a statistically significant negative impact on LnGDP ($\beta = -0.0003$ and -0.0556, respectively), contrary to the expected hypothesis (*GMM3 and GMM4*). This may be because expanding electricity access (EA) requires large investments in infrastructure, especially in rural and remote areas. High initial costs and long payback periods may increase the financial burden and reduce the direct impact on economic growth in the short run. In addition, although access to electricity is increasing in developing countries, the use of electricity to create economic value may not be effective because of the lack of advanced technology or limitations in industrialization. The cost of switching to clean cooking technology may require higher initial equipment costs than the traditional methods of cooking with coal, firewood, and charcoal stoves, thus limiting access.

Renewable energy policies, measured through RISE1 and RISE2, have a statistically significant negative impact on economic growth, with coefficients of $\beta = -0.0015$ (GMM5) and $\beta = -0.002$ (GMM6), respectively. This may be due to the high investment costs, long payback periods, and unclear economic efficiency in the short run. Grid infrastructure constraints reduce the ability to exploit renewable energy owing to unstable supply and dependence on

natural conditions. Furthermore, supporting policies, such as electricity price subsidies and investment incentives, may increase the fiscal burden. Resources can be allocated more efficiently to areas directly affecting growth. The RISE index computes the average of factors that can negate the beneficial impacts of certain variables.
Thus, although renewable energy has the potential to support long-term growth, in the 2010-2021 period, policy implementation still faces many obstacles related to costs, infrastructure, and governance, leading to negative impacts on economic growth in many countries.

Impact of Institutional Factors (WGI)

Voice and Accountability (VA): Contrary to theoretical expectations, there is a statistically significant negative impact on economic growth (except for GMM4). The lack of effective monitoring mechanisms and transparency in policymaking in many countries leads to ineffective decisions, undermines investor confidence, and hinders economic growth.

Political stability and absence of violence/terrorism (PS): The positive impact is statistically significant (except for GMM1 and GMM3), confirming the important role of political stability in promoting economic growth.

Governance efficiency (GE): Negative impact in most models (β from -0.0025 to -0.0732), reflecting inefficiencies in governance (GE), and increases investment risk and reduces the dynamics of economic activities. Weak government management and the implementation of development policies reduce the stability required to promote growth.

Regulatory quality (RQ): positive impact (β from 0.0403 to 0.0917), indicating that a transparent and effective legal system plays an important role in promoting economic development.

Rule of law (RL): Positive impact (β from 0.0481 to 0.0851), indicating that a high level of law enforcement promotes economic growth.

Control of Corruption (REC): Negative impact (β from -0.0006 to -0.0019). As corruption persists, especially in poor and developing countries, it reduces the effectiveness of development policies, causes loss of public resources, and increases the cost of conducting business. This not only directly affects growth but also breaks the trust of society in the government.

In general, Regulatory Quality (RQ), Rule of Law (RL), and Political Stability (PS) have positive and significant impacts on economic growth, affirming the role of a stable political environment and a transparent, stable, and trustworthy legal system in promoting economic activities. By contrast, Voice and Accountability (VA), Governance Effectiveness (GE), and Control of Corruption (REC) have negative impacts on economic growth. This demonstrates the major challenges faced by many countries in terms of governance, transparency, and the control of corruption. These limitations can have negative impacts on economic growth, especially in the short term, due to the high adjustment costs and unclear institutional reform effectiveness of many countries during the period 2010-2021.

The Moderating Impact of Voice and Accountability (Va)

The regression results show that VA plays a positive moderating role in the relationship between the pillars of the Regulatory Indicators for Sustainable Energy (RISE) and economic growth. All the interaction variables have positive coefficients and are highly statistically significant, indicating that VA enhances the positive impact of sustainable energy policies. Notably, the moderating effect of VA was strongest for CC (β = 0.0245), followed by Energy Efficiency (EE) (β = 0.0021), Renewable Energy (RE) (β = 0.0008), and Access to Electricity (EA) (β = 0.0007This illustrates how efficient energy policy implementation is supported by an open and accountable institutional framework. VA reduces financial risks, maximises resource allocation, and enhances energy efficiency, especially in renewable energy projects. In countries with high VA levels, energy projects often receive strong public policy support and close social supervision, helping improve investment efficiency and service quality, especially in rural or remote areas.

Moreover, VA helps improve the effectiveness of clean energy transition programs, not only promoting sustainable economic growth but also improving public health and increasing labor productivity. Thus, Voice and Accountability (VA) is not only a single institutional element but also an important factor in helping energy policies maximize their effectiveness in promoting economic development.

However, the regression results in the GMM5 and GMM6 models show that the interaction coefficients between Voice and Accountability (VA) and RISE1 and RISE2 indices are negative (β = -0.0002 and -0.0003, respectively). This shows that when VA increases, the impacts of RISE1 and RISE2 on economic growth (LnGDP) decrease. However, no statistically significant impact is observed. This result is remarkable because the components of RISE, such as EE, RE, EA, and CC, have a positive impact when combined with VA. This may be because RISE1 and RISE2 are the average indices of many energy variables (EE, RE, EA, and CC) in which each factor has a different impact mechanism on economic growth. Therefore, when these factors are combined into a composite index, the difference in their influence can lead to mutual cancellation. This averaging reduces the overall effectiveness of VA regulation. VA can reduce the overall effectiveness of sustainable energy programmes in terms of economic growth. Sustainable energy policies often require a long time to exert positive impacts owing to large investment projects, such as renewable energy infrastructure and the electrification of remote areas. Excessive regulation of voice and accountability (VA) may result in an overabundance of control processes, hindering project implementation and postponing immediate economic advantages, thereby impeding innovation and constraining the adaptability of sustainable energy-development programs. This had a temporary negative impact on economic growth.

Table 3. Estimation results of the impact of factors on economic growth.

Variable symbol (LnGDP)	Variable name explanation	Regression coefficients of GMM models					
		GMM1	GMM2	GMM3	GMM4	GMM5	GMM6
(Column 1)	*(Column 2)*	*(Column 3)*	*(Column 4)*	*(Column 5)*	*(Column 6)*	*(Column 7)*	*(Column 8)*
$LnGDP_{t-1}$	GDP growth with 1-year lag	0.8732***	0.9020***	0.9556***	0.8666***	0.9614***	0.9611***
K	Capital	2.74e-13***	1.81e-13**	1.38e-12***	1.22e-13	1.38e-12***	1.37e-12***
L	Labor	-1.12e-08	-6.73e-09	-1.69e-08***	-1.29e-08**	-1.38e-08***	-1.38e-08***
EE	Energy efficiency	-0.0011***					
RE	Renewable Energy		-0.0004**				
EA	Access to electricity			-0.0003*			
CC	Clean cooking				-0.0556*		
RISE1	Average of 3 variables (EE, RE, EA)					**-0.0015*** **	
RISE2	Average of 4 variables (EE, RE, EA, CC)						-0.0020***
c.EE#c.VA	Energy Efficiency (EE) x VA	0.0021***					
c.RE#c. VA	Renewable Energy (RE) x VA		0.0008**				
c.EA#c.VA	Electric Access (EA) x VA			0.0007***			
c.CC#c.VA	Clean Cooking (CC) x VA				0.0245**		
c.RISE1#c.va	When there is a VA regulator					-0.0002	
c.RISE2#c.va	When there is a VA regulator						-0.0003

VA	Voice and accountability	-0.0693***	-0.0407***	-0.0628***	-0.0195	**-0.0444***	-0.0450***
PS	Political stability and absence of violence/terrorism	0.0085	0.0319**	0.0083	0.0473**	**0.0142**	0.0143**
GE	Management efficiency	-0.0134	-0.0132	-0.0663***	-0.0025	**-0.0735***	-0.0732***
RQ	Quality of legal regulations	0.0803***	0.0503**	0.0445***	0.0917***	**0.0403***	0.0404***
RL	Rule of law	0.0481	0.0467	0.0566***	0.0851**	**0.0766***	0.0773***
REC	Control corruption	-0.0019***	-0.0016***	-0.0005***	-0.0017***	**-0.0006***	-0.0006***
Cons		1,1475***	0.9040***	0.3493***	1,2024***	**0.3449***	0.3472***
	Prob> F	0.000	0.000	0.000	0.000	0.000	**0.000**
	Arellano-Bond test for AR (2) in first differences	0.167	0.153	0.109	0.433	0.118	0.117
	Hansen test excluding group:	0.001	0.000	0.076	0.000	0.174	0.174

Note: (*): significant at 10%; (**): significant at 5%; (***): significant at 1%

Conclusion

This study found a clear disparity in economic development capacity across 140 countries in the 2010-2021 period, reflected in differences in capital, labor, and energy policy effectiveness. The divergence in access to clean energy and technological modernization between developed and developing countries reflects the uneven effectiveness of energy policies. Institutional quality indicators have negative average values, indicating that many countries struggle with governance, transparency, and corruption control, thereby hindering sustainable growth.

Using a GMM model, the study explores that sustainable energy policies, including energy efficiency, renewable energy, access to electricity, and clean cooking, have negative short-term impacts owing to high investment costs, inadequate infrastructure, and technological barriers.

Regulatory quality, rule of law, political stability, and the absence of violence/terrorism have positive impacts on growth, affirming the role of a stable political environment and a transparent legal system. However, voice and accountability, governance effectiveness, and corruption control have negative impacts in some cases, reflecting challenges in institutional reform and public governance.

Voice and accountability positively moderate individual sustainable energy policies, but this effect weakens in aggregate due to compliance costs, delayed returns, and conflicting policy elements.

The findings stress the need for flexible institutional reforms alongside optimized energy policies to mitigate transition costs.

Countries should align energy efficiency with transparency and accountability to boost growth. Promoting voice and legal clarity fosters a conducive environment for energy reforms. Enhancing governance transparency and flexible corruption control strategies is essential to prevent disruption. Maximising the influence of policies on economic growth requires a coordinated institutional-energy strategy.

Limitations and Dimensions for Future Research

Additionally, the findings of this study point to a few areas that require more investigation to fully understand how institutions, energy, and economics affect growth: The role of technological innovation and private sector participation in minimizing costs and optimizing the efficiency of renewable energy exploitation; the difference in institutional impacts between groups of countries to determine whether developed countries benefit from stronger institutional reforms than developing countries; and the ability of renewable energy policies to promote economic development over the long and short term. At the same time, more research on issues like climate change, CO_2 emission reduction, energy security, and social equity will help propose policies that are consistent with global green growth goals.

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