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Renewable energy policy, renewable energy consumption and economic growth: The moderating role of governance quality

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ABSTRACT

Transitioning to clean and affordable renewable energy consumption is one of the Sustainable Development Goals (SDGs) set by the United Nations (UN) in 2015. However, the evidence regarding the effectiveness of implementing renewable energy policies is mixed across countries. The purpose of this study is to explore how governance quality can explain cross-country heterogeneities and moderate the associations between renewable energy policies, renewable energy consumption, and economic growth. The study adopts a quantitative research design and the method of panel regression analysis based on the Two-step System Generalized Method of Moments. The research examines a sample of 140 countries, which constitute more than 70% of the total population of countries, during the period from 2010 to 2021. The period is determined by data availability. The results reveal a significant positive effect of renewable energy consumption and renewable energy policies on Gross Domestic Product (GDP). Furthermore, the findings confirm the positive moderating effect of governance quality on the relationship between renewable energy policies and economic growth. This study contributes both theoretically and managerially to the exogenous growth model by highlighting the importance of renewable energy policies and governance quality in fostering economic growth.

Contribution/ Originality: This is the first study to investigate how the quality of governance moderates the interrelationships between energy policies, renewable energy consumption, and economic growth in the international context. The study provides empirical support for the Porter Hypothesis and extends the traditional Solow-Swan Growth Model.

1. INTRODUCTION

Energy consumption is essential for industries to produce goods and sustain economic growth (Tang, Peng, & Xu, 2018). However, energy use is not homogeneous across countries, and some rely on non-renewable sources, such as fossil fuels, which create negative externalities in the economy, whereas others have already switched or are transitioning to renewable sources (Simionescu, 2021). The importance of switching to renewable sources was emphasized by one of the Sustainable Development Goals (SDG 7) set by the United Nations (UN) in 2015. However, international evidence on the impact of renewable energy consumption on economic development remains unclear. Past research on the associations between renewable energy consumption and GDP growth largely relies on cross-country analyses to capture the economic variations across nations, as evidence from a single country is usually limited and insufficient for a robust assessment (Smolović, Muhadinović, Radonjić, & Durašković, 2020). However, the findings remain mixed. Some studies support the neutrality hypothesis, showing no significant impact

(Li & Leung, 2021) while others find positive effects in countries such as Germany, but no effects in France, the UK, Italy, or Japan (El-Karimi & El-Houjjaji, 2022). In five Mercosur nations, a bidirectional relationship between energy consumption (both renewable and fossil fuels) and economic growth was observed (El-Karimi & El-Houjjaji, 2022). These mixed results may be explained by omitted variable bias, a limited number of countries investigated, narrow periods of time considered, and methodological limitations such as imperfections in reported statistics and weaknesses in research methods, especially when it comes to detecting causality.

This study contributes to knowledge by addressing the first limitation of potential omitted variable bias. It introduces and tests governance quality as a moderating variable that can potentially explain the variation in the relationship between energy use, energy policies, and economic growth across nations. The choice of this moderator is justified by the argument that market forces alone cannot drive the transition to renewable energy, and government intervention is essential. Although this statement has been proposed in several studies, it has never been tested empirically (Abban & Hasan, 2021; Smirnova, Kot, Kolpak, & Shestak, 2021; Zhang, Chiu, & Hsiao, 2022; Zhao, Zhou, & Wen, 2021). Traditional exogenous growth theories, such as the Solow-Swan model based on the Cobb-Douglas production function, do not explain the transition to renewable energy use and the associated innovations, as these factors are considered exogenous and given (Dolderer, Felber, & Teitscheid, 2021; Gotz, 2021). At the same time, endogenous growth theories overlook the role of government in driving innovation and development, focusing primarily on human capital (Sarwar, Khan, Sarwar, & Khan, 2020; Xu & Li, 2020). As a result, a gap emerged between these two groups of theories, and this research contributes to filling this gap by expanding the Solow-Growth model with the Porter Hypothesis on the favorable role of governance in promoting renewable energy innovation and stimulating economic growth. While this hypothesis provides a critique of traditional economic thought, which states that a transition to renewable sources should be considered a necessary cost for the economy, the Porter Hypothesis has not been empirically tested. The limited evidence available on the links between renewable energy policies and growth does not explain cross-country variations and the instability of this relationship (Wu & Lin, 2022). The primary aim of this study is to examine the interrelationships among governance, policies, energy consumption, and economic growth. The objectives are to (i) test the effects of renewable energy consumption on economic growth; (ii) examine the direct and indirect effects of renewable energy policy on economic growth; and (iii) assess the moderating effect of governance quality on the relationship between renewable energy policy and economic growth.

This paper is organized as follows. Section 2 develops the theoretical foundation of the research and the testable hypotheses. Section 3 explains the data and the methods implemented. Section 4 presents the empirical results and their interpretation. Section 5 concludes the paper with a final discussion, contributions, limitations, and recommendations for future research.

2. THEORETICAL FRAMEWORK AND HYPOTHESIS DEVELOPMENT

2.1. Theoretical Framework

Traditionally, economic growth determinants have been studied using both exogenous and endogenous growth theories. The theoretical literature originates from the Cobb-Douglas production function, which links the total output in the economy (Y) to inputs broadly divided into labor (L) and capital investments (K).

$$Y = AK^{\alpha}L^{\beta} \quad (1)$$

Where A is the ratio of total output in the economy to aggregate inputs, known as total factor productivity (TFP). Equation 1 can be rewritten as follows by converting the multiplicative model to the additive model through log transformation, which allows for testing the model using econometric tools, such as regression analysis. Unexplained variance in the output can be represented by adding an error term.

$$lnY = lnA + \alpha lnK + \beta lnL + \varepsilon \quad (2)$$

The slope coefficients in Equation 2 represent the marginal product of capital and the marginal product of labor, both of which are expected to be positive. The second derivative of output with respect to each factor of production, namely K and L, represents the change in the marginal products of capital and labor, and this change is expected to be less than zero, thus complying with the law of diminishing returns.

The Cobb-Douglas production function gained even more recognition when notable economists, such as Solow (1957), used it to build their exogenous growth theory, the Solow-Swan growth model. It added the labor factor from the Cobb-Douglas production function and introduced technological progress or innovation as a factor responsible for achieving greater economic growth without proportional capital accumulation. This led to the following reformulation of the Cobb-Douglas production function in the Solow-Swan growth model.

$$Y = K^{\alpha}(AL)^{1-\alpha} \quad (3)$$

This model also measures Y as per capita income (GDP per capita), accounting for population growth. The key outcome of this model is that economic growth can be achieved by increasing the savings rate to facilitate higher capital accumulation and innovations that produce more output with a given amount of labor. However, this model treats both the savings rate and the rate of innovation or technological progress as exogenous factors that are unexplained by the model (Sasaki, 2019; Zhao, 2019).

One way to endogenize innovations (A) from Equation 3 is to introduce the role of the government, which was ignored in both the original Cobb-Douglas production function and the Solow-Swan model. Porter's hypothesis proposes that government regulations on energy use and environmental preservation positively contribute to innovation and higher rates of adoption of renewable energy sources in the private sector because companies face a trade-off between investing in renewable energy use and the costs of violating regulations (Wang, Zhang, Nathwani, Yang, & Shao, 2022; Wang, Sun, & Guo, 2019; Wu & Lin, 2022). Thus, adding the factor of regulation (R) to Equation 3 leads to the following improvement in the growth model.

$$Y = K^{\alpha}(AL)^{1-\alpha} R^{\gamma} \quad (4)$$

Since environmental regulation in the context of energy use can be captured by Regulatory Indicators for Sustainable Energy (RISE) scores available for different countries, and worldwide governance indicators can measure overall governance, the extended model with interactions between the variables is depicted in Figure 1.

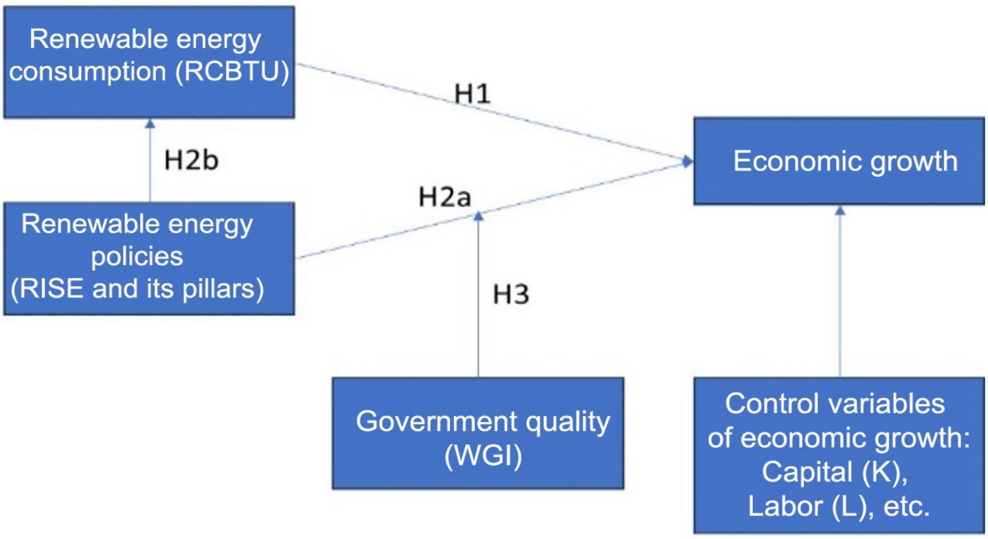

Figure 1. Theoretical framework.

In line with Porter's hypothesis, the effect of environmental regulation (RISE) on economic growth was analyzed alongside renewable energy consumption. Strong environmental policies drive investments in renewable technologies, fostering innovation and economic efficiency. However, this relationship depends on governance quality: democratic institutions, low corruption, and strong enforcement enhance policy effectiveness, while weak enforcement hinders desired outcomes (Alsaad, 2022).

2.2. Hypothesis Development

Prior research highlights a positive relationship between total energy consumption and economic growth, with stronger effects in emerging economies (Komarova, Filimonova, & Kartashevich, 2022). However, the evidence on the impact of renewable energy remains mixed (Koçak & Şarkgüneşi, 2017; Ntanos et al., 2018), with some findings suggesting no significant effect in OECD countries (Ivanovski, Hailemariam, & Smyth, 2021). However, they also found that renewable energy is a stronger driver of economic growth in emerging non-OECD economies. This implies substantial cross-country variation in this relationship. Other researchers have found nonlinear and asymmetric associations between renewable energy consumption and GDP, which can be explained by the Environmental Kuznets Curve (Li, Wang, & Guo, 2023; Namahoro, Nzabanita, & Wu, 2021; Ramadhan, 2019). According to the theory, early-stage economic growth is accompanied by high pollution levels; however, as per capita income rises, pollution declines (Guo & Shahbaz, 2024; Leal & Marques, 2022). This suggests there is a non-linear link between GDP per capita and environmental pollution, and potentially bidirectional causality, a hypothesis proposed in several studies such as Okumus, Guzel, and Destek (2021); Rahman and Velayutham (2020) and Wang, Zhang, and Zhang (2021). However, other studies have shown unidirectional causal effects of renewable energy on the GDP (Aslan, Ocal, Ozsolak, & Ozturk, 2022; Doytch & Narayan, 2021; Namahoro et al., 2021). The rationale for this is that renewable energy use requires investments in new technologies, which produce positive direct effects on GDP and create long-term benefits for the economy, making production more efficient (Hao, Kang, Li, Wu, & Song, 2023; Shao, Hu, Cao, Yang, & Guan, 2020). However, companies will not be willing to switch to renewable energy without external stimuli provided by government policies. While, from the viewpoint of neoclassical economic theory, regulation will increase costs for businesses, Porter's hypothesis suggests that it will eventually be beneficial for both individual businesses, which will become more innovative and resilient, and the economy as a whole (Salehnia, Karimi Alavijeh, & Salehnia, 2020; Xie, Liu, & Yang, 2023). Thus, the following hypotheses are proposed:

H_1: Renewable energy consumption is positively associated with economic growth.

H_2: Renewable energy-promoting policies are positively associated with economic growth.

At the same time, it is valid to argue that policies without enforcement will be ineffective, and one of the factors that can predict whether policies will be effectively implemented is the institutional and governance quality (Le & Ozturk, 2020). Previous studies also relate institutional factors to economic growth and development (Qiang & Jian, 2020; Ramadhan, 2019). The role of governance in economic growth has been explored in previous studies, such as Barro (1990). Frankel and Romer (1999) further posited that governance and institutional factors, which encompass the strength of the legal system, democracy, and the rule of law, are pivotal in enforcing environmental regulations, facilitating the transition to sustainable energy sources, and fostering economic growth. Given the theoretical connection between governance, economic growth, and environmental regulation, particularly in terms of the ability to ensure effective enforcement, this study examines whether stronger governance enhances the positive impact of renewable energy policy on economic growth compared with weaker governance frameworks. This leads to the following hypothesis.

H_3: Higher governance quality is positively associated with a more pronounced impact of renewable energy policy on economic growth.

3. DATA AND METHODOLOGY

3.1. Data

This study uses annual data on macroeconomic indicators, renewable energy policy variables, governance factors, and renewable energy consumption for 140 countries from 2010 to 2021. Table 1 provides a description of the data series. Using the multiplicative model derived from the Cobb-Douglas production function, the variables are initially collected in level forms, measured in local currency units, and subsequently transformed into their natural logarithms to transition from a multiplicative to an additive model. Consistent with the Solow-Swan growth model, GDP per capita is the dependent variable. All other economic variables were converted to per-capita values prior to logarithmic transformation to control for the population factor on both sides of the equation. Two key factors production, capital, and labor were included as important control variables. Capital is proxied by gross fixed capital formation, while total wages and compensation within the labor force represent labor. Both capital and labor are adapted from the World Development Indicators (World Bank, 2023a).

Renewable energy consumption data were obtained from the International Energy Agency with raw data measured in quadrillions of British Thermal Units (BTU). These values were adjusted for population size by dividing the total renewable energy consumption by the population of each country, yielding renewable energy use per capita per year. These per capita values were further transformed into natural logarithms for the panel regression analysis.

Environmental policies are represented by Regulatory Indicators for Sustainable Energy (RISE), which include indices for Energy Access (EA), Energy Efficiency (EE), and Renewable Energy (RE), all measured on a 0–100 scale from the World Bank database. These scores are derived from international surveys conducted by energy industry experts. The EA index assesses government-led electrification plans and grid frameworks, with higher values indicating greater access to affordable electricity. The EE index reflects government policies aimed at achieving energy efficiency, including mechanisms, codes, and incentives, with higher scores denoting more available incentives to promote energy efficiency. The RE index measures legal frameworks, planning, and incentives for renewable energy, with higher scores indicating more comprehensive policies. While these survey-based scores may involve participant bias, the World Bank administers surveys to minimize the researcher's influence. However, the potential bias remains a limitation of this study.

Table 1. Variable definitions and sources.

Variable	Codes	Definitions/Measures	Sources
Economic growth	GDP	Measured by the log of GDP	World development indicators
Capital	K	Measured by the log of capital	World development indicators
Labor	L	Measured by the log of labor	World development indicators
Renewable energy consumption	REC	Measured by the log of renewable energy consumption per capita	Energy Information Administration
Energy efficiency	EE	The log of the Energy Efficiency index reflects government policies aimed at achieving energy efficiency, including mechanisms, codes, and incentives.	Regulatory indicators for sustainable energy (RISE)
Renewable energy	RE	The log of the Renewable Energy index measures the legal foundations, planning, support, and incentives provided by the government for renewable energy use.	Regulatory indicators for sustainable energy (RISE)
Energy access	EA	The log of the Energy Access index measures the availability of government-issued electrification plans and grid frameworks to provide consumers with affordable electricity.	Regulatory indicators for sustainable energy (RISE)
Voice and accountability	VA	Measured by a dummy variable with a value of 1 assigned to positive scores and 0 otherwise.	Worldwide governance indicators
Government effectiveness	GE	Measured by a dummy variable with a value of 1 assigned to positive scores and 0 otherwise.	Worldwide governance indicators

Governance quality was proxied by the global governance indicators obtained from the World Bank (2023b). These indicators include six indices, but this study utilizes two dimensions of the Worldwide Governance Indicators: Voice and Accountability (VA), which measures the degree of voice and accountability, and Government Effectiveness, which gauges the quality and independence of public policymaking by regulators. Since these governance indicators are standardized and range from -2.5 to +2.5, encompassing both negative and positive values, they cannot be transformed into natural logarithms. For the moderation analysis, these indicators were converted into dummy variables, with a value of 1 assigned to positive scores and 0 otherwise.

3.2. Methodology

Theoretically, a two-way fixed-effects panel regression model can be used to analyze the relationships between renewable energy policy and economic growth. This model was chosen to account for cross-country variations in the relationship between renewable energy policy, economic growth, and temporal dynamics, given the potential exogenous shocks within the study period. Although these differences can also be investigated using random-effects panel regressions, there is concern regarding the potential endogeneity between renewable energy policy, renewable energy consumption, and economic growth. Based on the theoretical framework in Section 2, this study employs the Two-step System Generalized Method of Moments (S-GMM) for estimation, a dynamic panel data technique developed by Arellano and Bond (1991) to address potential endogeneity. This method is advantageous for maintaining data integrity and minimizing unnecessary data loss. It is particularly effective for balanced panel datasets because it offers more accurate and consistent coefficient estimates Arellano & Bover (1995). The S-GMM has been preferred over alternative estimation techniques that could be applied to panel data, such as pooled Ordinary Least Squares (OLS), fixed effects models, random effects models, and Difference GMM, for several reasons. First, S-GMM is a dynamic model, and past economic growth tends to predict future economic growth. Second, this model addresses endogeneity issues in panel regressions when independent variables can correlate with the error term. Third, it produces consistent estimates, unlike random effects models that can often yield inconsistent coefficients. Finally, it is less sensitive to the structure of the panel data and whether it is balanced, which makes it effective when there are missing values or gaps in observations.

Based on the theoretical framework presented in Section 2, the S-GMM model is specified as follows:

$$\begin{cases} Y_{it} = \alpha + \varphi Y_{it-1} + X_{it}\beta + G_{it}\theta + \mu R_{it} + Z_{it}\delta + \gamma X_{it}G_{it} + \varepsilon_{it} \\ R_{it} = a + X_{it}b \end{cases} \quad (5)$$

Where Y_{it} and Y_{it-1} are the GDP and lagged GDP of country i at time t and t-1, respectively; X_{it} is a vector of renewable energy policy of country i at time t; G_{it} is a vector of the governance quality of country i at time t; R_{it} is the renewable energy consumption of country i at time t; the term $X_{it}G_{it}$ represents the interaction between renewable energy policies and governance quality of country i at time t; and ε_{it} is the error term.

4. RESULTS

The dataset includes up to 1,680 country-year observations per indicator. Governance indicators government effectiveness, voice, and accountability have no missing values. However, observations for macroeconomic indicators vary: log GDP (1,645), log gross fixed capital (1,436), log labor (1,666), and RISE indicators (1,645).

The RISE indicators ranged from 0 to 100. However, in practice, using the sampled countries for which data are available, the actual scores range from a minimum of 0.13 for Energy Efficiency to a maximum of 93.93 for

Renewable Energy. The geographical distribution of the countries, based on their regulatory indicators for sustainable energy, is shown in Figure 2.

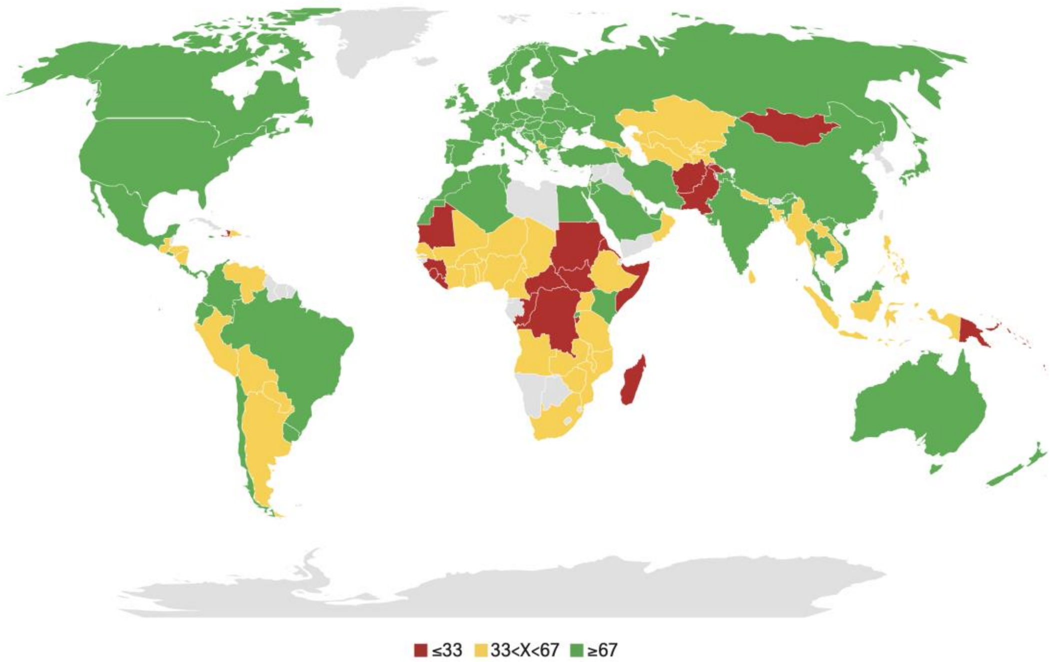

Figure 2. Regulatory indicators for sustainable energy in 2021.

The GDP per capita, gross fixed capital formation, labor, and energy consumption were transformed into natural logarithms. The data were cleaned of outliers, including negative renewable energy values, which may stem from methodological errors by the International Energy and the World Bank. The RISE and macroeconomic variables have no negative values. Governance indicators centered around zero are symmetrically distributed; countries with stronger governance have positive values, while those with weaker governance fall into the negative range. Table 2 presents the detailed statistics of the variables used.

Table 2. Descriptive statistics of the research sample.

Variable	Obs.	Mean	Std. dev.	Min.	Max.
Log of GDP	1,645	25.05	1.95	20.33	30.65
Log of capital	1,436	23.68	2.01	18.84	29.51
Log of labor	1,666	12.78	1.60	7.56	17.74
Log of renewable energy consumption	1,521	0.20	0.41	0.00	3.07
Log of energy efficiency (EE)	1,645	2.97	1.10	0.12	4.48
Log of renewable energy (RE)	1,645	3.20	1.03	0.29	4.55
Log of energy access (EA)	1645	3.10	0.90	0.65	4.51
Voice and accountability	1,680	-0.20	1.03	-2.86	1.96
Government effectiveness	1,680	-0.12	1.03	-3.00	2.28

To estimate the two-step system GMM model, we initially performed a multicollinearity test among the independent variables using a Pearson correlation matrix. The results of this test, presented in Table 3, revealed no evidence of multicollinearity among the independent variables. Next, a test for endogeneity between renewable energy consumption, renewable energy policy, and GDP was conducted. The test results confirmed the presence of endogeneity among these variables, which is consistent with theoretical expectations. Based on these diagnostic tests, the two-step system GMM model is deemed appropriate for estimating the impact of renewable energy policies and renewable energy consumption on GDP.

Table 3. Pearson correlation matrix.

ID	Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1)	Log of capital	1.0000							
(2)	Log of labor	0.6553	1.0000						
(3)	Log of Rew. energy consumption	0.6195	0.5771	1.0000					
(4)	Log of Energy Efficiency	0.2603	0.2413	0.2699	1.0000				
(5)	Log of Renewable Energy	0.2938	0.2461	0.2667	0.5224	1.0000			
(6)	Log of Energy Access	0.3050	0.2228	0.1989	0.4482	0.4541	1.0000		
(7)	Voice and accountability	0.2216	0.0087	0.2495	0.1624	0.1164	0.1752	1.0000	
(8)	Government effectiveness	0.4731	0.2709	0.3887	0.3798	0.3289	0.3084	0.5119	1.0000

The correlation analysis reveals moderate positive correlations between variables, suggesting that no multicollinearity issues are expected.

First, we estimate the impact of renewable energy policy on renewable energy consumption using fixed effects, random effects, and the GMM; the results are shown in Table 4. The estimation results indicate a consistent and positive effect of renewable energy policy on renewable energy consumption. These results are similar to those reported in the literature (Li & Leung, 2021; Wang et al., 2022; Wang et al., 2019). Therefore, better renewable energy-promoting policies have been developed to encourage renewable energy consumption.

Table 4. Effects of renewable energy policies on renewable energy consumption.

Variable	FEM	REM	S-GMM
Log of energy efficiency	0.00359** (0.0018)	0.00369** (0.0018)	0.00103*** (0.0000)
Log of renewable energy	0.00401** (0.0017)	0.00410** (0.0018)	0.000142*** (0.0000)
Log of energy access	0.00001 (0.0019)	0.00004 (0.0019)	0.00171*** (0.0000)
Log of renewable energy consumption			0.947*** (0.0001)
Constant	0.0499*** (0.0057)	0.0440* (0.0236)	0.00812*** (0.0003)

Note: Standard errors are in parentheses; *** p<0.01, ** p<0.05, * p<0.1

Second, this study estimates the impact of renewable energy policy and consumption on economic growth, considering both the direct and indirect effects, while also examining the role of governance quality in moderating the relationship between renewable energy policy and economic growth. This study employs S-GMM for each variable, representing different aspects of governance quality. Models 1 to 4 use Voice and Accountability as proxies for governance quality, whereas Models 5 to 8 use Government Effectiveness as a proxy for governance quality. Models 1 and 5 in Table 5 are estimated as the main effects models, whereas the other models sequentially incorporate the interaction terms between governance quality and renewable energy variables. The estimation results are presented in Table 5.

Table 5. Dynamic GMM Estimated Results.

Variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Log of GDP	0.831*** (0.0100)	0.833*** (0.0093)	0.831*** (0.0094)	0.825*** (0.0078)	0.819*** (0.0100)	0.809*** (0.0092)	0.818*** (0.0077)	0.818*** (0.0098)
Log of capital	0.153*** (0.0129)	0.144*** (0.0123)	0.141*** (0.0147)	0.151*** (0.0118)	0.183*** (0.0122)	0.213*** (0.0248)	0.239*** (0.0179)	0.183*** (0.0202)
Log of Labor	0.0518*** (0.0043)	0.0518*** (0.0045)	0.0516*** (0.0035)	0.0541*** (0.0047)	0.0567*** (0.0052)	0.0599*** (0.0065)	0.0545*** (0.0047)	0.0558*** (0.0052)
Log of Re. energy consumption	0.0297*** (0.0037)	0.0282*** (0.0037)	0.0296*** (0.0040)	0.0256*** (0.0042)	0.0282*** (0.0047)	0.0302*** (0.0055)	0.0302*** (0.0048)	0.0269*** (0.0051)
Log of energy efficiency (EE)	0.00946*** (0.0007)	0.00983*** (0.0011)	0.00927*** (0.0010)	0.00871*** (0.0004)	0.00936*** (0.0005)	0.0129*** (0.0016)	0.00968*** (0.0006)	0.0101*** (0.0008)
Log of renewable energy (RE)	0.00478*** (0.0008)	0.00505*** (0.0008)	0.00419*** (0.0009)	0.00448*** (0.0007)	0.00515*** (0.0008)	0.00381*** (0.0009)	0.00569*** (0.0008)	0.00545*** (0.0008)
Log of energy access (EA)	0.00233*** (0.0006)	0.00215** (0.0011)	0.00273*** (0.0009)	0.00210** (0.0010)	0.00291*** (0.0007)	0.00179* (0.0010)	0.00302*** (0.0009)	0.00145* (0.0008)
Voice and accountability	0.0108*** (0.0040)	0.0160*** (0.0041)	0.00843* (0.0051)	0.00757** (0.0039)				
Government effectiveness					0.00795*** (0.0021)	0.0675*** (0.0059)	0.181*** (0.0221)	-0.106*** (0.0109)
EE*VA		-0.00344** (0.0016)						
RE*VA			0.00266** (0.0013)					
EA*VA				0.00209** (0.0009)				
EE*GE						-0.0218*** (0.0017)		
RE*GE							0.0466*** (0.0058)	
EA*GE								0.0245*** (0.0030)
Constant	3.249*** (0.1720)	3.199*** (0.1710)	3.256*** (0.1650)	3.297*** (0.1530)	3.412*** (0.1420)	3.594*** (0.1690)	3.511*** (0.1270)	3.452*** (0.1560)

Note: Standard errors are in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$.

The estimation results in Table 5 indicate a positive, direct, and consistent impact of renewable energy consumption on economic growth, supporting the growth hypothesis (Apergis & Payne, 2010; El-Karimi & El-Houjjaji, 2022). Renewable energy consumption constitutes a component of overall energy consumption and mainly determines economic growth. Therefore, an increase in renewable energy consumption leads to economic growth because it is an important input for production, stimulating the supply side. Simultaneously, it increases aggregate demand within the economy, ultimately fostering economic growth. Renewable energy sources can reduce reliance on fossil fuels, enhance energy security, and result in significant cost savings. These savings could be reallocated to other sectors of the economy to promote further economic expansion. Additionally, renewable energy consumption can drive technological advancements and improvements in energy efficiency. The latter are expected to lower production costs in line with Porter's hypothesis and contribute to sustainable growth (Bhuiyan et al., 2022). The evidence was found to be robust with respect to the choice of the governance measure and produced consistent results for the relationships between RE and GDP.

In addition to this, renewable energy policy was found to be directly and indirectly affecting GDP growth across countries. The spillover effects of this policy can be seen in the reduced dependency on costly fossil fuels, increased efficiency of businesses, and improved competitiveness. Such changes become drivers for the switch to renewable energy by more industry players, leading to an overall improvement in sustainability and a reduction in environmental pollution. These positive shifts are able to ensure long-term economic growth with less volatility, which is often triggered by changes in fossil fuel prices.

The direct effects of institutional and governance variables on GDP were previously investigated in past research by Knack and Keefer (1995) and North (1990). However, this is the first study to test the moderation of the associations between renewable energy policy, renewable energy use, and GDP by governance variables. According to this original research, higher levels of governance quality are associated with stronger positive links between renewable policy and GDP compared to countries with lower levels of governance quality. This can be explained by greater transparency in legislation, clearer enforcement mechanisms, and increased public awareness in countries with higher levels of voice, accountability, and good governance. Such countries also pose lower systematic risks for investors, promote green activism, and facilitate the spread of renewable energy use in the economy.

The traditional factors of growth, based on the Solow-Swan model and Cobb-Douglas production function, were also found to be significant, which supports rather than challenges mainstream theories. In particular, both labor and capital were significant control variables positively associated with GDP across 140 countries. Coupled with governance quality and renewable energy policies, this research produced a more elaborated version of economic growth models that incorporated the Porter Hypothesis on green regulation and innovation, and empirically tested this combination. The statistically significant results validate the proposed model and suggest that it provides greater explanatory power for predicting the GDP of countries. Considering the choice of methods and the sample of countries, which covers more than 70% of the population, the results are generalizable to other nations not included in the sample due to missing data.

5. DISCUSSIONS AND CONCLUSIONS

The goal of this paper was to investigate the impact of renewable energy policy and energy use on GDP in 140 countries, evaluating how governance quality in these countries moderates these associations. The goal was achieved by applying a quantitative research design and the S-GMM panel regression analysis method over a period from 2010 to 2021. The period was determined by data availability. The results supported the proposed model of economic growth, in which renewable energy policies produce positive stimulating effects, in line with Porter's hypothesis, and governance quality positively moderates these relationships. Based on two alternative proxies for governance quality used in this research, namely, voice and accountability and governance effectiveness, the results remain robust and consistent. Both proxies produced similar moderating effects. This result helps resolve previous discrepancies and mixed evidence from different countries as documented in the empirical literature by El-Karimi and El-Houjjaji (2022), Ivanovski et al. (2021), Li and Leung (2021), Ramadhan (2019), and Smolović et al. (2020). Based on the confirmed moderating effects of governance quality, it can be concluded that such heterogeneities arise not from geographical factors but primarily from variations in governance structures as well as the levels of voice and accountability within societies. Countries with higher scores for voice, accountability, and political stability tend to exhibit stronger positive associations between renewable energy policy and economic growth.

This study has limitations, including low data frequency, missing values, and potential bias in the RISE data sourced from World Bank surveys. Future research can address these gaps in three ways. First, replacing renewable energy consumption per capita (log) with its share of total energy use would be better account for the volume effect because a small renewable share may obscure its distinct impact. Second, analyzing how macroeconomic variables and energy consumption respond to new government policies is crucial, as composite indicators, such as RISE, may not capture individual policy effects. Third, Porter's hypothesis can be tested further using alternative innovation metrics, such as R&D expenditures, to assess its global validity.

Notwithstanding these limitations, this study makes both theoretical and empirical contributions to the literature. It expands the Solow-Swan growth model by incorporating Porter's hypothesis and testing it worldwide. This highlights the vital importance of renewable energy policy in stimulating economic growth, both directly and indirectly through increased renewable energy usage. The study emphasizes the significance of institutions in promoting growth and illustrates that renewable energy is essential for achieving sustainable economic development.

Empirically, this study fills a key research gap by explaining heterogeneities in the renewable energy-growth nexus. Using a system GMM model, this study addresses endogeneity and accounts for variations in governance quality, including levels of voice and accountability. It is among the first to examine governance quality as a moderator of the relationship between renewable energy policy and GDP. Additionally, it is one of the few studies to analyze these relationships across a broad sample of countries using robust statistical data.

These findings have important implications for policymakers. First, they emphasize the positive impact of transitioning to renewable energy policies on economic growth, reinforcing that increased renewable energy consumption drives both sustainability and development. Second, environmental regulations should be designed to support growth directly and facilitate the transition to renewable energy. Moreover, as reflected in the environmental policy variables, the quality of policy frameworks and government planning facilitate this transition, mainly when accounting for country-specific and time variations. Third, continued institutional reform and the enhancement of governance quality can stimulate growth both directly and indirectly by regulating the relationship between renewable energy policy and economic growth at the national level.

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REFERENCES

Abban, A. R., & Hasan, M. Z. (2021). Revisiting the determinants of renewable energy investment - New evidence from political and government ideology. *Energy Policy, 151*, 112184. https://doi.org/10.1016/j.enpol.2021.112184

Alsaad, A. (2022). E-government and corruption control: The mediating effect of law enforcement. *Electronic Government, an International Journal*, *18*(1), 1-8. https://doi.org/10.1504/EG.2022.119619

Apergis, N., & Payne, J. E. (2010). Renewable energy consumption and economic growth: Evidence from a panel of OECD countries. *Energy Policy*, *38*(1), 656–660.

Arellano, M., & Bond, S. (1991). Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. *Review of Economic Studies*, *58*(2), 277-297. https://doi.org/10.2307/2297968

Arellano, M., & Bover, O. (1995). Another look at the instrumental variable estimation of errorcomponents models. *Journal of Econometrics*, *68*(1), 29-51. https://doi.org/10.1016/0304-4076(94)01642-D

Aslan, A., Ocal, O., Ozsolak, B., & Ozturk, I. (2022). Renewable energy and economic growth relationship under the oil reserve ownership: Evidence from panel VAR approach. *Renewable Energy*, *188*, 402-410. https://doi.org/10.1016/j.renene.2022.02.039

Barro, R. J. (1990). Government spending in a simple model of endogenous growth. *Journal of Political Economy*, *98*(2), 103-125. https://doi.org/10.1086/261726

Bhuiyan, A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., & Huang, X. (2022). Renewable energy consumption and economic growth nexus—A systematic literature review. *Frontiers in Environmental Science*, *10*, 878394. https://doi.org/10.3389/fenvs.2022.878394

Dolderer, J., Felber, C., & Teitscheid, P. (2021). From neoclassical economics to common good economics. *Sustainability*, *13*(4), 2093. https://doi.org/10.3390/su13042093

Doytch, N., & Narayan, S. (2021). Does transitioning towards renewable energy accelerate economic growth? An analysis of sectoral growth for a dynamic panel of countries. *Energy*, *235*, 121290. https://doi.org/10.1016/j.energy.2021.121290

El-Karimi, M., & El-Houjjaji, H. (2022). Economic growth and renewable energy consumption nexus in G7 countries: Symmetric and asymmetric causality analysis in frequency domain. *Journal of Cleaner Production*, *342*, 130618. https://doi.org/10.1016/j.jclepro.2022.130618

Frankel, J. A., & Romer, D. H. (1999). Does trade cause growth? . *American Economic Review*, *89*(3), 379-399. https://doi.org/10.1257/aer.89.3.379

Gotz, E. (2021). Neoclassical realist theories, intervening variables, and paradigmatic boundaries. *Foreign Policy Analysis*, *17*(2), 1-9.

Guo, X., & Shahbaz, M. (2024). The existence of environmental Kuznets curve: Critical look and future implications for environmental management. *Journal of Environmental Management*, *351*, 119648. https://doi.org/10.1016/j.jenvman.2023.119648

Hao, Y., Kang, Y., Li, Y., Wu, H., & Song, J. (2023). How does environmental regulation affect economic growth? Evidence from Beijing-Tianjin-Hebei urban agglomeration in China. *Journal of Environmental Planning and Management*, *66*(9), 1813-1840. https://doi.org/10.1080/09640568.2022.2042795

Ivanovski, K., Hailemariam, A., & Smyth, R. (2021). The effect of renewable and non-renewable energy consumption on economic growth: Non-parametric evidence. *Journal of Cleaner Production*, *286*, 124956. https://doi.org/10.1016/j.jclepro.2020.124956

Knack, S., & Keefer, P. (1995). Institutions and economic performance: Cross-country tests using alternative institutional measures. *Economics and Politics*, *7*, 207–227. https://doi.org/10.1111/j.1468-0343.1995.tb00111.x

Koçak, E., & Şarkgüneşi, A. (2017). The renewable energy and economic growth nexus in Black Sea and Balkan countries. *Energy Policy*, *100*, 51-57. https://doi.org/10.1016/j.enpol.2016.10.007

Komarova, A. V., Filimonova, I. V., & Kartashevich, A. A. (2022). Energy consumption of the countries in the context of economic development and energy transition. *Energy Reports*, *8*, 683-690. https://doi.org/10.1016/j.egyr.2022.07.072

Le, H. P., & Ozturk, I. (2020). The impacts of globalization, financial development, government expenditures, and institutional quality on CO2 emissions in the presence of environmental Kuznets curve. *Environmental Science and Pollution Research*, *27*(18), 22680-22697. https://doi.org/10.1007/s11356-020-08812-2

Leal, P. H., & Marques, A. C. (2022). The evolution of the environmental Kuznets curve hypothesis assessment: A literature review under a critical analysis perspective. *Heliyon*, *8*(11), 1-10. https://doi.org/10.1016/j.heliyon.2022.e11521

Li, R., & Leung, G. C. (2021). The relationship between energy prices, economic growth and renewable energy consumption: Evidence from Europe. *Energy Reports*, *7*, 1712-1719. https://doi.org/10.1016/j.egyr.2021.03.030

Li, R., Wang, Q., & Guo, J. (2023). Revisiting the Environmental Kuznets Curve (EKC) hypothesis of carbon emissions: Exploring the impact of geopolitical risks, natural resource rents, corrupt governance, and energy intensity. *Journal of Environmental Management*, *352*, 119663. https://doi.org/10.1016/j.jenvman.2023.119663

Namahoro, J. P., Nzabanita, J., & Wu, Q. (2021). The impact of total and renewable energy consumption on economic growth in lower and middle-and upper-middle-income groups: Evidence from CS-DL and CCEMG analysis. *Energy*, *237*, 121536. https://doi.org/10.1016/j.energy.2021.121536

North, D. C. (1990). *Institutions, institutional change and economic performance.* Cambridge, MA: Cambridge University Press.

Ntanos, S., Skordoulis, M., Kyriakopoulos, G., Arabatzis, G., Ghalikias, M., Galatsidas, S., & Katsarou, A. (2018). Renewable energy and economic growth: Evidence from European countries. *Sustainability*, *10*(8), 1-12. https://doi.org/10.3390/su10082626

Okumus, I., Guzel, A. E., & Destek, M. A. (2021). Renewable, non-renewable energy consumption and economic growth nexus in G7: Fresh evidence from CS-ARDL. *Environmental Science and Pollution Research.*, *28*(40), 56595-56605. https://doi.org/10.1007/s11356-021-14618-7

Qiang, Q., & Jian, C. (2020). Natural resource endowment, institutional quality and China's regional economic growth. *Resources Policy*, *66*, 101644. https://doi.org/10.1016/j.resourpol.2020.101644

Rahman, M. M., & Velayutham, E. (2020). Renewable and non-renewable energy consumption-economic growth nexus: New evidence from South Asia. *Renewable Energy*, *147*, 399-408. https://doi.org/10.1016/j.renene.2019.09.007

Ramadhan, M. (2019). Assessing of the impact of good governance and institutions on economic growth in Indonesia. *International Journal of Scientific & Technology Research*, *8*(11), 2594-2598.

Salehnia, N., Karimi Alavijeh, N., & Salehnia, N. (2020). Testing Porter and pollution haven hypothesis via economic variables and CO2 emissions: a cross-country review with panel quantile regression method. *Environmental Science and Pollution Research*, *27*(25), 31527-31542. https://doi.org/10.1007/s11356-020-09302-1

Sarwar, A., Khan, M. A., Sarwar, Z., & Khan, W. (2020). Financial development, human capital and its impact on economic growth of emerging countries. *Asian Journal of Economics and Banking*, *5*(1), 86-100. https://doi.org/10.1108/AJEB-06-2020-0015

Sasaki, H. (2019). The Solow growth model with a CES production function and declining population. *Economics Bulletin*, *39*(3), 1979-1988.

Shao, S., Hu, Z., Cao, J., Yang, L., & Guan, D. (2020). Environmental regulation and enterprise innovation: A review. *Business Strategy and the Environment*, *29*(3), 1465-1478. https://doi.org/10.1002/bse.2446

Simionescu, M. (2021). The nexus between economic development and pollution in the European Union new member states: The role of renewable energy consumption. *Renewable Energy*, *179*, 1767-1780. https://doi.org/10.1016/j.renene.2021.07.142

Smirnova, E., Kot, S., Kolpak, E., & Shestak, V. (2021). Governmental support and renewable energy production: A cross-country review. *Energy*, *230*, 120903. https://doi.org/10.1016/j.energy.2021.120903

Smolović, J. C., Muhadinović, M., Radonjić, M., & Durašković, J. (2020). How does renewable energy consumption affect economic growth in the traditional and new member states of the European Union? *Energy Reports*, *6*(6), 505-513. https://doi.org/10.1016/j.egyr.2020.09.028

Solow, R. M. (1957). Technical change and the aggregate production function. *Review of Economics and Statistics*, *39*(3), 312–320. https://doi.org/10.2307/1926047

Tang, E., Peng, C., & Xu, Y. (2018). Changes of energy consumption with economic development when an economy becomes more productive. *Journal of Cleaner Production*, *196*, 788-795. https://doi.org/10.1016/j.jclepro.2018.06.101

Wang, J., Zhang, S., & Zhang, Q. (2021). The relationship of renewable energy consumption to financial development and economic growth in China. *Renewable Energy, 170*, 897-904. https://doi.org/10.1016/j.renene.2021.02.038

Wang, X., Zhang, T., Nathwani, J., Yang, F., & Shao, Q. (2022). Environmental regulation, technology innovation, and low carbon development: Revisiting the EKC hypothesis, Porter hypothesis, and Jevons' Paradox in China's iron & steel industry. *Technological Forecasting and Social Change, 176*, 121471. https://doi.org/10.1016/j.techfore.2022.121471

Wang, Y., Sun, X., & Guo, X. (2019). Environmental regulation and green productivity growth: Empirical evidence on the Porter hypothesis from OECD industrial sectors. *Energy Policy, 132*, 611-619. https://doi.org/10.1016/j.enpol.2019.06.016

World Bank. (2023a). *World development indicators*. Washington, DC: The World Bank Group.

World Bank. (2023b). *Worldwide governance indicators*. Washington, DC: The World Bank Group.

Wu, R., & Lin, B. (2022). Environmental regulation and its influence on energy-environmental performance: Evidence on the Porter Hypothesis from China's iron and steel industry. *Resources, Conservation and Recycling, 176*, 105954. https://doi.org/10.1016/j.resconrec.2021.105954

Xie, F., Liu, Y., & Yang, M. (2023). Spatial spillover effect of environmental regulation on regional economic growth. *Environment, Development and Sustainability, 25*(7), 7149-7160. https://doi.org/10.1007/s10668-022-02366-8

Xu, Y., & Li, A. (2020). The relationship between innovative human capital and interprovincial economic growth based on panel data model and spatial econometrics. *Journal of Computational and Applied Mathematics, 365*, 112381. https://doi.org/10.1016/j.cam.2019.112381

Zhang, W., Chiu, Y.-B., & Hsiao, C. Y.-L. (2022). Effects of country risks and government subsidies on renewable energy firms' performance: Evidence from China. *Renewable and Sustainable Energy Reviews, 158*, 112164. https://doi.org/10.1016/j.rser.2022.112164

Zhao, G., Zhou, P., & Wen, W. (2021). Feed-in tariffs, knowledge stocks and renewable energy technology innovation: The role of local government intervention. *Energy Policy, 156*, 112453. https://doi.org/10.1016/j.enpol.2021.112453

Zhao, R. (2019). Technology and economic growth: From Robert Solow to Paul Romer. *Human Behavior and Emerging Technologies, 1*(1), 62-65. https://doi.org/10.1002/hbe2.116