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Heterogeneous Effects of Economic Policy Uncertainty and Financial Development on Global Renewable Energy Consumption

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Abstract

The objective of this study is to analyze the role of economic policy uncertainty (EPU) and financial development in shaping renewable energy consumption employing panel data of 130 economies from 1990 to 2020. The empirical analysis is based on pooled ordinary least squares, fixed effects, random effects, and system generalized method of moments estimation techniques. The empirical outcomes suggest that EPU is positively connected with global renewable energy consumption (REC). This effect, however, is not consistent across developed and developing economies. In developed countries a rise in EPU is positively linked with REC while in middle- and low-income economies the EPU is negatively associated with REC. Similarly, the effects of financial development on REC vary across income groups. It exerts a favorable effect on REC in developed countries. On the contrary, it has a negative influence on REC in developing countries. These findings suggest that rich economies are taking benefit of REC drivers while the developing world is not exploiting the favorable role of these drivers. Finally, the study also predicts the statistically significant role of economic prosperity, trade, and inflation in explaining the REC. The study offers useful policy implications.

Keywords: clean energy consumption, economic policy uncertainty, trade, growth, financial development, inflation, developing economies.

1. Introduction

Greenhouse gas (GHG) emissions are continuously rising in the atmosphere across the globe. Such concentration is creating many problems for the global environment. According to a recent United Nations report, GHG emissions have been increased by an average of 1.5% annually over the past ten years, reaching a record-high of 55.3 Gt CO2 equivalent in 2018 (Christensen & Olhoff, 2019). The increase in the temperature of the planet and rising sea levels are the main outcomes of GHG emissions. One of the plausible reasons for such an increase in GHG emissions is the growing fossil fuels burning. The studies show that the burning of different fossil fuels contributes differently to GHG emissions. For example, crude oil emits 45% followed by natural gas, which emits 31%, and coal, which emits 24%. These substantial shares to GHG emissions need to be curtailed by working out the potential ways to reduce the fossil fuels burning.

In this respect, renewable energy as a green substitute for fossil fuels needs to be emphasized. It is imperative to enhance renewable energy use to mitigate GHG emissions in the atmosphere. Currently, such usage is quite low and there exists enough potential for renewable energy to replace fossil fuels. For instance, the Energy Indicators Report of Sustainable Development Goals reveals that in 2016, the share of renewable energy in total world energy consumption was only 17.5%. (World Bank, 2019). Likewise, the generation of electricity from renewable sources remained at 24% of the total electricity consumption in 2018. Hence, there is a need to identify the barriers that have been hindering the deployment and growth of renewable energy across the globe.

Painuly (2001) considers market uncertainty as an important barrier to investment in the renewable energy sector while Ameli and Barndt (2015) suggested that information asymmetries, financial constraints, and consumer preferences act as the main barriers to diffusing REC across the OECD economies. Furthermore, REC is more expensive as compared to fossil fuels which discourage investors from diverting their resources to this sector (Foster et al., 2017; Reddy & Painuly, 2004). Another challenge with the renewable sector is that an extensive level of investment is required to achieve economies of scale (EOS). According to the International Renewable Electricity Agency, between 2018 and 2030, an average investment of around $55 billion would be needed to expand energy access to achieve sustainable development goal (SDG) 7 (IRENA, 2018). Furthermore, about $700 billion is required for improving renewable energy in the same period.

In this respect, the literature recognizes the significance of the financial sector in supporting renewable energy markets. The empirical literature, however, did not yet provide conclusive evidence on the influence of the financial sector on REC (see, for details, Majeed and Hussain, 2022). One possible reason could be that the empirical studies overlooked the role of EPU while framing the influence of the financial sector on REC. Renewable energy investments are long-term, permanent, and susceptible to new ideas and technological advancements. Thus, the future of the renewable energy sector has certain uncertainties which inhibit investment in this sector.

The literature suggests some potential negative links between EPU and REC. For example, Pastor & Veronesi (2013) argued that a high policy uncertainty intensifies "financing friction" in capital markets, thus, escalating default risk on loans, and multiplying the equity finance costs. Besides, the gains from renewable energy investment require a long time and pose more risks than that of the conventional energy sector (Majeed and Luni, 2019). Policy uncertainties are reflected in the feed-in-tariff, subsidies, and certification system which are major concerns for investors in the renewable energy market (Reuter et al., 2012). According to Ragosa and Waren (2019), investing in the renewable energy industry internalizes the cost of risk related to the unpredictability of power prices.

In contrast, the literature also suggests such channels which alter the negative effects of EPU on the energy sector. For example, the future growth prospects in the area of the renewable energy sector alter the adverse effect of EPU on consumption and investment. The chances of having a high-profit increase owing to high growth in the energy markets. Hence, firms can afford the high risk of investment and huge sunk costs in this area with the expectation of harnessing future prospective profits (Gennaioli et al., 2016). Such opportunities are particularly prevalent in the field of the renewable energy business (Liu et al., 2020).

Though the literature has linked EPU with REC, no past research has examined the association between EPU, financial development, and REC in a global setting and heterogenous income groups of economies. Prior research has focused on country-specific experiences or small groups of economies, overlooking a comparative global perspective. Since the need and usefulness of clean energy have become the major concern of the present world, analyzing its drivers in a global economy can provide wider and more comprehensive insights for both developed and developing economies. Besides, EPU is not just a concern at the national level, it has far-reaching implications for global economies.

Against this milieu, this research provides novel insights by analyzing the role of EPU on REC in a global economy and heterogenous income groups. The present research extends the existing literature in the following manners. First, this study explores the associations of EPU and financial development with REC using panel data based on 130 economies from 1990 to 2020. Second, this study extends the analysis for income groups of global economies to provide a comparative and a better understanding estimating of EPU on renewable energy consumption. Third, this study also considers the role of financial development in determining REC as the available literature provides conflicting evidence using small samples. Finally, this research takes care of the endogeneity issues between EPU and REC by employing the 2-step system-GMM technique.

The study is structured in the following ways: Section 2 contains prior studies having both theoretical and empirical support for the mentioned issue. Section 3 demonstrates the modeling framework based on the literature context. Section 4 explains the data and methodology while section 5 presents the empirical outcomes based on statistical and econometric analysis. Lastly, Section 6 concludes the research.

2. Literature Review

The focus on policy uncertainties gained attraction following the "great depression, global financial crisis, the US and European taxation, the European debt crisis, the US-China trade war, Brexit, and other events related events" (Cohn & Hira, 2020). Uncertainty about future government policy has been identified as one of the reasons for slowing down economic activity and investment in the renewable energy sector. Theoretical insights to explain EPU and REC nexus can be explained using the following theories. Ecological modernization theory suggests that the industrial structure of an economy gradually transits from environmentally non-friendly to environmentally friendly production practices. In modern societies industrial production is based on clean technologies because environmental awareness in such societies increases and the public demands clean production. Besides, the willingness to pay for a clean environment also increases in modern society (Majeed & Mazhar (2019).

The structural and contingency theories postulate that businesses in a modern economy consistently revise the best resource bundling and improve internal resource allocation to become environmentally friendly and adapt business models based on renewables and economic circularity. The "transaction cost theory" suggests business corporations prefer cooperative business models to better handle adaption and pressures arising from sustainability needs and environmental regulations in the value chain. The "resource-based theory" predicts that designing and selecting a firm's best resource portfolio provides a sustainability advantage to form and adapt a renewable and circular business model. The "network theory" predicts that new networks are evolved when companies implement circular and renewable business approaches and costs associated with contrast are declined due to specific network features such as trust and information-sharing practices (see for details, Majeed & Luni, 2020).

As far as EPU is concerned, the opportunity expectation (OE), real option (RO) and financing premium (FP) theories are relevant. According to OE theory, uncertainties are the avenues of business profits. This theory predicts that future profits are disappeared when future changes become predictable. The RO and FP theories postulate that an increase in EPU will serve as an obstacle to investments of companies, and enhance financing constraints of companies, thereby limiting the development of the renewable energy sector (see, for example, Zhu & Yu, 2022).

Economic uncertainty can deter economies by changing the consumers' and investors' consumption and investment decisions which, in turn, influence aggregate consumption, investment, output, energy demand, and environmental parameters in an economy (Sum, 2012). In the presence of economic uncertainty firms postpone their investment and hiring, the economy tightens, and a recession turns out to be more visible (Bernanke, 1983). According to Rodrik (1991), many delays in investment are largely allied with EPU. The presence of greater uncertainty also raises financing costs (Sim et al., 2010), which reduces investment and economic activity (Nyawo & Van Wyk., 2018). Investors and consumers will also postpone investment and consumption spending owing to uncertainty about future taxes, healthcare reforms, spending patterns, policy rates, and other policies' misalignment repercussions (Davis et al., 2013).

EPU has significant implications for energy market and environmental sustainability (Jin et al., 2020). Theory, however, suggests conflicting relationships between EPU and REC. One dominant view suggests that EPU hinders the development of the renewable energy sector. In this respect, Pastor & Veronesi (2013) argued that EPU exerts a negative influence on firms' investment behavior by escalating the "capital markets' financing frictions, debt default risk, and equity financing costs". Halkos & Tzemeres (2005) and Aastveit et al. (2017) argue that in the presence of high policy uncertainty, investors revise and reschedule their investment choices, causing other "economic units" to delay their consumption, investment, and savings decisions. In such a scenario, businesses adopt cheap energy sources for production to compensate for the low turnover. Resultantly, the "net income" of the firms will rise and they may adopt cleaner energy production methods in the long run. Similarly, in the period of uncertainty, the discount rate (DR) is much higher which further makes complications in investment decisions. While evaluating renewable energy projects, investors use a higher DR than that of the market rate which can lead to the rejection of a financially sound project (Helm et al., 2009).

Further, according to Reuter et al. (2012), EPU affects investment in the renewable energy sector through variations in feed-in tariffs, investment subsidies, tax credits, portfolio requirements, and certificate systems during the uncertainty period. A reduction in subsidies, for example, will discourage investors from investing in green and clean projects by raising the cost. Since investors commit resources to a project if the "net present value (NPV)" of a project is positive. The NPV is determined by two factors namely "future cash flows (FCF)" and the "discounting rate". The perceived risk of a project has a significant impact on its estimated FCF. Since the technologies propelling renewable energy are usually complicated and vastly uncertain, EPU makes evaluating the jeopardy related to CF difficult for decision-makers (Zhang et al., 2019).

According to Wang et al. (2020), the consumption and investment of energy-intensive goods substantially escalate in more open economies. Additionally, they discussed how a decline in traditional energy investment results in a decrease in energy demand when there is policy uncertainty. Such a decline in the energy demand is termed the "consumption impact" that leads to a decrease in GHG emissions and an improvement in environmental quality. However, equally, the production and consumption of clean energy may decline as a result of a drop in investment in renewable energy projects. This is referred as to the "investment impact (substitution effect)" that leads to a decrease in environmental quality. Thus, an empirical analysis is important to determine the dominant effect.

Contrary to this, the literature also predicts a favorable effect of EPU on REC (Gennaioli et al., 2016; Liu et al., 2020). Gennaioli et al., (2016) assert that the potential for future growth in the field of renewable energy offsets the detrimental effects of policy uncertainty on investment and consumption. The high expansion in the energy markets increases the likelihood of making a high profit. Therefore, businesses can afford the high investment risk and significant sunk expenditures in this field with the expectation of capturing future potential rewards. Such opportunities are particularly prevalent in the field of the renewable energy business (Liu et al., 2020).

On the empirical front, recently some studies have explored the influence of EPU on REC. The empirical literature can be divided into flowing strands. The first strand of the empirical literature suggests a negative influence of EFU on REC (Shafiullah et al., 2021; Qamruzzaman et al., 2022; Khan & Su, 2022). Using the monthly data of the US economy over the period 1986-2019 and applying nonparametric econometric methodologies, Shafiullah et al. (2021) demonstrated that EPU has a devastating impact on the REC in the long run. Using panel quantile regression analysis over the period 2000:01-2020:12, Khan & Su (2022) demonstrated the negative effect of EPU on REC in G7 economies across all quantiles of REC.

The strand of the literature suggests mixed effects depending on the form of renewable energy or the existing level of renewable energy or the type of uncertainty (Liu et al. 2020; Hermit & Benlagha, 2021; Su et al., 2022). In this respect, Liu et al. (2020) explored the influence of EPU on energy investment using the data of 55 nonrenewable energy and 116 renewable energy enterprises in China from 2007Q1 to 217Q4. The study concluded the differential effects across different forms of energy. In the case of nonrenewable energy, EPU hinders the investment in coal and petroleum while increasing investment in natural gas. In the case of renewable energy, an increase in EPU reduces investment in hydro, wind, geothermal, and biomass energy investment while increases in solar and other energy sources.

Using the daily data from January 3, 2005, to June 30, 2020, Hermit & Benlagha (2021) showed that EPU is negatively associated with renewable energy while pandemic uncertainty is positively linked with renewable energy mainly in lower quantiles. Su et al. (2022) utilized the quantile regression approach for G 7 economies and the results showed that the impact of EPU on REC remains negative. The results, however, vary depending upon the quantiles. In Canada, France, Germany, the UK, and the U.S, the EPU impact is negative in all quantiles. In Italy and Japan, the EPU impact is negative in upper and medium quantiles while positive in the lower quantile.

The third strand of the literature focuses on the asymmetric effects of EPU on REC (Sohail et al., 2021; Borozan, 2022; Zeng & Yue, 2022; Qamruzzaman et al., 2022). According to

Sohail et al. (2021), monetary policy uncertainty is negatively associated with REC in the short and long run. However, the study confirms asymmetric effects in terms of direction and magnitude as both positive and negative shocks in EPU exert a negative influence on REC. Similarly, Borozan (2022) concluded an asymmetric effect of EPU on REC for G7 countries from 1997 to 2019 as both positive and negative shocks exert a negative influence on REC. Zeng & Yue (2022), in a sample of BRICS economies from 1991 to 2019, suggested that the impact of EPU on REC is asymmetric and more influential as compared to non-REC. Similarly, Qamruzzaman et al. (2022) exhibited a negative influence of EPU on REC in the top 13 oil-producing economies using the data from 1995 to 2018 and a symmetric estimation approach. Besides, they also exhibit an asymmetric effect of EPU on REC as both positive and negative shocks in EPU exert a negative influence on REC.

The fourth strand of the literature declares that EPU does not affect REC. In this respect, Appiah-Otoo (2021) investigated the impact of EPU on renewable energy growth in 20 economies applying the ordinary least squares and GMM methods from 2000 to 2018. The results provide evidence of the negative but insignificant relationship between EPU and renewable energy growth. The findings also negate the presence of a causal relationship between both variables. Rakpho & Yamaka (2021) consider EPU as an important predictor of energy demand and supply. They apply Bayesian Vector Autoregressive (BVAR) model for the empirical analysis taking the data from 1997M1 to 2019M12. The BVAR model results clarified that EPU acts as a principal pointer of energy supply prediction instead of energy demand.

In nutshell, the empirical studies suggest both the positive and negative influence of EPU on REC. The negative association between EPU and REC, however, dominates the empirical literature. Presently, there is a dearth of literature on this topic and few studies are found in this area, which particularly focused on the US and China, BRICS countries, and G7 economies. This important issue is not explored for the global economy with heterogenous income groups. Further, the studies do not focus on the role of the development stage in determining the EPU and REC nexus. The issue of potential endogeneity problem is overlooked. The present study explores EPU and REC nexus using a global sample of economies including heterogeneous income groups in a comparative perspective.

3. Methodology

To examine the EPU and REC nexus the data have been taken from different secondary sources. The study used panel data covering the time from 1990 to 2020. The data for the focused variable is taken from EPU (2022) represented by World Uncertainty Index (WUI). The remaining indicators are extracted from World Bank (2022). Following the prior literature, the econometric model for the empirical analysis is specified as follows:

$$\mathrm{LREC_{it}} = \beta_0 + \beta_1 \mathrm{LWUI_{it}} + \beta_2 \mathrm{LGDPC_{it}} + \beta_3 \mathrm{LDCP_{it}} + \beta_4 \mathrm{LTR_{it}} + \beta_5 \mathrm{LINF_{it}} + v_i + \mu_t + \varepsilon_{\mathrm{it}} \quad (1)$$

Where, subscript *i* represents the number of cross sections 130 in the case of the global panel, 39 in the case of upper-income countries, 73 in case of middle-income countries, and 18 in the case of low-income countries (see table A in appendix). Whereas the subscript *t* is the time period from 1960 to 2021. β_0 is the intercept term representing the impact on LREC when all independent variables are equal to zero. The remaining β_1 to β_5 are the elasticity showing the percentage effect of the respective independent variable on the dependent variable. The term v_i capture the unobservable effects specific to a country, and μ_t is a time-specific component. The term ε_{it} is the error term.

The outcome variable LREC is the log of renewable energy consumption measured as share of renewable energy in total final energy consumption. The focused variable LWUI is the log of the world uncertainty index calculated considering frequency counts of the "world uncertainty" in Economic Intelligence Unit (EIU) country reports and newspapers. The index is normalized by the "total number of words" and rescaled by multiplying by 1,000. The data is available quarterly, which is transformed to annual by taking the simple average. The greater the WUI rating, the greater the degree of uncertainty and vice versa. WUI is considered the most appropriate measure of EPU and is used frequently in the recent literature (Appiah-Otoo, 2021; Qamruzzaman et al., 2022; Borozan, 2022; Zeng & Yue, 2022).

LGDPC is the log of GDP per capita measured in constant 2015 US$. According to World Bank (2022) "GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products". LDCP is the log of domestic credit to the private sector as a ratio of GDP. World Bank (2022) define it as "the financial resources provided to the private sector by financial corporations, such as through loans, purchases of no equity securities, and trade credits and other accounts receivable, that establish a claim for repayment".

LTR is the log of trade as a percentage of GDP. It is "the sum of exports and imports of goods and services measured as a share of gross domestic product" World Bank (2022). LINF is the log of inflation, consumer price measured in annual percentage. As per World Bank (2022), "it reflects the annual percentage change in the cost to the average consumer of acquiring a basket of goods and services that may be fixed or changed at specified intervals, such as yearly".

For the regression analysis, the study will employ the panel regression methods of Driscoll & Kraay's (1998) (DK) standard error technique with POLS, FE and RE specifications. This technique is efficient and provides robust estimates taking care of heteroskedasticity, cross-sectional and serial dependence (Driscoll & Kraay, 1998). According to Arellano & Bond (1991), system-GMM is an advanced econometric approach to provide efficient estimates in the presence of "small T, large N" panels, endogeneity problems, fixed individual effects, heteroskedasticity, and autocorrelation.

4. Results and Discussion

4.1 Summary Statistics

Table 1 reports the summary statistics for all the indicators used in the present analysis of global, upper-income, and lower-income countries. On the global level, the average REC is 30.5 percent, while in upper income it is 10.6 and in the lower-income group, it is 71.9 %. The maximum REC remains 98.3 for the economy of Chad in 1991 and Congo, Dem. Rep. in 1998. In upper-income countries, it was the maximum for Gabon in 1990, Iceland in 2018, and Madagascar in 1999. Among the middle-income countries, REC was the maximum in 1991 for Bhutan and in 1995 for Uganda. While in the low-income group, REC remains 98.3 for the economy of Chad in 1991 and Congo, Dem. Rep. in 1998. WUI represents that on average world uncertainty remains almost similar across all income groups. It was maximum (1.3) in South Africa in 2017.

Table 1: Summary Statistics

Global Countries					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
REC	6,071	30.5	30.7	0.0	98.3
WUI	7,824	0.136	0.144	0.0	1.343
GDPC	9,595	11674.5	18664.9	144.2	181709.3
DCP	6,702	43.8	265.5	0.0	15675.3
TR	8,376	78.2	54.1	0.0	863.2
INF	8,294	23.8	332.0	-18.1	23773.1
Upper-Income Countries					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
REC	2,141	10.6	14.8	0	78.2
WUI	2,222	0.141	0.130	0.0	1.180
GDPC	3,116	30158.5	23523.4	1027.5	181709.0
DCP	1,874	71.5	48.3	0.2	304.6
TR	2,637	100.7	73.9	10.8	863.2
INF	2,921	10.3	59.9	-4.9	1500.0
Middle-Income Countries					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
REC	3,140	34.1	27.5	0.0	95.9
WUI	4,229	0.136	0.150	0.0	1.343
GDPC	5,267	3281.1	2575.6	144.2	16438.6
DCP	3,645	31.9	26.1	0.0	182.4
TR	4,602	72.4	39.4	0.0	375.4
INF	4,420	27.4	265.8	-18.1	11749.6
Low-Income Countries					
Variable	**Obs.**	**Mean**	**Std. Dev.**	**Min**	**Max**
REC	761	71.9	29.9	0.0	98.3
WUI	1,311	0.124	0.146	0.0	1.036
GDPC	1,212	628.2	373.6	167.2	2722.5
DCP	1,129	10.4	7.0	0.0	53.2
TR	1,082	49.2	22.2	0.8	140.9
INF	945	48.2	790.7	-13.1	23773.1

4.2 Correlation Matrix

Table 2 shows the correlation matrix, where the diagonal values represent the perfect correlation with the indicator itself. A medium correlational relationship is observed for most of the variables in all specified groups.

Table 2: Correlation Matrix

Global Countries						
	REC	**WUI**	**GDPC**	**DCP**	**TR**	**INF**
REC	1					
WUI	0.0146	1				
GDPC	-0.465	0.0044	1			
DCP	-0.549	0.056	0.7023	1		
TR	-0.3393	-0.0432	0.2737	0.3043	1	
INF	0.0392	-0.0126	-0.0249	-0.0291	-0.0285	1
Upper-Income Countries						
REC	1					
WUI	0.1199	1				
GDPC	0.0734	0.0351	1			
DCP	-0.0476	0.1056	0.5137	1		
TR	-0.2298	-0.1001	0.0604	0.0663	1	
INF	0.1295	-0.0593	-0.2453	-0.2329	-0.0914	1
Middle-Income Countries						
REC	1					
WUI	0.0244	1				
GDPC	-0.5084	0.1306	1			
DCP	-0.4445	0.0773	0.3702	1		
TR	-0.2625	-0.0511	0.1423	0.2983	1	
INF	0.0015	-0.0095	0.0125	-0.0021	-0.0688	1
Low-Income Countries						
REC	1					
WUI	0.0149	1				
GDPC	-0.7371	0.0328	1			
DCP	-0.038	0.1146	-0.0965	1		
TR	-0.1505	0.2043	-0.0428	0.287	1	
INF	0.0583	-0.024	-0.0168	-0.0775	-0.0275	1

4.3 The Cross-sectional Dependence (CSD) Tests for Global, Upper, Middle- and Low-Income Countries

The results of CSD tests namely Breusch-Pagan LM, Pesaran scaled LM, Pesaran CD, & Friedman's tests are presented in table 3. The outcomes for the global panel, upper-income countries (UIC), middle-income countries (MIC) and low-income countries (LIC) are reported in columns (1-4), respectively. In each case, the test statistics are highly significant and reject the null hypothesis of "no cross-section dependence." This implies that all the countries in a global panel and across income-groups are dependent on each other.

Table 3: Cross-Section Dependence Test Results

	(1)	**(2)**	**(3)**	**(4)**
CSD Tests	**Global Panel**	**UIC**	**MIC**	**LIC**
Breusch-Pagan LM	300.801***	117.002***	40.606***	251.985***
	(0.000)	(0.000)	(0.000)	(0.000)
Pesaran scaled LM	23.436***	23.926***	4.675***	5.659***
	(0.000)	(0.000)	(0.000)	(0.000)
Pesaran CD	14.358***	10.409***	4.102***	-0.162***
	(0.000) ***	(0.000)	(0.000)	(0.000)
Friedman's Test	25.003***	59.040***	52.552***	-
	(0.005)	(0.000)	(0.000)	-

Probability values are in parentheses: "* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$"

4.4 Panel Regression Analysis for Global Countries

Table 4 presents the findings of the pooled ordinary least squares (POLS), random effects (RE), fixed effects (FE), and SGMM for the global panel in columns (1-4), respectively. The results suggest that a one percent increase in EPU is associated with 0.212%, 0.017%, 0.0150 %, and 0.361% increase in REC, respectively. This finding implies that a higher EPU has a positive influence on REC. This finding is consistent with OE theory which suggest that uncertainties create profit opportunities and predictability reduces future profits. In effect, policy uncertainty increases the risk of the investment as well as the return on the investment. Particularly, investors in rich economies can afford clean energy projects in an uncertain environment. These findings are consistent with the studies of Aastveit et al. (2017) & Liu et al. (2020).

The role of financial development in green energy adoption is critical, as this sector provides financing assistance in the installation of green technology projects. The SGMM estimates indicate that LDCP has a favorable and significant impact on REC. Particularly, a one percent increase in financial development leads to an increase of 0.639% in renewable energy consumption. Financial development removes the financial barriers that prevent businesses and individuals from using clean and environmentally friendly energy sources. Importantly, climate finance is essential for closing the financial gap and incentivizing private investment and foreign direct investment in clean renewable energy. Similar findings are discussed by Yi et al. (2023), Zhang and Razzaq (2022), Appiah-Otoo (2021) and Zahoor et al. (2021).

The impact of GDPC on REC remains negative and highly significant across all estimators. The likely reason could be that as income rises firms may opt for less expensive non-renewable energy sources to save money and increase profits. Similarly, consumers may spend their money on improving their living conditions, such as purchasing home appliances that may improve their living conditions but are not environmentally friendly. Furthermore, as income rises, the emphasis shifts from the environment to growth; thus, to achieve higher growth, less expensive energy sources are used, which slows the transition towards clean energy use. This finding is in line with Appiah-Otoo (2021). However, this finding is inconsistent with Nyiwul (2017) who showed positive, albeit insignificant, effect of income on renewable energy in Sub-Sahara Africa.

For trade, the estimates based on RE, and FE methods suggest that trade exerts a favorable influence on REC, implying that the transition to green technology is observed in trade-open economies. Since open economies face foreign competition, they have pressure to follow environmental standards (Shafik & Bandyopadhyay, 1992). This finding is consistent with ecological modernization theory as modern economies adopt evidentially clean technologies. However, the POLS and SGMM estimates suggest an opposite effect of trade on REC. Trade can close the "resource endowment" gap among economies by letting resources flow from areas of excess supply to areas of excess demand. Such resources flow prioritizes scale effect, thereby compromising environmental sustainability (Wang & Zhang, 2021).

Lastly, the impact of inflation on renewable energy remains negative and highly significant across all models. Inflation distorts the price mechanism in the economies and raises concerns about the future profitability of investment projects mainly when the project involves huge initial financing. Meanwhile, inflation also distorts lending and borrowing decisions by interacting with the tax system, thereby further delaying long-term investment projects. The increasing costs of inputs due to higher inflation can also depress investment. Since renewable energy requires huge financing costs, therefore, an increase in inflation reduces the investment and consumption of renewable energy (Cao et al., 2020).

Table 4: Regression Results (Global Countries)

Dependent Variable: LREC (1990-2020)				
	(1)	**(2)**	**(3)**	**(4)**
	POLS	**RE**	**FE**	**SGMM**
LWUI	0.212***	0.0170*	0.0150*	0.361***
	(0.0677)	(0.00904)	(0.00854)	(0.0216)
LGDPC	-0.575***	-0.315***	-0.259***	-1.070***
	(0.0308)	(0.100)	(0.0588)	(0.0427)
LDCP	-0.0359	-0.00834	-0.0159	0.639***
	(0.0556)	(0.0341)	(0.0304)	(0.0463)
LTR	-0.531***	0.172***	0.174***	-0.259***
	(0.0609)	(0.0322)	(0.0245)	(0.0902)
LINF	-0.114***	-0.0371***	-0.0347**	0.172***
	(0.0310)	(0.0130)	(0.0134)	(0.0122)
CONS	10.67***	4.830***	4.489***	11.25***
	(0.216)	(0.586)	(0.502)	(0.385)
Obs.	2291	2291	2291	2105
No of Groups	130	130	130	130
R^2	0.336		0.041	
F-Stats	231.14***	-	31.98***	-
	(0.000)	-	(0.000)	-
Wald Test	-	121.38***		-
	-	(0.000)		-
Hausman Test			-	
AR (1) Pr>z	-	-	-	0.003
AR (2) Pr>z	-	-	-	0.180
Hansen Test	-	-	-	0.208
Post Estimation Tests				
VIF	1.59	**Link Test**		0.0359
				(0.165)
BPG Test	510.92***	**Wooldridge Test**		88.764***
	(0.000)			(0.000)

"Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$"

4.5 Panel Regression Analysis for Upper-Income Countries (OLS, RE, FE, SGMM)

The results for upper-income countries are reported in table 5. In advanced economies, a 1 % increase in EPU will escalate REC by 0.368 %, 0.084 %, 0.082 %, and 0.331 %, respectively. This means that higher levels of policy uncertainty encourage the use of "green technology" in high-income countries. The impact of GDPC is positive suggesting that an incline in per capita income will encourage clean energy usage. Environmental concerns are more prevalent in higher-income countries than growth. Since the general public is more aware of environmental security; renewable energy consumption will rise as a result of higher income. These findings are supported by Borozan (2022).

The impact of financial development on REC is positive and significant. Increasing financial development assists advanced economies to adopt energy-efficient methods for production. Financial sector development removes financing constraints for firms and facilitates investment in renewable energy projects (Majeed & Mazhar, 2019). The impact of trade on REC is sensitive to the estimation method. Inflation dominantly poses a threat to REC. Inflation will delay investment in long-term projects such as renewable energy due to increased input costs, future profitability risk, price mechanism distortion, and income vulnerability (Cao et al., 2020).

Table 5: Regression Results (Upper-Income Countries)

Dependent Variable: LREC (1990-2020)				
	(1)	**(2)**	**(3)**	**(4)**
	POLS	**RE**	**FE**	**SGMM**
LWUI	0.368*	0.0842**	0.0828***	0.331***
	(0.186)	(0.0320)	(0.0290)	(0.0131)
LGDPC	0.176	0.221	0.196	-0.671***
	(0.173)	(0.202)	(0.195)	(0.206)
LDCP	-0.152	0.0923	0.0893	0.693***
	(0.182)	(0.0784)	(0.0683)	(0.150)
LTR	-0.780***	0.545**	0.594**	-0.859***
	(0.0623)	(0.210)	(0.215)	(0.167)
LINF	-0.00531	-0.0513	-0.0502	0.666***
	(0.0649)	(0.0344)	(0.0318)	(0.0340)
CONS	4.864***	-3.241*	-2.976	9.586***
	(1.157)	(1.847)	(1.854)	(2.094)
Obs.	689	689	689	649
No of Groups	39	39	39	39
R^2	0.080		0.175	
F-Stats	11.80***	-	31.98***	-
	(0.000)	-	(0.000)	-
Wald Test	-	133.19***		-
	-	(0.000)		-
Hausman Test	-	-		
AR (1) Pr>z	-	-	-	0.007
AR (2) Pr>z	-	-	-	0.143
Hansen Test	-	-	-	0.1000
Post Estimation Tests				
VIF	1.37	**Link Test**		-0.7587
				(0.000)
BPG Test	510.92***	**Wooldridge Test**		28.296***
	(0.000)			(0.000)

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.6 Panel Regression Analysis for Middle-Income Countries (OLS, RE, FE, SGMM)

The results for middle-income countries are discussed in table 6. Most countries are in the developing stage and trying hard to improve their growth rates and environmental standards. According to the results, a 1 % increase in EPU tends to reduce REC by 0.209 %, 0.0139 %, and 0.0146 % and 0.0045 %, respectively. This outcome is consistent with RO and FP theories which suggest a higher EPU hinders firms' investment plans by enhancing financing constraint of companies, thereby limiting development of renewable energy sector (see, for example, Zhu & Yu, 2022).

Uncertainty has a substantial impact on institutions, manufacturing firms, consumer income, and investment and consumption decisions. As a result, in times of high uncertainty, household and businesses postpone investment due to lower personal income or "corporate profitability". It will have a long-term impact on capital investments, thereby reducing investment in risky projects such as renewable energy projects. Consumers can also easily postpone non-essential and some essential purchases in a period of uncertainty including consumption of renewable energy. These findings are consistent with Rakpho & Yamaka (2021) and Khan & Su (2022).

Economic growth and financial development are important for promoting environmental sustainability. However, environmental concerns are less prevalent in middle-income economies as they are working hard to boost their growth rates. The results show that an increase in per capita income is negatively associated with renewable energy demand. Similarly, financial development is also negatively associated with renewable energy demand. The findings imply that the "scale effect" dominates in these economies where economic activities are prioritized while overlooking environmental concerns. The relationship between inflation and renewable energy consumption remains negative and significant across all models (except SGMM).

Table 6: Regression Results (Middle-Income Countries)

Dependent Variable: LREC (1990-2020)				
	(1)	**(2)**	**(3)**	**(4)**
	POLS	**RE**	**FE**	**SGMM**
LWUI	0.209***	-0.0139***	-0.0146***	-0.00458***
	(0.0629)	(0.00492)	(0.00468)	(0.00127)
LGDPC	-0.791***	-0.462***	-0.447***	-0.350***
	(0.0261)	(0.0346)	(0.0300)	(0.0253)
LDCP	-0.0638	-0.0202	-0.0232	-0.00965***
	(0.0424)	(0.0337)	(0.0331)	(0.00180)
LTR	-0.342***	0.0573	0.0609*	-0.0923***
	(0.0678)	(0.0375)	(0.0306)	(0.00980)
LINF	-0.0944***	-0.0278***	-0.0269***	0.00856***
	(0.0335)	(0.00483)	(0.00407)	(0.00153)
CONS	11.60***	6.595***	6.512***	-
	(0.293)	(0.384)	(0.303)	-
Obs.	1302	1302	1302	1029
No of Groups	73	73	73	73
R^2	0.293		0.191	
F-Stats	107.65***	-	57.96***	-
	(0.000)	-	(0.000)	-
Wald Test	-	309.86***		-
	-	(0.000)		-
AR (1) Pr>z	-	-	-	0.084
AR (2) Pr>z	-	-	-	0.119
Hansen Test	-	-	-	0.626
Post Estimation Tests				
VIF	1.14	**Link Test**		0.0953
				(0.082)
BPG Test	148.10***	**Wooldridge Test**		208.70***
	(0.000)			(0.000)

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.7 Panel Regression Analysis for Low-Income Countries (LS, RE, FE, SGMM)

Table 7 documents the regression results for low-income countries. The impact of EPU on REC is negative and significant. Particularly, a 1 % rise in EPU is associated with a 0.0134 %, 0.0136 %, and 0.0114 % fall in REC in the case of RE, FE, and SGMM, respectively. This implies that policy uncertainty has varying effects depending on the level of development in these countries. Within the group of upper-income countries, the countries with higher income may adopt renewable energy sources due to an increased "net worth" of firms as a result of uncertainty (Liu et al., 2020). On the other hand, low-income countries have a lower capacity to absorb shocks, and economic recovery takes time. As a result of increased uncertainty, firms delay long-term investment projects, consumers limit their spending to necessities, and thus production and consumption of renewable energy consumption will decrease (Rakpho & Yamaka, 2021).

The goal of low-income countries is to achieve higher and more consistent growth, higher income, higher living standards, and full utilization of the available resources. Concerns about environmental preservation and energy efficiency are less desirable in low-income economies. As a result, as income rises, firms tend to invest more in low-cost projects with higher returns. Renewable energy projects require higher financing and are riskier, making firms hesitant to invest in them. Consumers also spend money on luxuries and home appliances to improve their living standards without thinking about the environmental consequences. As a result, the use of renewable energy is decreasing. This finding is consistent with Appiah-Otoo (2021). The impact of financial development on renewable energy consumption is negative and significant. This finding implies that inflation discourages REC by increasing energy prices in low-income countries. Finally, to assess the robustness of empirical findings the interactive effect of GDPC and EPU is estimated. The results reported in Table A2 confirm that the influence of EPU on REC is negative, however, its interactive effect with GDPC is positive and statistically significant. This finding confirms baseline findings that the effects of EPU on REC vary across income levels. Overall, EPU has a negative impact on REC but this effect turns out to be positive and statistically signficant in high-income economies.

Table 7: Regression Results (Low-Income Countries)

Dependent Variable: LREC (1990-2020)				
	(1)	**(2)**	**(3)**	**(4)**
	POLS	**RE**	**FE**	**SGMM**
LWUI	0.0397	-0.0134**	-0.0136**	-0.0114*
	(0.0261)	(0.00589)	(0.00524)	(0.00593)
LGDPC	-0.760**	-0.166***	-0.159***	-0.324***
	(0.289)	(0.0270)	(0.0252)	(0.0867)
LDCP	0.0115	-0.0261***	-0.0273***	-0.0396***
	(0.0318)	(0.00619)	(0.00708)	(0.0136)
LTR	-0.117*	0.0214	0.0212	0.0101
	(0.0639)	(0.0130)	(0.0138)	(0.0164)
LINF	-0.00311	-0.000325	-0.000215	-0.00460
	(0.0162)	(0.00487)	(0.00430)	(0.00331)
CONS	9.684***	5.182***	5.310***	-
	(2.059)	(0.351)	(0.183)	-
Obs.	300	300	300	175
No of Groups	18	18	18	18
R^2	0.325		0.327	
F-Stats	28.29***	-	26.95***	-
	(0.000)	-	(0.000)	-
Wald Test	-	130.11***	-	-
	-	(0.000)	-	-
Hausman Test	-	-	1.70	-
	-	-	(0.889)	-
AR (1) Pr>z	-	-	-	0.758
AR (2) Pr>z	-	-	-	0.556
Hansen Test	-	-	-	1.000
Post Estimation Tests				
VIF	1.12	**Link Test**		-2.0724
				(0.000)
BPG Test	1349.61***	**Wooldridge Test**		6.718***
	(0.000)			(0.019)

Standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

5. Conclusion

Environmental degradation has become a pressing issue in the present world. Numerous studies have been devoted to understanding the factors responsible for decreasing environmental quality and finding solutions to environmental preservation. It is widely believed that switching fossil fuels-based energy with green energy can greatly resolve environmental issues. However, investment in renewable energy is not following the desired pace. Why investment in the renewable energy sector is slow? Recently researchers pointed out the conducive role of the financial sector in influencing the renewable energy sector, however, the results remain inconclusive. These studies ignored the role of EPU which is another great global challenge and a potential driver of renewable energy sector. It has greater implications for the renewable energy sector as the returns in the renewable sector are longer-term and EPU has a great role in the decisions of investors. Some studies consider EPU but ignore financial sector and provided evidence in a specific case setting. Since renewable energy, and EPU are global challenges and their understanding can vary across income groups, it is the need of the present time to conduct a comparative global analysis.

Against this milieu, this study explores the role of EPU in REC using panel data of 130 economies over the period 1990 to 2020. The empirical results show that EPU is positively associated with global REC. However, a disaggregated analysis of different groups of economies according to their income levels shows that this positive association is mainly dominated by upper-income countries. An increase in EPU is associated with an increase in REC in upper-income economies while EPU has a negative influence on REC in middle- and low-income economies.

The results for financial development suggest that financial development increases the demand for renewable energy in a global panel and upper-income economies. This finding confirms that a drive for sustainable energy and development in upper-income economies is supported by financial sector development. However, the role of the financial sector in middle-income and low-income economies is not promising in supporting renewable energy transition as financial development is inversely associated with renewable energy. This finding implies that developing economies use financial support for conventional sources of energy usage. Furthermore, the study also predicts the statistically significant role of economic growth, trade openness, and inflation in explaining the demand for renewable energy.

5.1 Theoretical & Practical Implications

This study establishes an association between EPU and REC in a global panel and across heterogenous income groups. The empirical outcomes suggest that EPU is positively associated with global REC. This finding is consistent with OE theory which suggests that uncertainties create profit opportunities and predictability reduces future profits. This finding, however, varies across developed and developing economies. In effect, the consistency of OE theory is observed in developed economies while in the middle- and low-income economies the EPU is negatively associated with REC. This outcome is consistent with RO and FP theories which suggest a higher EPU hinders firms' investment plans by enhancing financing constraints of companies, thereby limiting the development of the renewable energy sector. Similarly, the association between financial development and REC differs across income groups. Financial development boosts REC in developed economies while reduces it in middle and low-income economies. These findings support the financial Kuznets curve (Majeed & Hussain, 2022). Table 1 indicates that the mean value DCP in upper-income economies is 71.5 which is considerably high than that of counterpart middle and low-income economies (31.9) and low-income economies (10.4). That is, economies with a low level of financial development observe negative effects on REC while economies with a high level of financial development observe positive effects on REC.

The empirical analysis suggests the following practical implications. First, the effects of EPU are not similar across different income groups. A global policy to map the association between EPU and REC will not be effective. The policies associated with REC need to be devised considering the heterogeneity of income groups. For instance, developed economies can afford EPU while promoting the renewable energy sector while developing cannot boost this sector in the presence of EPU. Therefore, combating EPU is the main concern of developing economies. Similarly, financial sector growth can hamper a sustainable drive through REC in developing economies if financial development is not aligned with the requirements of the flourishing renewable energy sector. This research emphasizes the potential barriers to the flourishment of the renewable energy sector.

5.2 Limitations of the Study

This research study has certain limitations. First, the objective of this study was to analyze the role of EPU in shaping REC by employing global panel data. However, the data on the main concerned variables is not available for all economies, and analysis is limited to 130 economies. Second, this research mainly focuses on the aggregate form of REC whereas EPU can have diverse effects on different forms of REC. Third, this study suggests a non-monotonic association between EPU and REC across heterogenous income groups using sub-samples. Alternative approaches to detect non-linearity are not used.

5.3 Future Study Directions

Future studies can explore the influence of EPU on different forms of renewable energy such as solar energy, wind energy, hydro energy, geothermal energy, and biomass energy. Second, a panel threshold analysis can be conducted to locate the threshold level of economic development. Third, the role of environmental policies can be framed to better understand the relationship between EPU and REC.

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Appendix

Table A1: List of Sample Countries

UIC	**UIC**	**MIC**	**MIC**	**MIC**	**LIC**
Australia	Latvia	Albania	Gabon	Myanmar	Burkina Faso
Austria	Lithuania	Algeria	Georgia	Namibia	Burundi
Belgium	Netherlands	Angola	Ghana	Nepal	Cent. African Rep.
Canada	New Zealand	Armenia	Guatemala	Nicaragua	Chad
Chile	Norway	Azerbaijan	Haiti	Nigeria	Congo, Dem. Rep.
Croatia	Oman	Bangladesh	Honduras	Pakistan	Gambia
Czech Republic	Poland	Belarus	India	Panama	Guinea
Denmark	Portugal	Benin	Indonesia	Paraguay	Guinea-Bissau
Finland	Saudi Arabia	Bolivia	Iran	Peru	Madagascar
France	Singapore	Bosnia	Iraq	Philippines	Mali
Germany	Slovak Republic	Botswana	Jamaica	Romania	Mozambique
Greece	Slovenia	Brazil	Jordan	Russian Fed.	Niger
Hong Kong	Spain	Bulgaria	Kazakhstan	Senegal	Rwanda
Hungary	Sweden	Cambodia	Kenya	South Africa	Sierra Leone
Ireland	Switzerland	Cameroon	Kyrgyz Republic	Sri Lanka	Sudan
Israel	United Arab Emirates	China	Lao PDR	Tajikistan	Togo
Italy	United Kingdom	Colombia	Lebanon	Tanzania	Uganda
Japan	United States	Congo, Rep.	Lesotho	Thailand	Yemen, Rep.
Korea	Uruguay	Costa Rica	Libya	Tunisia	
Kuwait		Cote d'Ivoire	Malaysia	Turkey	
		Dominican Rep	Mauritania	Ukraine	
		Ecuador	Mexico	Vietnam	
		Egypt	Moldova	Zambia	
		El Salvador	Morocco	Zimbabwe	

Table A2: Regression Results (Global Countries)

	(1)	(2)	(3)
	POLS	FE	RE
LWUI	-0.439***	-0.338***	-0.335***
	(0.159)	(0.0468)	(0.0470)
LGDPC	-0.410***	-0.165***	-0.221***
	(0.0487)	(0.0399)	(0.0380)
LDCP	0.151***	-0.00888	-0.00150
	(0.0348)	(0.0167)	(0.0167)
LTR	-0.400***	0.167***	0.165***
	(0.0445)	(0.0285)	(0.0285)
LINF	-0.0880***	-0.0338***	-0.0361***
	(0.0206)	(0.00691)	(0.00693)
LWUI*LGDPC	0.0557***	0.0425***	0.0424***
	(0.0189)	(0.00555)	(0.00558)
Constant	6.963***	3.712***	4.051***
	(0.479)	(0.317)	(0.334)
Observations	2291	2291	2291

Standard errors in parentheses * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$