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Nexus between foreign direct investments renewable energy consumption: What is the role of Government debt?

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Abstract
The motivation of the study is to gauge the role of foreign direct investment and government debt in developing renewable energy growth for the period 1990-2020. The study has implemented several economical tools, including cross-sectional dependency, Panel –ARDL with symmetry and asymmetry framework. The government debt and FDI coefficients revealed a positive and statistically significant link to renewable energy growth in the economy, especially in the long run. The asymmetric assessment has documented the asymmetric association between government debt and renewable energy consumption and FDI and renewable energy consumption in the long and short run. Finally, the directional causality test revealed unidirectional causality from government debt to renewable energy and bidirectional causality between FDI and renewable energy consumption.

Keywords: FDI, Debt, ARDL, NARDL, causality test

1. Introduction

As a result of expanding energy use, the need for sustainable energy has increased in both developed and developing countries. As the price of fossil fuels fluctuates, there is an increasing need for reliable, sustainable, and secure energy sources. As an alternative to relying only on imported fossil fuels, it may be possible to increase the usage of domestic renewable energy sources. One argument for greener energy provides more environmental advantages than traditional fossil fuels. Renewable energy (abbreviated as RE from here on) is often seen as less hazardous than traditional energy sources since it does not generate significant quantities of greenhouse gases while in use. Increasing renewable energy production might reduce CO2 emissions and energy imports (Nepal, 2012) [47]. It is believed that renewable energy generation has the greatest influence on energy security since it minimizes dependency on foreign fuel imports and debt (Vaona, 2016) [73]. (Borenstein, 2012) [12]. Numerous studies have examined the influence of RE on macro parameters such as economic growth, energy efficiency and security, environmental quality, financial development, FDI, etc.

In contrast, the second line of research focused on the factors that inhibit the expansion of RE production in the economy (Qamruzzaman and Jianguo, 2020a; Przychodzen and Przychodzen, 2020; Aguirre and Ibikunle, 2014; Papie *et al*., 2018; da Silva *et al*., 2018) [65, 60, 4, 50, 19]. Ultimately, the research identified several significant barriers to RE integration into the economy, including financial development, investment, foreign direct investment, etc. Renewable energy is a crucial part of the energy supply since it may enhance the present energy mix, mitigate market disputes, and safeguard the environment. Thus, developing renewable energy sources becomes a crucial problem in transitioning to a low-carbon economy on a national and regional scale. The shift from conventional to renewable energy has been a crucial step in reducing greenhouse gas (GHG) emissions. (Mohsin *et al*., 2021) [44]. Research & development expenditures are positively affected by the adoption of renewable energy in economic activities (Adedoyin *et al*., 2020) [3]. RE promotes aggregate output growth with little environmental impact (Qamruzzaman and Jianguo, 2020a) [65]. The rising environmental damage brought on by the excessive use of nonrenewable energy heightens concerns about the future effects of climate change, especially on the achievement of sustainable development (Wang and Dong, 2019) [75.76].

Nations have constantly invested in energy diversification by changing to RE applications rather than conventional energy to maintain the environment and mitigate the consequences of climate change on the normal path of civilization (Celk, 2012). Population growth and economic expansion have fueled global carbon dioxide emissions since both need substantial energy use. However, the environmental impact of energy depends on the kind of energy sources used. Most environmental degradation is attributed to nonrenewable energy sources, while renewable energy contributes to environmental betterment (Majeed and Luni, 2019) [39].

Since nonrenewable energy sources harm the environment, renewable energy integration is gaining importance among policymakers. According to the literature on renewable energy, there are several ways to improve environmental quality via renewable energy. In addition, renewable energy does not contribute to environmental damage since it does not discharge harmful substances into the atmosphere. The substitution effect is a second mechanism through which renewable energy helps to reduce environmental degradation. Renewable energy sources will replace polluting fossil fuels to lessen their effect (Bilgili *et al*., 2016; Li and Qamruzzaman, 2022; Jia *et al*., 2021) [11, 31]. Renewable energy does not harm the environment similarly to fossil fuels because it does not use resources (Akella *et al*., 2009) [5]. The dynamic implications of economies of scale and the spillover effects of renewable energy contribute to the improvement of the environment.

This study examines the impact of economic policy uncertainty (EPU), compelled direct investment, and public debt on renewable energy development from 1980 to 2021. Panel ARDL was done according to Pesaran *et al*. (1999), CS-ARDL was implemented according to Chudik and Pesaran (2015) [17], and NARDL was implemented according to the nonlinear formwork launched by Shin *et al*. (2014) [70] for identifying the long-run and short-run influence of explanatory factors on RE. Moreover, using Dumitrescu and Hurlin's (2012) [22] Panel Causation Tests, directional causality was shown between EPU, FDI, GD, and RE. The present study contributes the following to the existing body of knowledge: The remaining structure of the paper is as follows. Section II deals with the pertinent literature survey and a hypnotized conceptual model of the study: variables definition, data sources and econometrical strategy discussed in Section III. Empirical model estimation and interpretation are reported in Section IV. Section V contains the discussion of the study findings, and finally, the conclusion is reported in Section VI.

2. Literature review

Global governments are grappling with the problem of energy transition because of the negative effects of fossil fuel usage on economic production. As a consequence of our overreliance on conventional energy sources, climate change and environmental degradation are inevitable. As a result, if we are to reduce our contribution to global warming, we must switch to renewable energy sources. It is possible to reduce greenhouse gas emissions by increasing investments in renewable energy sources, such as wind and solar power (Acheampong *et al*., 2019) [1]. The use of renewable energy sources, including solar, hydropower, wind, and biomass, is becoming more popular to reduce environmental damage. It is possible that, unlike fossil fuels, renewable energy sources may be able to supply the growing need for energy without harming economic or environmental growth or generating pollutants that are bad for the environment. In addition, traditional energy production's thermal pollution may be avoided (Akella *et al*., 2009) [5]. As a result of investments in energy diversification, such as tax subsidies and international happenings, regional players are significantly impacted (Adedoyin *et al*., 2020) [3]. It will need significant research and development, smart government policies, and foreign investment encouragement to switch from nonrenewable to renewable energy sources (Qamruzzaman and Jianguo, 2020a) [65]. The only long-term solution to the global energy crisis is to invest in R&D to diversify the world's energy supply. Because research into renewable energy sources is stimulated by reducing nonrenewable energy usage, it may be critical to general economic progress (Shahbaz *et al*., 2015). Though FDI serves as a source of finance for both developed and developing nations, it is also recognized as a source of innovation that can decrease energy consumption. As a result, the new era has begun to concentrate on the impact of FDI on energy consumption in the host nation. However, the discussion has been inconclusive so far. Existing literature suggests two lines of evidence in explaining the nexus between FDI-led energy consumption.

Foreign Direct Investment (FDI) inflows have been found to have an impact on aggregate output levels via an increase in energy consumption (Qamruzzaman and Jianguo, 2020a; Rezagholizadeh *et al*., 2020; Khandker *et al*., 2018; Fan and Hao, 2020; Azam *et al*., 2015) [65, 68, 33, 25, 7]. To minimize pollution, finding a solution to the conflict between supply and demand has become an important part of increasing energy efficiency. Because FDI is made up of money, technology, and management, experts have found that it impacts energy efficiency. As a consequence of the spillover effect, FDI has an impact on energy efficiency as well as efficiency in other sectors. Informally or non-market-oriented technology transfer is responsible for the vast majority of spillover. The flow effect, the connection effect (teaching, advising, and leading), the competition influence, and the demonstration influence may all impact how technology is distributed. A surge in renewable energy use may be attributed to the development of new technology (Ferrier *et al*., 2016) [26].

Most FDI comes from nations where the manufacturing sector is more likely to adhere to stringent environmental regulations (Neumayer, 2001) [48]. In their manufacturing processes, most of these enterprises utilize or are affected by renewable and productive energy (Stalley, 2020; Qamruzzaman, 2014) [71]. Since local industry may imitate energy-efficient products from their home countries through foreign investment, MNCs will contribute to the advancement of energy efficiency in the hosting economy. International investment (FDI) is projected to decrease nonrenewable energy use in developing nations by transferring cleaner technology and improved management practices (Mabey and McNally, 1999) [37]. Increased renewable energy integration is connected to foreign direct investment (Ergun *et al*., 2019) [24]. Investment in green capital spillovers, which increase FDI flow to the country's total energy consumption, improves efficiency (Doytch and Narayan, 2016) [21].

Polat (2018) [59] investigated a study by employing a dynamic panel data technique to evaluate the impact of FDI on renewable and nonrenewable energy consumption in 85 industrialized and developing countries from 2002 to 2014.

The study found that FDI lowers energy usage in industrialized nations while having little impact in underdeveloped countries. Moreover, the openness index and energy costs also influence energy use in industrialized nations. However, the adverse association between FDI and renewable energy consumption is documented in the literature (Marton and Hagert, 2017; Wang and Jiayu, 2019) [40, 75, 76].

Capital sufficiency for renewable energy investments accelerates the creation of clean energy and alters the current energy structure by increasing the proportion of oil-based energy replaced by renewable energy. Changes in energy costs, namely the price of oil on the global market, harm energy demand and need a reassessment of fossil energy integration (Domac *et al*., 2005) [20]. Higher fossil energy costs prompted the development of renewable energy sources to decrease energy demand, resulting in a rise in research and development expenditures for a workable solution (Vickers, 2017) [74]. Renewable energy has become a significant energy source in several countries because it provides millions of people with clean, reliable, affordable, and sustainable energy (Cedrick and Long, 2017) [15]. Nations have embraced renewable energy technologies due to the negative externalities of fossil fuels and the positive externalities associated with renewable energy (El-Guindy and Mahmoud, 2013; Qamruzzaman and Karim, 2020) [23, 67]. Financial capital is essential for developing renewable energy projects, with banking credit acting as the principal external source of finance for energy investments in the overwhelming majority of countries. Due to the substantial initial investment necessary for renewable energy technologies, private sector capital, innovation, and technology are often mobilized via public-private partnerships to supplement limited public sector finances to deliver such public services (Mazzucato and Semieniuk, 2017) [42].

The widespread opinion is that governments own a significant quantity of resources that may be deployed to facilitate the transition to renewable energy. This is achieved through increasing public financing for initiatives that use earmarked monies. Governmental sources of finance are more accessible than private ones to enterprises in the energy industry. Fleta-Asn and Muoz (2021) [27] evaluated the variables of private and governmental investment in renewable energy generation using a sample of 1,371 firms from 63 developing nations between 1997 and 2016. The study reveals that better economic and political frameworks stimulate public-private partnerships in the renewable energy sector (PPP). Furthermore, the study hypothesizes that unstable institutional frameworks have a detrimental effect on energy sector investment. Government efforts that encourage third-party institutional funding and modifications to their structures and economic environments are emphasized due to their favorable effect on private engagement in the renewable energy sector. Similarly, strong signals of these traits aid private investors in selecting projects with a higher possibility of success. From 1999 to 2017, Bayale *et al*. (2021) [8] analyze the determinants of RE in transition economies in Central and Eastern Europe, the Caucasus, and Central Asia. Research reveals that economic development, job creation, and government debt have emerged as forces boosting renewable energy production in nations in transition. Radioactive waste is a byproduct of nuclear energy generation, demanding long-term, capital-intensive investments and generating radioactive waste. Another kind of energy is characterized by substantial capital expenditures, extended lead times, and the danger of resource depletion. Given the prominence of state-owned firms in the energy sector of many nations, public money should considerably promote the expansion of renewable energy in the above initiatives (Best, 2017) [10]. From 1990 to 2016, Wang *et al*. (2021) [77] examined the link between renewable energy consumption, government debt, and human capital growth in the BRICS nations using econometric panel techniques. According to the conclusions of their study, there is a statistically significant relationship between human capital development and renewable energy output, but a negative link between human capital development and the length of intergovernmental debt and renewable energy. A bidirectional causal relationship was discovered between renewable energy and government debt. Direct R&D spending, subsidies, and tax credits aimed toward renewable energy innovators and other types of public funding may help speed the adoption of renewable energy (Bergek *et al*., 2013; Zhang *et al*., 2021) [9, 81]. Olmos *et al*. (2012) [49] proposed that when a lack of liquidity hampers the capital market, government loans supporting alternative energy projects should take the place of private loans. Furthermore, when the public sector has greater experience than the private sector, public financial help may be more effective than private resources.

3. Data and methodology of the study

3.1 Variables and methodology of the study

For an aggregation of research variables, the study considered several public domes such as world development indicators (WDI) published by World Bank (2022) [79] and international financial statistics (IFS) published by IMF (2018) [30]. The study collected data for 1997-2018 based on date availability. The variables description displayed in Table I.

Table 1: Variables definition and data sources

Variables	Definition	Data sources	Units
Renewable energy	Renewable energy as a share of total energy consumption	U.S. EIA	%
ln_FDI_inflow	The logarithm of net FDI inflows in the current USD	WB	$
Debt	Public debt is measured by the ratio of total gross government debt and gross domestic product	IMF	%

Estimation strategy

Correctional dependency

The cross-section dependency test is crucial in panel data empirical research, especially when representative nations have comparable economic characteristics, such as emerging economies, rising economies, and transition economies. Due to trade internationalization, financial integration, and globalization, a comparable economy is susceptible to shocks in other nations. Therefore, cross-sectional dependency analysis is often required in panel data empirical research. According to the available literature, a variety of CSD tests have been developed and used to identify the existence of common dynamics in research units, such as the LMBP test proposed by Breusch and Pagan (1980) [13], from which the test statistics may be obtained using the following equation:

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it} \qquad i= 1\text{……}N,\ t=1\text{……}T \qquad (3)$$

Panel unit root test

The Discovery of the properties of variables in empirical estimation has been considered a critical step, especially in panel data assessment. Detecting variables stationarity properties study applied three first-generation unit toot tests such as Levin, Lin & Chu test (Levin *et al*. (2002) [35], Im, Pesaran and Shin W-stat (Im *et al*., 2003), and ADF - Fisher Chi-square (Maddala and Wu, 1999) [28]. However, Due to the issue of cross-sectional dependency (CSD), the study utilized second-generation unit root tests that cross-sectional augmented Dickey-Fuller (CADF) and cross-sectional augmented Im Pesaran and Shin (CIPS) familiarized by Pesaran (2007). The framework for unit root test with CADE following Pesaran (2007) is as follows:

$$\Delta Y_{it} = \mu_i + \theta_i y_{i,t-1} + \gamma_i \bar{y}_{t-1} + \vartheta_i \bar{y}_t + \tau_{it} \quad (7)$$

Panel Autoregressive Distributed Lagged (PARDL)

To detect the impact of EPU, FDI and government debt on REC, the study considered Panel ARDL familiarized by Pesaran *et al*. (1999), which can identify both long-run and short-run magnitudes in empirical assessment. The first fundamental assumption of PGM is that the error correction term is free from correlation dependency and is normally distributed by regressors. Additionally, the dependent and explanatory variables are related throughout time, which means there will be a long-term correlation between them; finally, the long-term parameters will stay consistent across nations. Pesaran proposed the following ARDL (p, q ….n) as an empirical structure:

$$REC_{it} = \epsilon_{it} + \sum_{j=1}^{p} \beta_{ij} REC_{i,t-j} + \sum_{j=0}^{q} \gamma_{ij} Q_{i,t-j} + \epsilon_{it} \quad (16)$$

Where,

$$\epsilon_{it} = \omega_t' G_t + \varepsilon_{it} \quad (17)$$

$$Q_{i,t-j} = \alpha_i + \beta_{ij} REC_{\,i,t-j} + \omega_t' G_t + \mu_{it} \quad (18)$$

The generalized empirical ARDL is as follows

$$\Delta REC_{it} = \alpha_i + \xi_i (EPU_{it-1} - \omega_t' Q_{it-1}) + \sum_{J=1}^{M-1} \gamma_{ij} \Delta EPU_{it-J} + \sum_{J=0}^{N-1} \beta_{ij} \Delta Q_{it-J} + \mu_{it} \quad (19)$$

4. Results and interpretation

Before proceeding to empirical assessment, preliminary evaluations are conducted, including the cross-sectional dependency test (CSD) as reported by Breusch and Pagan (1980) [13], Pesaran (2004), Pesaran (2006), and Pesaran *et al*. (2008). Pesaran and Yamagata's homogeneity slope test (2008). The results of the CSD and homogeneity tests are shown in Table II. The study results with CSD test statisticians reveal that the null hypothesis of "cross-sectional independence" has been rejected, indicating the existence of a comparable dynamic across the research units. In addition, the statistical significance of the slope of homogeneity test findings indicates that the null hypothesis of the slope of homogeneity is rejected. In contrast, the investigation revealed that the slope of coefficients differed according to the panel.

Table 2: Cross-sectional dependency and Slope homogeneity test

	(Breusch and Pagan, 1980) [13]	Pesaran (2004)	Pesaran *et al*. (2008)	Pesaran (2006)	Δ	Adj.Δ
REC	406.642***	16.684***	149.079***	8.034***	29.754***	122.14***
FDI	233***	41.713***	218.723***	36.806***	31.288***	81.599***
DEBT	376.148***	42.701***	108.602***	6.297***	53.019***	99.245***

Note: the superscript *** specifies the level of significance at 1%.

The study then analyzes the characteristics of research variables using both first-generation and second-generation unit root tests. Table III includes first-generation unit root tests, including the LLC test by Levin *et al*. (2002) [35], the IPS-W test by Im *et al*. (2003), and the ADF test results.

According to the study's findings, all variables are stable after the first difference, but neither is stable following the second difference.

Table 3: First-generation unit root test

	Levin, Lin & Chu t		Im, Pesaran and Shin W-stat		ADF - Fisher Chi-square	
	t	t&c	t	t&c	t	t&c
Panel –A: Al level						
REC	-3.011	-3.279	-2.556	-1.093	60.727	56.716
FDI	-2.943	-1.582	-2.432	-0.4	42.226	41.839
DEBT	-2.607	-1.972	-3.906	-0.102	35.214	39.226
Panel –B: After the first difference						
REC	-6.18***	-14.33***	-22.261***	-9.4***	301.707***	78.623***
FDI	-7.169***	-20.652***	-14.731***	-6.726***	136.966***	165.166***
DEBT	-6.038***	-9.216***	-12.023***	-5.261***	301.434***	114.813***

Note: the superscript of ***/**/* denotes the level of significance at a 1%, 5% and 10%, respectively

Panel unit root test with cross-sectional dependency, study implements second-generation unit root test that is CIPA and CADF following Pesaran (2007). The study documents the test statistics with constant and constant, and trends (c&t) are statistically significant at a 1% level of significance after the first difference, see Table IV. Study findings suggest that the selected cross-sectional units can initiate a further empirical assessment.

Table 4: Second generation unit root test

	CIPS		CADF	
			At level	Δ
REC	-1.42	-2.948***	-2.432	-5.536***
FDI	-2.091	-2.162***	-1.211	-4.531***
DEBT	-2.236	-2.847***	-1.917	-2.319***

Note: the superscript of ***/**/* denotes the level of significance at a 1%, 5% and 10%, respectively

The long-run link between REC, FDI and DEBT was evaluated using panel cointegration following Pedroni (2004) [52], Pedroni (1999) [51], Kao (1999) [32], and an error correction-based cointegration test following Westerlund (2007) [78]. The results of the panel cointegration test are shown in Table V. Eight out of eleven test statistics for the Pedroni cointegration test are statistically significant at the 1% significance level, suggesting that the null hypothesis "no cointegration" should be rejected. The empirical model establishes the alternative long-term connection. In addition, the ADF test results using the cointegration test of Kao (1999) [32] are statistically significant at the 1% level, supporting the long-term relationship between REC and the list of explanatory variables. In addition, the group and panel test statistics of Westerlund's (2007) [78] panel cointegration test were statistically significant at the 1% level, indicating that the null hypothesis of "no cointegration" was rejected. The results suggest the presence of a long-term connection.

Table 5: Results of Panel cointegration tests

Panel-A: Pedroni cointegration test				
Panel v-Statistic	2.059		Panel v-Statistic	-1.683
Panel rho-Statistic	-5.112		Panel rho-Statistic	-8.63
Panel PP-Statistic	-8.536		Panel PP-Statistic	-6.999
Panel ADF-Statistic	-6.823		Panel ADF-Statistic	-6.724
Group rho-Statistic	-6.267			
Group PP-Statistic	-10.335			
Group ADF-Statistic	-4.151			
Panel-B: Kao panel cointegration test				
ADF	-2.9726***			
Panel –C: Error correction based cointegration test				
Model	Gt	Ga	Pt	Pa
REC|DEBT, FDI,	-13.847***	-14.944***	-13.75***	-10.282***

Note: the superscript of ***/**/* denotes the level of significance at a 1%, 5% and 10%, respectively

The coefficients of government debt to the usage of renewable energy are statistically significant at a 1% level of significance for all four model results. Consistent with the existing literature, consider, for example, Przychodzen & Przychodzen (2020) [60], Florea *et al* (2021) [28]. (2021). Access to financial investment for renewable energy increases clean energy production and reduces the cost of environmental protection; consequently, an alternative source of capital investment and government efforts is regarded as the most significant source of renewable energy development. Brunnschweiler (2010) [14] hypothesizes in a study that external financing opportunities from financial institutions improve energy output by facilitating long-term investments in the energy business. Referring to short-term assessment, a study reveals that public debt supports incorporating renewable energy into the economy.

Table 6: Results of ARDL and CS-ARDL

Variable	**PGM (ARDL)**		**CS-ARDL**	
	[1]	**[2]**	**[3]**	**[4]**
Panel –A: Long-run coefficients				
FDI	-0.2(0.0241) [-8.268]	0.252(0.0194) [12.971]	0.324(0.0337) [9.606]	0.187(0.0182) [10.269]
DEBT	0.059(0.0132) [4.447]	0.045(0.0049) [9.079]	0.241(0.0303)[7.938]	0.693(0.0692) [10.001]
Panel-B: short-run coefficients				
COINTEQ1	-0.253(0.0003) [7.851]	-0.638(0.1198) [5.324]	-0.611(0.0547) [11.169]	-0.116(0.0163) [-7.112]
D(FDI)	0.038(0.0034) [11.109]	0.322(0.0515) [6.25]	0.569(0.0799) [7.118]	0.169(0.0137) [12.288]
D(DEBT)	-0.007(0.0006) [-10.46]	0.54(0.114)[4.733]	0.225(0.0197) [11.368]	0.476(0.0612) [7.776]
C	-0.093(0.0126) [-7.323]	0.542(0.0897)[6.038]	-0.204(0.0246) [-8.283]	-0.139(0.033) [-4.202]
H test	0.7412	0.5221		
CD test			12.8452	14.554

Note: the superscript of ***/**/* denotes the level of significance at a 1%, 5% and 10%, respectively

The asymmetric effects of economic policy uncertainty, foreign direct investment and public debt on renewable energy consumption have been investigated by implementing the nonlinear framework familiarized by Shin *et al*. (2014). The results of asymmetry assessment with and without interactive terms display in Table VIII with model [1] for without interactive terms and model [2] for with interactive terms.

The asymmetric effects of foreign direct investment on renewable energy consumption reveal positive statistical significance at a 1% level both in the long-run and short-run. Specifically, a 10% growth in FDI inflow that is a positive shock can increase the state of renewable energy consumption by 1.37% in the model [1] and by 0.601% in the model [2]. In contrast, a similar rate of adverse variations in FDI decreases the renewable energy integration process by 1.575% [1] and 1.323% in the model [2]. Refers to short-run asymmetric assessment, the statistically significant connection disclosed in the model [1] that is 10% variations in FDI can increase REC by 0.216% due to positive shocks and reduction of REC by 0.776% due to negative shocks. Findings suggest that continual inflows of FDI play a thriving role in augmenting the clean energy integration process by creating an ambiance with technological advancement (QAMRUZZAMAN and JIANGUO, 2020b; Qamruzzaman and Jianguo, 2019; Qamruzzaman and Jianguo, 2018).

The asymmetric shocks of government debt on renewable energy consumption exposed positive statistical significance at a 1% level in both empirical assessments. According to the positive and negative shocks coefficients, a 10% innovation in government debt can increase the REC by 1.362% [1] and 1.115% in the model [2]. On the other hand, a similar rate of government debt reduction can adversely influence green energy integration in REC by 0.799% in the model [1] and by 1.446% in the model [2]. Furthermore, in the short run, the asymmetric shocks of government debt revealed a positive, statistically significant linkage with renewable energy consumption in both model estimations. In particular, 105 variations in government debt can result in intensifying the process of renewable energy integration by 0.620% in the model [1] and by 0.289% in the model [2], whereas with negative shocks, the process of clean energy transformation can dwindle the process by 0.101% in the model [1], and by 0.9835 in the model [2]. Study findings suggest that government debt is positively connected with renewable energy integration in the aggregate economy,

Table 7: Results of no asymmetric effects of EPU, FDI and DEBT

	Without interactive term			With interactive term		
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Coefficient**	**Std. Error**	**t-Statistic**
Panel –A: Long Run confidence and symmetry test						
FDI^+	0.07556	0.0257	2.94001	0.17893	0.0436	4.1038
FDI^-	0.0967	0.0357	2.7086	0.1052	0.0281	3.7437
$DEBT^+$	0.10315	0.0313	3.2955	0.12721	0.0394	3.2286
$DEBT^-$	0.15036	0.0171	8.7929	0.08259	0.035	2.3597
W_{EPU}	12.8451***			15.2841***		
W_{FDI}	8.7754***			10.8542***		
W_{DEBT}	12.4512***			21.8451***		
Panel –B: Short Run Equation and symmetry test						
ζ	-0.4147***	0.2361	-1.7564	-0.1015***	0.0136	-7.4625
ΔFDI^+	0.16856	0.0247	6.824	0.10723	0.016	6.7018
ΔFDI^-	0.13337	0.0163	8.1822	0.1201	0.0196	6.1275
$\Delta DEBT^+$	0.07737	0.0225	3.4386	0.08273	0.0468	1.7677
$\Delta DEBT^-$	0.09909	0.024	4.12875	0.13103	0.0346	3.7869
W_{EPU}		8.754***			12.485***	
W_{FDI}		0.845			7.845***	
W_{DEBT}		5.945**			9.884**	

Note: the superscript of ***/**/* denotes the level of significance at a 1%, 5% and 10%, respectively

5. Conclusion

The motivation of the study is to gauge the impact of economic policy uncertainty, foreign direct investment and public debt on clean energy transition, that is, the integration of renewable energy instead of fossil fuel in the top 13 oil-importing nations for the period 1997-2018. Several econometric tools were employed to detect the observed association and the key findings from the study are as follows:

Panel unit root tests of the first and second generations were used to examine the stationary properties of research variables. After a single update, it was shown that all variables were static. Slope homogeneity tests demonstrated that research units were not homogenous but had a dynamic structure. Pedroni (2004) [52], Kao (1999) [32], and Westerlund (1999) [78] claim that a panel cointegration test and an error correction-based panel cointegration test were used to examine the long-term association between REC, FDI, and DEBT (2007). The long-term connection of an empirical equation may be derived from cointegration test results that exhibit statistical significance at the 1% level of significance. Economic policy uncertainty was shown to negatively influence renewable energy consumption in ARDL's panel estimate. There was a statistically significant correlation between foreign direct investment (FDI) and government debt. This research used asymmetrical ARDL to examine the nonlinear impacts of EPU, FDI, and DEBT on renewable energy use. The research found a negative correlation between positive and negative shocks to the EPU and renewable energy consumption when looking at the asymmetrical impacts of EPU on REC. According to this research, FDI and DEBT imbalance and renewable energy use are statistically significant.

For the panel casualty test by Dumitrescu and Hurlin (2012) [22], FDI and DEBT were examined in connection to REC. Bidirectional causality is found in the feedback hypothesis between foreign direct investment and renewable energy usage [FDI←→REC)]. The assumption that public debt and renewable energy consumption [DEBT→RCG)] are linked is supported by Florea *et al*. (2021) [28] and Zhang *et al*. (2021) [77]. (Andriamahery, Qamruzzaman, Xia, *et al*., 2022; Zhuo, Qamruzzaman, 2022) [6, 82] Macroeconomic instability, which indicates the presence of fundamental macro volatility, has been shown to have a deterring impact on the transition to clean energy consumption, based on research findings According to the results, a supportive economic climate is necessary for a smooth transition from conventional energy to clean energy for the green eco-system. A positive association was found between foreign direct investment (FDI) and government debt, demonstrating that advancements in technology and the availability of capital increase energy efficiency. Efficiently integrating renewable energy into the economy requires the government to support stable economic conditions and a favorable investment climate for international investors (Li and Qamruzzaman, 2022; Muneeb *et al*., 2021a; Muneeb *et al*., 2021b; Meng *et al*., 2021; Jia *et al*., 2021) [6, 45, 46, 43, 31].

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