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How Financial Development and Energy Dependency Affect Renewable Energy Production in EU Countries

Alessia Spignese*, Francesco Campanella*, Luana Serino*

Abstract

This study aims to examine the drivers of investment in renewable energy production. These include the development of the financial system, the price of Brent crude oil and the energy dependency of EU economies. Following the outbreak of the Russia-Ukraine war and the resulting increase in the price of traditional energy sources, it is necessary to understand how to promote the development of alternative energy sources to ensure greater EU energy independence from Russia and meet green energy targets. The PMG-ARDL panel model is conducted to analyse the short-run and long-run relationships between variables. This model can solve the problems of endogeneity, heteroscedasticity, autocorrelation and multi-collinearity. The results obtained are consistent with the literature. However, they add several contributions. First, the study shows how the development of the financial system has an impact on the production of renewable energy sources (RES). Second, the study analyses how the degree of energy dependence of EU countries on export countries influences the production of RES. Finally, the study confirms that geopolitical risk is also a criterion in the assessment of investments in renewable energy. Therefore, this study contributes to the existing literature. Specifically, the study shows that EU countries with more developed financial systems produce more renewable energy. In addition, the study also has practical implications for policymakers and financial authorities.

Keywords: Renewables, Financial Development, Russia-Ukraine War, Energy Dependency, Brent Oil

Introduction

Energy is a vital element for the development and growth of economies, especially in the modern era, characterised by interconnectedness, high technological progress and globalisation. The debate on implementing renewable energy production, and the identification of the determinants of renewable energy production continue to be evolving topics of significant interest for different reasons. First, the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007) stated that 75% of CO_2 emissions derive from the use of fossil fuels in the production and industrial processes. Second, geopolitical turbulences, such as the Russia-Ukraine war, have also brought the need for states, such as European ones, to gain a greater degree of energy independence, including through the use of Renewable Energy Sources (RES). Internationally, there have been multiple efforts to increase the production and use of renewable energies. The first stimulus dates back to the 1970s, following the negative consequences caused by the Yom Kippur War. Finally, RES are the fastest-growing sources of electricity over the 2015–2040 period, with an average increase of 2.8% per year due to technological improvements and government incentives in many countries that support their use (International Energy Outlook, 2017).

The International Renewable Energy Agency (IRENA) also assumes that a growing number of countries are committed to the goal of a carbon-neutral economy through the use of RES, such as wind and solar power, which are becoming more cost-competitive and now dominate the global market for new electricity generation capacity (IRENA, 2021). This cost reduction offers a huge

* Department of Economics, University of Campania “L. Vanvitelli”, Capua, Italy. Email: alessia.spignese@unicampania.it; francesco.campanella@unicampania.it; luana.serino@unicampania.it

opportunity for all countries to achieve the zero-emission goal. However, investment in clean energy is still a long way from what is needed to make the energy system sustainable. Therefore, it is necessary to identify the main drivers of investment in RES to strengthen measures to mitigate global warming and improve energy security by increasing global energy demand and moving away from the fossil fuels that dominate global energy systems.

This study aims to investigate the drivers of investment in RES, such as the development of the financial system, the Brent Crude Oil Price and the degree of energy dependence of economies belonging to the European Union. The focus on EU major economies appears necessary because the crisis resulting from the outbreak of the Russia-Ukraine War (24th February 2022) turns out to be a crisis with a European dimension. The Council of the European Union states that the rapid increase in energy prices since the second half of 2021 has affected EU states more than other economies, aggravated by the outbreak of the conflict. Moreover, it should be kept in mind that in 2020 most of the energy available in EU member states was derived from imports and only 40% was produced from RES (Council of the European Union, 2020). Therefore, it seems clear that there is a need to push the accelerator towards more renewable energy production and thus ensure a greater degree of energy autonomy of EU states. To achieve this goal, it is necessary to deeply understand what are the determinants of investment in RES in EU countries. To this purpose, the PMG—ARDL (autoregressive-distributed lag) approach was conducted on panel data from 1980 to 2020 for 10 EU countries.

Literature Review and Hypothesis Development

In recent years, the focus on the determinants of renewable energy generation has become increasingly popular in academic research and government policies around the world. Indeed, while studies that have analysed historical energy transitions are numerous (Kunnas & Myllyntaus, 2009; Bartoletto & Rubio, 2008; Fouquet, 2008; Gales et al., 2007; Grübler, 2004), few have empirically explored the factors that influence the generation of RES (Marques et al., 2019; Liu et al., 2019; Lin & Omoju, 2017; Marques & Fuinhas, 2010). The empirical analysis by Bamati and Raoofi (2020), through the use of the GLS model, shows that the determinants of renewable energy generation vary by country income level. In developing countries GDP and CO_2 emissions appear to be the main drivers of renewable energy production. While in developed countries renewable energy production is significantly determined by high-tech exports.

The existing literature shows several drivers of renewable energy generation. These are political, economic, financial and environmental.

Political Factors: Geopolitical Risk and Energy Dependence Rate

The interaction between geopolitics and energy production has attracted strong research interest among scholars in recent years (Blondeel et al., 2021; Vakulchuk et al., 2020; Nilsson et al., 2011). In particular, most empirical studies examining the impact of geopolitical instability, as measured by geopolitical risk (GPR), on energy come to conflicting results. For example, Rasoulinezhad et al. (2020), implementing the ARDL model, focuses on how geopolitical risk can influence the behavior of energy transition and comes to state that there is a positive correlation between these two phenomena. In this regard, Sweidan (2021a; 2021b) also shows that geopolitical risk positively influences the diffusion of RES because renewable energy decreases the degree of energy dependence, thus providing energy security. Furthermore, it appears from the study of Alsagr and Hemmen (2021) that geopolitical risk is one of the factors that positively influence renewable energy consumption. However, some empirical studies, such as the one conducted by Flouros et al. (2022) found quite different results. They observe a significant negative relationship between GPR and investment in RES. Thus, they argue that despite the importance of an energy transition to "green" energy, the nature of investment in the sector does not exhibit characteristics different from those of other types of investment relying largely on traditional investment criteria such as GPR.

Consequently, taking into account the evidence in the literature, we want to test the following hypothesis:

H1. Geopolitical risk (GPR) affects the production of renewable energy sources (RES).

The correlation highlighted in previous studies between geopolitics and energy sources is perceived also in the form of energy security as a determinant of economic growth (Balitskiy et al., 2014; Yao & Chang, 2014). In a global context, the issues of energy security and energy autonomy through investment in renewable energy are quite urgent to ensure the development and economic growth of states. States that want to achieve adequate levels of energy security must address, in the short run, issues related to dependency rates, energy prices, scarcity of energy sources and environmental protection. In the long run, on the other hand, the issues are related to the political stability of supplier countries, investment and policies to support domestic RES.

The topic of energy security is widely debated in the literature. Some academics believe that energy security is the main driver for the diffusion of RES (Valentine, 2011; Narbel, 2013; Vald'e s Lucas et al., 2016), while others argue that energy security issues may hinder their diffusion (Marques & Fuinhas, 2011a; Marques & Fuinhas, 2011b; Marques & Fuinhas, 2012; Aguirre & Ibikunle, 2014). Fischhendler et al. (2021) note that energy security is an expression of countries' desire to be free from dependency on fossil fuel imports, thus believing that it is one of the important factors in incentivising the collective adoption of renewable energy. Hence, it can be assumed that governments pursue the goal of a higher level of energy independence by promoting the spread of RES.

However, it seems from the relevant literature that the empirical analyses conducted focus mainly on analysing how the deployment of renewable energy can reduce the degree of energy dependence of states. This study aims to contribute to the literature by testing whether, in light of the recent tensions between Russia and the European Union, the rate of energy dependence can influence the production of RES. In fact, the closure of the Maghreb-European gas pipeline between Algeria and Spain and tensions in the Middle East, leading to a sharp increase in fossil fuel prices, have made energy sourcing more complex. This has raised the need for EU member states to be more energy self-sufficient. In response to this price increase, the European Union replied with the ambitious "Green Deal" policy initiative, aiming to mitigate its dependence on other oil and natural gas-producing countries (Carfora et al., 2022).

Based on the above considerations, the study aims to test the following hypothesis:

H2. The level of energy dependence affects renewable energy sources (RES).

GDP as an Economic Factor

The ability to produce RES is inseparable from economic development. Therefore, the relationship between the generation of RES and the Gross Domestic Product (GDP) has been widely discussed in the literature. Most previous studies reveal that in the long run, increasing GDP per capita and CO_2 emissions per capita positively influence pro-capita renewable energy production (Le & Nguyen, 2019; Aguirre & Ibikunle, 2014; Balitskiy et al., 2014; Salim & Rafiq, 2012; Gasparatos & Gadda, 2009) In the Organization for Economic Cooperation and Development (OECD) countries, Gan and Smith (2011) showed that countries with higher GDPs are more interested in alternative energy supply. As a result, their policies appear to be more oriented toward the production capacity of RES.

Therefore, based on the empirical evidence reported in the literature, the following hypothesis is formulated to be tested:

H3. GDP positively influences the production of renewable energy sources (RES).

Environmental Factor: CO_2 Emission

The increase in energy use leads to increased CO_2 emissions. Carbon dioxide, along with methane, ozone, nitric acid and chlorofluorocarbons, represents a greenhouse gas associated with the phenomenon of climate change. Therefore, identifying the relationship between RES and CO_2 emissions appears to be a widely debated issue in the literature. On the one hand, empirical studies show that the presence of renewable energy mitigates the environmental problems of carbon emissions, implying a negative association between the production of RES and CO_2 emissions (Sadorsky, 2009; Marques & Fuinhas, 2011b). On the other hand, Omri and Nguyen (2014) and Nguyen and Kakinaki (2019) argue that rising CO_2 emissions exert political pressure for the development of cleaner energy by encouraging the use of renewable energy so a positive relationship between renewable energy production and CO_2 emissions is expected.

Therefore, based on these considerations, the following hypothesis is proposed to be tested:

H4. CO_2 emissions influence the production of renewable energy sources (RES).

Financial Factors: Financial System Development

Studies in the literature show that the financial sector plays an important role in monitoring energy emissions. Financial system development promotes investment in research and development (R&D) to support “Green” projects leading to a positive impact on environmental quality (Zhang et al., 2021). Indeed, according to Kirikkaleli and Adebayo (2021), a well-developed financial sector, by increasing the efficiency of the energy sector, promotes investment activities and controls the spread of energy emissions. Khan and Ozturk (2021) reveal how the development of the financial system can lead to a reduction in CO_2 emissions. Other studies (Zhang et al., 2021) predict a positive relationship between CO_2 emissions and financial system development. In other words, increased consumer lending and new purchases of energy-intensive durable goods lead to increased CO_2 emissions and energy consumption.

In addition, financial development also impacts the consumption of renewable energy because, as the studies by Haseeb et al. (2018) and Anwar et al. (2022) highlight, renewable energy consumption in emerging economies is supported by financial system development. Nevertheless, there seem to be no empirical studies in the literature to test whether financial development could influence renewable production. Therefore, this study aims to fill this gap in the literature. In this regard, we use the Financial Development Index by IMF which summarises how much developed financial institutions and financial markets are in terms of their efficiency (Institutions’ ability to provide financial services at low cost, with sustainable revenues and capital market activity), depth (size and liquidity) and access (to finance for individuals and businesses).

Taking everything into consideration, the following hypothesis is formulated to be tested:

H5. The development of the financial system positively influences the production of renewable energy sources (RES).

Market Factor: Brent Crude Oil Price

Analysing the factors that stimulate the generation of RES, the possible impact of the prices of traditional energy sources cannot be ignored. The prices of traditional energy sources are usually mentioned as determinants of the diffusion of renewable energy. Most studies in the literature (Apergis & Payne, 2015; Lean & Smyth, 2013; Payne, 2012; Sadorsky, 2009) analyse the relationship between oil prices, as the main traditional energy source and demand for renewable energy. Omri et al. (2015) demonstrate the existence of a positive link between oil prices and renewable energy demand because higher oil prices would encourage businesses and households to reduce consumption of traditional energy sources and switch to RES. A smaller number of studies in the literature, however, focus on the impact of fossil fuel prices on the production of RES. These studies show that the role of fossil fuel prices can be interpreted both negatively and positively on the production of RES. Yurong et al. (2021) show a positive relationship between oil prices and renewable energy production. Increasing international oil prices would increase the production of renewable energy. Brini et al. (2017) also state that the rise and fall of renewable energy production is consistent with the direction of changes in international oil prices. However, Shah et al. (2018) point out that the relationship between oil prices and renewable energy production is heterogeneous across countries. The study finds that the U.S. and Norway have a positive relationship, as predominantly oil-importing countries that support renewable energy relatively less than other countries, so changes in renewable energy investment reflect other market factors, like the price of substitutes, to a greater extent than countries where renewable energy receives more public support, as the UK.

Therefore, the present study contributes to the latter strand of the literature by wanting to analyse the relationship between Brent Crude Oil Price, as the main traditional energy source used by the EU, and the RES generation. In this regard, the following hypothesis is formulated to be tested:

H6. The price of Brent Crude Oil influences the production of renewable energy sources (RES).

Methods and Materials

The analysis of the determinants influencing the production of RES in EU countries cannot be examined using a typical regression model because investments in RES need a significant time horizon to be completed. To account for long-term relationships and the possible stationary evolution of variables in the short run, the PMG-ARDL model is used.

The PMG-ARDL model represents a variation of the ARDL model, proposed by Peseran et al. (1999). It has several econometric advantages over other traditional panel models. First, this model applies only to stationary variables at the I(0) level, the first difference I(1) or the mix of I(0) and I(1), but not to I(2). In addition, this model can solve the problems of endogeneity, heteroscedasticity, autocorrelation and multi-collinearity. In this study, the use of the ARDL model is accompanied by the choice of the PMG estimator, as it is more reliable than other estimators. The PMG estimator assumes the same long-run coefficients and different coefficients, intercepts and short-run error terms between groups. In addition, the PMG estimator is instead robust to lag order selection (Pesaran et al., 1999).

Model and Data

The econometric mode used is:

$$\Delta y_{i,t} = \beta_{0,i} + \sum_{l=1}^{p_y} \beta_{i,l} \Delta y_{i,t-l} + \sum_{j=0}^{p_x} \beta'_{i,l} \Delta x_{i,t-j} + \sum_{l=0}^{p_z} \psi'_{i,l} \underline{z}_{t-l} + \left(\theta_{o,i} y_{i,t-1} + \sum_{j=0}^{k} \theta_{i,k} x_{i,t-k} \right) + \varepsilon_{i,t}$$

Where:

- $(\theta_{o,i} y_{i,t-1} + \sum_{j=0}^{k} \theta_{i,k} x_{i,t-k})$ is the Error Correction Term (ECT) of the model. It captures long-term relationships between the dependent and the independent variabiles;
- p_y is the lag order of the dependent variable;
- p_x is the lag order of the control variables;
- $p_{\underline{z}}$ is the lag order of the added cross-sectional averages to account for endogeneity issye.

p_y, p_x e $p_{\underline{z}}$ are determined according to the Bayesian Information Criterio (BIC). The optimal lag is (1,0,0,0,0,0,0,0).

The econometric model proposed in the study, built on 400 country-year observations, is:

$$RESP_{i,t} = \alpha_{i,t} + \beta_1 (RESP_{i,t-1}) + \beta_2 (GPRH)_{i,t} + \beta_3 (DEPENR)_{i,t} + \beta_4 (CO2)_{i,t} + \beta_5 (FI)_{i,t} + \beta_6 (FM)_{i,t} + \beta_7 (Brent)_t + \beta_8 (GDP)_{i,t}$$

Where:

- $RESP_{i,t}$ is the dependent variable related to the production of RES at time t by the i-th country. It is a composite variable, measured in Twh, reflecting renewable energy from different sources (including hydropower, solar energy, gas from biomass and wind energy). Data collected from 1980 to 2020 were downloaded from the International Energy Agency (IEA) and BP Statistical Review of World Energy.
- $RESP_{i,t-1}$ indicates the lag at time t-1 of the dependent variable related to the production of RES.
- $(GPRH)_{i,t}$ is the historical geopolitical risk at time t for the i-th country. This study uses the Caldara and Iacovello GPR index. Data from 1980 to 2020 are collected.
- $(DEPENR)_{i,t}$ represents net energy imports as a percentage of energy used. It is a proxy variable that measures the level of energy dependence at time t of the i-th country. Data from 1980 to 2006 were downloaded from WorldBank Database, while data from 2007 to 2020 were downloaded from Eurostat Database.
- $(CO2)_{i,t}$ indicates the average value of global CO_2 emissions to air measured in ppm at time t by the i-th country. Data from 1980 to 2020 were downloaded from the Scripps CO_2 Program database at the University of California San Diego.
- $(FI)_{i,t}$ measures the development of financial institutions at time t for the i-th country. This is a variable used as a proxy to measure the development of the financial system. It is an aggregate of:

- *Financial Institutions Depth Index (FID)*, which compiles data on bank credit to the private sector in percent of GDP, pension fund assets to GDP, mutual fund assets to GDP, and insurance premiums, life and non-life to GDP;
- *Financial Institutions Access Index (FIA)*, which compiles data on bank branches per 100,000 adults and ATMs per 100,000 adults;
- *Financial Institutions Efficiency Index (FIE)*, which compiles data on banking sector net interest margin, lending-deposits spread, non-interest income to total income, overhead costs to total assets, return on assets and return on equity.

Data from 1980 to 2020 were collected from the IMF Financial data database.

- $(FM)_{i,t}$ measures financial market development at time t for the i-th country. This is a variable used as a proxy to measure the development of the financial system. It is an aggregate of:
  - *Financial Markets Depth Index (FMD)*, which compiles data on stock market capitalisation to GDP, stocks traded to GDP, international debt securities of government to GDP and total debt securities of financial and non-financial corporations to GDP;
  - *Financial Markets Access Index (FMA)*, which compiles data on the percent of market capitalisation outside of the top 10 largest companies and the total number of issuers of debt per 100,000 adults;
  - *Financial Markets Efficiency (FME)*, which compiles data on stock market turnover ratio (stocks traded to capitalisation).

Data from 1980 to 2020 were collected from the IMF Financial data database.

- $(Brent)_{i,t}$ indicates Brent Crude Oil Price at time t. It is a proxy variable for fossil fuel prices. Brent is the world's leading price benchmark for Atlantic Basin crude oils. Crude oil is one of the most closely observed commodity prices as it influences costs across all stages of the production process and consequently alters the price of consumer goods as well. Data are expressed in U.S. dollars. Data from 1980 to 2020 were downloaded from Investing.com.
- $(GDP)_{i,t}$ is the Gross Domestic Product at time t for the i-th country. Data are expressed in U.S. dollars. Data from 1980 to 2020 were downloaded from the World Bank Database.

Results and Discussion

Before estimating the model coefficients, the stationarity of the variables should be tested, since in a PMG - ARDL model we should have variables I(0) or I(1), but not I(2). In the case of a second-order ARDL integrated variable, the estimates may be explosive and irrelevant. Therefore, the IPS unit root test is performed by including cross-sectional averages to account for endogeneity issues in the regression (Hadri, 2000; Maddala & Wu, 1999; Im et al., 1997). The results of the panel unit root tests are shown in Table 1. It can be observed that most of the variables are not stationary at level I(0), but most of the variables are stationary at the first difference I(1). Therefore, the variables adopted in this study are all stationary at the level or first difference.

Table 1: Results of Panel Unit Root Test

Variables	IPS
Ln (RES)	(-7.2913) ***
Ln (CO_2)	(3.5191)
Dipendence	(1.1531)
Ln (GDP)	(-0.0654)
FI	(-1.3574)
FM	(-3.3718) ***
GPRH	(-5.8279) ***
Ln (Brent)	(0.7185)
ΔLn (CO_2)	(-7.0174) ***
Δ Dipendence	(-8.7142) ***
Δ Ln (GDP)	(-9.1739) ***
ΔFI	(-12.9753) ***
Δ Ln (Brent)	(-11.4769) ***

Note: ***, **, * denote significance level of 1%, 5% and 10%, respectively.

Since the variables adopted in this study are all stationary at the level or first difference, there could be a cointegration relationship, but this cannot be detected with a typical Pedroni Cointegration Test (Pedroni, 1999) because we have a mixture of I(0) and I(1) variables. The ARDL model approach is the only way to find the cointegration among the variables having different orders I(0) and I(1).

After the stationary test, we perform the Hausman Test to choose the most efficient estimators between the PMG estimators and the Fixed Effect (FE) estimators. The null hypothesis of Hausman's Test states that both of these estimators are consistent, but that the PMG estimator is more efficient because it has the smallest asymptotic variance. In the alternative hypothesis, the FE estimator is consistent, while the PMG estimator is not (Hausman, 1978). Table 2 shows the results of Hausman's Test.

Table 2: Results Hausman Test

Chi2	2.89
Prob > chi2	0.8948

Source: Stata.

Table 3 shows the results of the panel regression for 10 EU member countries (Belgium, France, Germany, Hungary, Italy, the Netherlands, Poland, Portugal, Spain and Sweden). The first part of Table 3 shows the long-run relationships between the "y" variable RES and the regressors. In contrast, the second part of Table 3 shows the short-run relationships. The estimated coefficients are valid for all countries included in the analysis.

Table 3: Results PMG - ARDL

Long-Run Relationship		
Variables	*Coefficient*	*Std. Error*
Tasso di dipendenza energetica	(-0.0156) *	(0.0090)
Ln_CO_2	(-0.6983) **	(0.2721)
GPRH	(-1.5001) **	(0.6228)
Ln_GDP	(0.0945)	(0.1498)
Ln_BrentCrudeOilPrice	(0.0002)	(0.0830)
FI	(0.5447) ***	(0.0770)
FM	(0.4272) ***	(0.0468)
Short – run Relationship		
ECT	(-0.2105) ***	(0.0710)
Tasso di dipendenza energetica D1.	(-0.0118)	(0.0089)
Ln_CO_2 D1.	(0.7102) ***	(0.2125)
GPRH D1.	(-0.4121)	(0.3599)
Ln_GDP D1.	(-0.2473)	(0.1659)
Ln_BrentCrudeOilPrice D1.	(-0.0158)	(0.0383)
FI D1.	(-0.0936) **	(0.0493)
FM D1.	(-0.0089)	(0.0366)
Cons	(1.3041) ***	(0.4713)

Note: ***, **, * denote significance level of 1%, 5% and 10%, respectively.

Source: Stata.

The results show that the ECT has a negative sign (-0.2105) and is statistically significant (1%). It signals the presence of cointegration and, in absolute value, is less than unity. Moreover, the results show a negative (-1.5001) and statistically significant (5%) relationship between GPRH and renewable energy production in the long run. This implies that the growth of geopolitical risk brings a reduction in the production of RES. However, in the short run, the analysis does not reveal a statistically significant relationship between the dependent variable RES and GPRH. Therefore, it can be said that Hypothesis No. 1 is proposed in Section 2.1. can be verified in the long run. These results are consistent with the study by Flouros et al. (2022) and reinforce the thesis that investments aimed at fostering an energy transition, through increased production of RES, have to be evaluated in the same way as other types of investments, the evaluation of which is based on traditional criteria such as geopolitical risk. This implies that, even in the green energy sector, the geo-political risk of the country appears as a deterrent to investment.

Moreover, the analysis shows the presence of a negative (-0.0156) and statistically significant (10%) relationship between the degree of energy dependence and the production of RES in the long run. However, in the short run, this relationship does not appear to be statistically significant. Therefore, Hypothesis No. 2 in section 2.1. is supported only in the long run. This implies that for EU countries there is a negative influence of the degree of energy dependence on the diffusion of renewable energy. In this way, the present study contributes to expanding the existing literature about the factors influencing the production of RES. Although several studies (Vaona, 2016; Chien & Hu, 2008; Domac et al., 2005) have focused on analysing how the generation of RES can significantly reduce foreign energy dependence, none on analysing how countries' desire for greater dependence can influence the generation of RES. However, analysing this relationship is by no means straightforward as additional variables such as policy and the complicated design process would need to be considered (Fischhendler et al., 2021; Bourcet, 2020; Vald'es Lucas et al., 2016). Considering the relationship between GDP and RES, in the long run, it turns out to be positive (0.0945), but not statistically significant. Even in the short run, the relationship between GDP and RES, which appears to be negative (-0.2473), is not statistically significant. The negative short-run relationship between economic growth and RES is similar to the empirical results of Dogan (2015) and Alam and Murad (2020) who conducted studies in Turkey and OECD countries, respectively. Therefore, Hypothesis No. 3 proposed in Section 2.2. is not supported.

Considering the relationship between CO_2 emissions and renewable energy production, the analysis shows mixed results between the long run and the short run. In the long run, there is a negative (-0.6983) and statistically significant (5%) relationship between CO_2 emissions and renewable energy production, while in the short run, there is a positive (0.7102) and statistically significant (1%) relationship. Clarifying the association between electricity production and CO_2 emissions appears complex. The relentless increase in CO_2 emissions, increasing the desire for a cleaner environment, drives greater production of RES (Omri et al., 2015) However, in the long run, contrary to the literature, the prevalence of green energy sources mitigates environmental problems arising from CO_2 emissions, and a negative association between renewable energy production and CO_2 emissions can be observed. This implies that high CO_2 emissions strongly deter the implementation of RES. Therefore, Hypothesis No. 4 proposed in Section 2.3. is supported both in the long and short run.

A relevant contribution made by this study is to analyse the relationship between financial development (Financial Markets and Financial Institutions) and the production of RES. The results show in the long run the existence of a positive and statistically significant relationship (1%) between the development of the financial system, in terms of the development of financial institutions (0.5447) and the development of financial markets (0.4272), and the production of RES. This implies that a more developed financial system results in increased production of RES. In the short run, however, this relationship turns out to be negative (-0.0936) and statistically significant (5%) only for the development of financial institutions. This can be explained by the fact that investment in renewable energy production often has a certain level of risk because of the know-how required to design and implement the technologies and the high volume of financial resources required. Therefore, highly developed financial institutions may, in the short term, reject companies' requests for funds to finance this type of investment. Therefore, Hypothesis No. 5 proposed in Section 2.4. is supported only in the long run.

Furthermore, the analysis shows that the relationship between the Brent Crude Oil Price and RES generation, is negative in the short run (-0.0158), while in the long run, this relationship is positive (0.0002). However, this relationship is not statistically significant. Therefore, Hypothesis No. 6 proposed in Section 2.5. is not supported. Therefore, the nature of this relationship cannot be clearly stated, as the existence of policies to encourage greater use of renewable energy markets would also need to be considered, as well as the recent volatility of oil markets.

Conclusion

The study aims to identify the factors influencing RES generation in the EU Countries. In this regard, the PMG-ARDL model, a variant of the ARDL model proposed by Peseran et al. (1999), is used to conduct the analysis, which is capable of analysing short- and long-term relationships between variables. The variables used are all integrated at the levels I(0) and first difference I(1). In addition, they are cointegrated since ECT is statistically significant. The results obtained from the analysis, appearing in line with those reported in the literature, make several contributions to the relevant literature. In detail, an immediate contribution of the study is to analyse how the development of the financial system, both in terms of financial institutions and financial markets, can influence the production of RES. The existing literature (Haseeb et al., 2018; Anwar et al., 2022) mentions financial development as a driver of renewable energy consumption, but not as a potential driver of renewable energy production. Therefore, this paper aims to fill this gap in the literature by revealing that a more developed financial system encourages the production of RES. An additional contribution of the study is that it analyses how the degree of energy dependence of EU countries may influence the production of RES. The existing literature mainly analyses how the production of RES reduces the degree of the energy dependence of oil-importing countries compared to exporting ones. The analysis shows that for EU countries, energy dependence negatively affects the diffusion of RES. Finally, the study confirms the conclusions reached by Flouros et al. (2022), pointing out that the geo-political risk (GPRH) criterion is also used when evaluating investments in the renewable energy sector. Thus, high geo-political risk inhibits the Green Transition of EU countries.

Pratical Implications

This study has practical implications for policymakers and financial authorities. First of all, policymakers must implement measures to encourage the production of RES, which are the main tool for achieving the ecological transition goal of EU countries, beyond being an important driver in energy diversification that can ease geopolitical tensions. In addition, EU policymakers must necessarily achieve initiatives to remove barriers related to institutional constraints in energy markets and encourage the use of renewable energy. It is beyond necessary for regulators to introduce incentives (e.g., tax breaks, subsidies, financial facilities, state guarantees) to encourage businesses to invest in renewable energy. At the same time, the role played by financial authorities is also important. They must ensure that the capital allocation process, the monitoring of financed productive investments and the risk diversification process are improved. In this way, a developed financial system can support the growth of RES. In addition, financial authorities, to ensure the development of the financial system, must implement measures aimed at minimising information asymmetries and risk sharing (Bernanke et al., 1999) to reduce volatility and ensure better capital allocation.

Limits and Future Research

Although the study offers interesting contributions to the existing literature and insights into policymakers' activities, it does not appear to be without limitations. First of all, the analysis highlights the difficulty of understanding the nature of the link between the degree of energy dependence of EU countries and the production of RES, as additional variables need to be taken into account (i.e., the implemented energy policies and their complicated design process) (Fischhendler et al., 2021; Bourcet, 2020; Vald'es Lucas et al., 2016). Therefore, future studies could analyse the relationship between the degree of energy dependence and the production of renewable sources in light of these variables. In addition, we emphasise the need to consider these policies on a country-by-country basis, taking into account whether the country is an importer or exporter of crude oil and thus consider non-EU countries jointly with EU countries. Finally, due to the limited data available, the analysis focuses on only 10 EU countries. Therefore, future studies could expand the sample under analysis.

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