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Impact of Foreign Direct Investment on Renewable Energy Generation: Evidence from Europe

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ABSTRACT

Currently, energy production is mainly dependent on fossil fuels and nonrenewable energy. However, reducing the reliance on fossil fuels and employing renewable energy technology is essential for maintaining environmental sustainability and energy security. Despite noteworthy research on foreign financing and renewable energy consumption, few studies have discussed the relationship between foreign direct investment (FDI) and renewable energy generation (REG) that enables such consumption. Thus, this study fills this gap in the literature by applying the generalized method of moments/dynamic panel data (GMM/DPD) estimation technique to determine the impact of FDI on REG in European economies from 2010 to 2022. Based on the results, FDI has a significant and negative impact on REG. The implication of the findings is that policymakers should decide on suitable incentive programs, such as feed-in tariffs, electricity purchase agreements, and renewable project tax credits, in order to redirect FDI from nonrenewable energy sources to the renewable energy sector.

Keywords: Renewable Energy Generation, Foreign Direct Investment, Generalized Method of Moments
JEL Classifications: C26, F21, Q42

1. INTRODUCTION

In today's society, energy production is mainly dependent on fossil fuels and nonrenewable energy. However, instability of the energy market and price changes (due to limited resources), damage and destruction of the environment, and climate change are just some of the problems related to nonrenewable energy (Becker and Fischer, 2013). In recent years, renewable energy consumption has become increasingly recognized as the best alternative. Although renewable energy generation (REG) is more expensive than nonrenewable energy over the short-term, it is more efficient over the long-term, considering the environmental and social effects of nonrenewable energy production and consumption (Akpanke et al., 2023; Becker and Fischer, 2013).

To date, various studies have examined the determinants of renewable energy consumption and generation. In this regard, macroeconomic and environmental variables, such as urbanization, economic growth, CO_2 emissions, trade openness, and energy prices, have been considered as the factors that affect REG (e.g., Lin and Okoye, 2023; Cui et al., 2022; Acheampong et al., 2021; Rintamaki et al., 2017; Al-Mulali et al., 2015; Ohler and Fetters, 2014). Nevertheless, limited research has focused on the relationship between foreign direct investment (FDI) and REG, while the former (as a major source of capital) facilitates the transfer of technology and expertise to host countries (Kilicarslan, 2019; Doytch and Narayan, 2016). According to previous research, encouraging FDI in renewable energy can help promote the expansion of knowledge in green technologies (Dossou et al., 2023). FDI can also help boost the host country's economy by generating direct, indirect, and inclusive employment opportunities in low-carbon and resource-efficient fields, commonly referred to as "green jobs" (Abe et al., 2017). On the other hand, the role of governments in attracting and directing FDI is extremely important. In this case, the higher the institutional quality of countries, the greater the FDI inflows (Reza et al., 2021). Thus, recognizing the importance of governance quality is vital for attracting FDI, which, in turn, can promote renewable energy development (Belaïd et al., 2021).

Based on this foundation, it is important to understand the impact of FDI in advancing REG. Thus, this study fills this gap in the literature by determining the impact of FDI on REG in European economies from 2010 to 2022. The reasons for selecting Europe are as follows. First, there is a lack of conventional energy resources in this region. Thus, it tends to be more affected by global energy crises. Second, most European countries are democratic, stable, and wealthy, with a high level of good governance. They are also known to prioritize and pursue environmental goals. Finally, to the best of our knowledge, such investigations are rare in Europe.

The remainder of this study is organized as follows. Section 2 includes a literature review on this topic, while Section 3 discusses the data and methodology. Section 4 details the results, while Section 5 presents the conclusions and policy suggestions.

2. LITERATURE REVIEW

There are two subsections in this section. First, we present the theoretical framework about foreign direct investment inflows in the renewable energy sector. Second, a summary of the literature on relevant empirical evidence is provided.

2.1. Theoretical Framework

Investment in renewable energy has been significantly increasing over the last decade. For example, the amount of investment in clean energy worldwide increased from USD 1,100 billion in 2015 to approximately USD 1,700 billion in 2022 (an increase of 45%), whereas investment in fossil fuels decreased from USD 1,300 billion to roughly USD 1,000 billion (a decrease of 23%). It is noteworthy that among clean energies, renewable energy had the largest share, with 37% of the total clean energy investment in 2022. Meanwhile, solar power was the star performer, with more than USD 1 billion per day invested in solar power in 2023, for the first time surpassing upstream oil expenditures (International Energy Agency [IEA], 2023). Threats to global energy security and the increasingly visible effects of climate change can justify this significant growth in investment in renewable energy. The increase in energy prices caused by geopolitical crises can create strong economic incentives for investors to increase supply and find alternative (or more efficient) ways to meet demand. Also, renewable resources are more accessible than conventional ones. Additionally, supportive government policies, such as the U.S. Inflation Reduction Act and new initiatives in Europe, Japan, and the People's Republic of China, provide attractive opportunities for investors, since investments are boosted by the strong alignment of climate and energy security goals, especially in raw material import-dependent economies; and another factor is the focus on industrial strategies by governments, especially as countries aim to strengthen their footholds in the emerging clean energy economy (IEA, 2023). Hence, FDI inflows can have significant implications for developing renewable energy (Ergun et al., 2019). They are important for developing the energy sector, due to the transfer of capital, technology, and expertise from the home countries to the host ones (Abe et al., 2017). Also, foreign direct investment can host many players to gain benefit, not only in the energy sector but also outside this sector. Knutsson and Flores (2022) stated that a significant portion of FDI in energy is from sources outside the energy sector. In fact, over the past decade, approximately 70% of cross-border mergers and acquisitions (M&A)[1] in renewable energy were driven by companies primarily focused on activities other than energy production in order to provide energy security and diversify their portfolios.

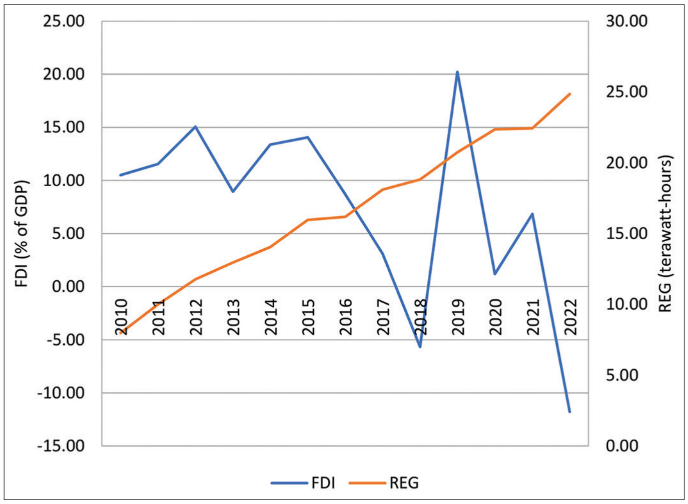
As many countries attempt to strengthen their energy independence in response to growing geopolitical tension, the mobilization of foreign investment in environmental policy objectives is particularly challenging (Knutsson and Flores, 2022). In this regard, establishing an environment conducive to FDI in renewable energy involves active promotion and targeted approaches that utilize appropriate marketing strategies and incentives, while reducing bureaucratic impediments (Abe et al., 2017). On the other hand, factors influencing foreign investment include the market conditions and policies of the investing company's home country, along with aspects such as the production costs and business conditions in the host country (Hanni et al., 2011).

Among the determinants affecting FDI in renewable energy, various incentives linked to renewable support policies such as feed-in tariffs, renewable energy certificates, and renewable portfolio standards are considerable (Keeley and Matsumoto, 2018). Governments must also restructure national financial policies to monitor and restrict dirty FDI inflows.[2] In this case, not only dirty FDI, but also government members may divert funds for their own personal benefit, instead of development (OECD, 2014). In related research, Carballo et al. (2023) showed that the client portfolios of investment promotion agencies mainly consist of multinational companies with higher pollution levels. This is why governments must enhance the stringency of existing environmental rules and regulations to safeguard their respective economies from transforming into so-called pollution havens (Murshed et al., 2021). Figures 1 and 2 demonstrate how FDI does not follow REG growth in the 27 European countries from 2010 to 2022. During this period, REG shows an upward trend, while FDI shows a volatile downward trend, and there is a significant and negative correlation between these two aspects. Other influencing variables include the distance between the nations, a contiguous border and a shared common official language, their market scale, and their participation in a regional trade pact (Knutsson and Flores, 2022). These factors also stimulate policymakers to focus on the long-term consequences (Ahmed et al., 2019).

1 Cross-border M&As are defined as any transaction in the assets of two firms belonging to two different economies.

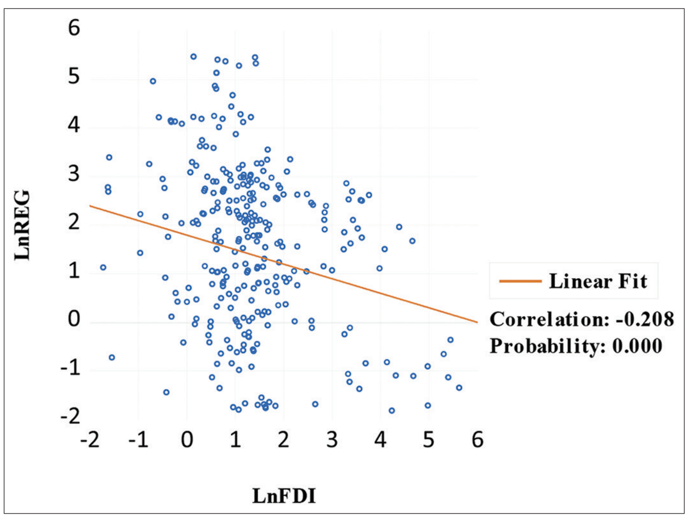
2 Dirty FDI refers to foreign direct investment that has negative social, environmental, or governance impacts. It also involves businesses and endeavors that have a major impact on environmental degradation, pollution, and other harmful issues.

Figure 1: Average FDI and REG of the 27 European countries from 2010 to 2022



Source: Author's compilation

Figure 2: The nexus between *LnREG* and *LnFDI* in the 27 European countries from 2010 to 2022[3]



Source: Author's compilation

2.2. Empirical Evidence

Ahmed et al. (2019) examined the empirical interactions among FDI, CO_2 emissions, and REG. To examine the long- and short-term interactions among the variables of interest, the Bayer-Hanck combined cointegration and autoregressive distributed lags (ARDL) approaches were employed on the time series data of China for the period from 1991 to 2017. The empirical results revealed that both FDI inflows and CO_2 emissions increase REG, while the intensity of long-term impacts is much stronger than that of short-term ones. Any addition to renewable energy generation in response to the rise in CO_2 emissions is derived from policy response which may prompt policymakers and governors to promote renewables to attain the CO_2 emissions curtailment goals. Likewise, Dossou et al. (2023) investigated the impacts of FDI on REG in 37 sub-Saharan African economies from 1996 to 2020. By using the panel-corrected standard errors estimation approach, they found that FDI has a significant and positive impact on REG. Murshed et al. (2021) focused on the dynamic associations between FDI inflows and REG in Bangladesh between 1972 and 2015. They also evaluated both the direct and indirect impacts of FDI inflows on the country's environmental sustainability. Based on the results from the regression, causality analyse, and ARDL technique, they found a unidirectional causality from FDI inflows to REG shares over the long run. Khandker et al. (2018) utilized the Johansen cointegration and Granger causality tests to explore the relationship between FDI and renewable energy consumption in Bangladesh from 1980 to 2015. They revealed a bidirectional causality between FDI and renewable energy consumption. Kilicarslan (2019) used the Pedroni cointegration test and the ARDL approach to evaluate the relationship between FDI inflows and REG in BRICS (Brazil, Russia, India, China, and South Africa) countries and Turkey from 1996 to 2015. Conversely, the results indicated that in the long run, FDI has a negative impact on REG in BRICS countries and Turkey, with no significant impact in the short run. The analysis also showed that FDIs were not directed toward the renewable energy sector.

Based on the aforementioned theoretical frameworks and the corresponding empirical evidence, the present study enriches the literature by employing the generalized method of moments/dynamic panel data (GMM/DPD) estimation technique to determine the impact of FDI on REG in European economies from 2010 to 2022.

3. DATA, MODEL SPECIFICATION, AND METHODOLOGY

3.1. Data and Variables Description

Using panel data from 2010 to 2022, an empirical analysis was conducted on 27 European countries, all of which claim to protect the environment and support renewable energy. However, these countries are sensitive to the energy market, due to their lack of access to conventional resources (Table 1). The data for the variables was aggregated from the Energy Institute (EI) and the World Bank's World Development Indicators (WDIs) databases. Table 2 includes a list of the variables employed in this investigation (briefly described in this subsection), while Table 3 presents the descriptive statistics of the dataset, including the number of observations as well as the mean, standard deviation, and minimum and maximum values of each variable.

3.1.1. Dependent variable

Renewable energy generation: In this study, electricity generated (in terawatt-hours) from wind, solar, geothermal, biomass, and other sources of renewable energy was used as the indicator of REG, following Murshed et al. (2021), Shahzad et al. (2021), and Kilicarslan (2019). The data was extracted from the EI database.[4]

3.1.2. Explanatory variable

Foreign direct investment: Following Shaari et al. (2022), Zhang et al. (2021), and Kilicarslan (2019), FDI net inflows were used, representing the total volume of FDI flowing into a country, as a

3 LnREG and LnFDI are the natural logarithms of REG and FDI, respectively.

4 See https://www.energyinst.org/statistical-review.

Table 1: The list of European countries

Austria	Estonia	Ireland	Norway
Belgium	Finland	Italy	Poland
Bulgaria	France	Latvia	Portugal
Croatia	Germany	Lithuania	Romania
Cyprus	Greece	Luxembourg	Slovakia
Czech Republic	Hungary	Netherlands	Slovenia
Denmark	Iceland	North Macedonia	

Source: Author's compilation

Table 2: Variables, abbreviations, data sources

Variable	Abbreviation	Source
Renewable energy generation	REG	EI
Foreign direct investment	FDI	WDIs
CO_2 emissions	CO_2E	EI
Economic growth	GDPP	WDIs

Source: Author's compilation

percentage of its gross domestic product (GDP). The data on FDI was collected from the WDIs.[5]

3.1.3. Control variables

In accordance with the literature, two control variables were added to the model to account for the omission of a pertinent variable and to prevent biased estimators.

CO_2 emissions: In this study, CO_2 emissions represent the sum of such emissions from energy and reflect those through the consumption of oil, gas, and coal for combustion-related activities. The CO_2 emissions (in million tons) data was obtained from the EI database. REG can help reduce the overall impact of CO_2 emissions on the environment and climate (Saba and Biyase, 2022; Murshed et al., 2021).

Economic growth: The GDP per capita (GDPP), which is the GDP divided by the total midyear population, was used as an indicator of economic growth. It is also one of the most frequently used factors for analyzing its correlation with REG. In this regard, economic growth has proven to be a major factor in the process of transitioning toward renewable energy (Murshed et al., 2021; Ahmad et al., 2019). The data on economic growth (in current USD) was collected from the WDIs.[6]

3.2. Empirical Model Specification

Following the literature and combining elements of the previously mentioned studies that investigated renewable energy drivers, this study examines the relationship between REG, FDI inflows, CO_2 emissions, and economic growth. For this purpose, it applies the GMM/DPD estimation technique, which is optimal for analyzing the 27 European economies from 2010 to 2022. In this regard, the following model is utilized:

$$LnREG_{it} = \beta_0 + \beta_1 LnREG_{(t-1)} + \beta_2 LnFDI_{it} + \beta_3 LnCO_2E_{it} + \beta_4 LnGDPP_{it} + v_i + u_{it} \quad (1)$$

Where i denotes the country, t is the time period, β_0 is the constant parameter, and β_x (x = 1, 2, 3, 4) represent the elasticity parameters to be estimated. Moreover, v, and u measure the country-specific effect, the time-specific effect, and the error term, respectively, while *LnREG* and *LnFDI* are the natural logarithms of REG and FDI, respectively. The control variables, inclusive of CO_2E and gross domestic product per capita (*GDPP*), are CO_2 emissions and economic growth respectively They are also used to prevent variable omission bias. All of the variables are converted into their natural logarithms to facilitate estimation.

3.3. Empirical Strategy

For the data analyses and the estimation of the research model, Eviews 13 software was used, based on the probability and a confidence level of 95%. First, the research variables were tested in terms of stationarity. In this case, the Levin, Lin, and Chu (LLC) unit root test was used. Levin et al. (2002) showed that, using the unit root test for data combination has more power than using the unit root test for each section in the panel data. Based on the results of the unit root tests, the structure (the large number of cross-sections and the short time series (T < N)), the specification (the dynamics of the panel data), and approach of the study, the GMM/DPD technique was considered as the appropriate estimation method. In the econometric models, the dynamic relationship is determined by introducing a lag or lags from the dependent variable (as an explanatory variable in the models). The following includes the dynamic panel regression model (2) and the difference GMM model (3):

$$Y_{it} = \alpha Y_{(t-1)} + \beta X_{it} + \omega_i + \varepsilon_{it} \quad (2)$$

$$\Delta Y_{it} = \alpha \Delta Y_{(t-1)} + \beta \Delta X_{it} + \Delta \varepsilon_{it} \quad (3)$$

where $Y_{i(t-1)}$ is the lagged dependent variable and regressor (endogenous by construction); α is the autoregressive parameter; X_{it} is the regressor; ω_i is the fixed-effect error term; εit is the white noise error term; Δ is the first difference of variables. The GMM was developed by Holtz-Eakin et al. (1988) and Arellano and Bond (1991). This method provides a convenient framework for obtaining estimates with asymptotic efficiency. It also considers the effects of dynamic modulation of the dependent variable. In this case, if the dependent variable enters the model with lag values, then it will create a correlation between the explanatory variables and the error term. Consequently, using the ordinary least squares method will present inconsistent results. However, the difference GMM can solve this problem by using instrumental variables. Moreover, individual-specific effect is controlled in the model.

It is important to note that in dynamic panel data models, since the lag value of the dependent variable is correlated with the error term, the second lag of the dependent variable is used as the instrument for the lag value of this variable in order to fix this correlation. As suggested by Arellano and Bond (1991), the GMM removes cross-section fixed effects. In this research, two-step GMM was applied, which is asymptotically more effective in the presence of heterogeneity variance of the error term.

The consistency of GMM depends on the validity of the noncorrelation between the instruments and error terms, the serial nonautocorrelation of the error terms, and the joint significance

5 See https://data.worldbank.org/indicator/BX.KLT.DINV.WD.GD.ZS.
6 See https://data.worldbank.org/indicator/NY.GDP.PCAP.CD.

Table 3: Descriptive statistics

Variable	n	Mean	Standard Deviation	Maximum	Minimum
Renewable energy generation	351	16.631	34.856	236.500	2.600
Foreign direct investment	351	7.392	38.794	280.145	−394.471
CO_2 emissions	351	101.361	156.039	797.571	1.815
Economic growth	351	35989.287	26454.001	133711.794	4577.689

Source: Author's calculations

Table 4: The LLC test results

Variable	Statistic	P-value
LnREG	−12.231	0.000
LnFDI	−3.181	0.000
$LnCO_2E$	−5.021	0.000
LnGDPP	−5.613	0.000

Source: Author's calculations

of regressors, all of which can be considered by three tests. The first test is the Sargan test, which examines the validity of the instruments. In this case, the instruments are valid if there is no correlation between the instruments and the error terms (Sargan, 1958). Specifically, the instruments are valid if the P-value is between 0.25 and 1, indicating that they are not correlated with the error terms in the first-order differential equation. Meanwhile, the Sargan statistic (j-statistic) includes a chi-square distribution. The second test is the Arrellano-Bond serial correlation test, which determines the existence of second-order serial correlation in the first-order differential equation of error terms (Baltagi, 2008). In this test, failure to reject the null hypothesis provides evidence for the assumption of no serial correlation. The third test is the Wald test, which recognizes the joint significance of regressors in models. In this test, rejecting the null hypothesis proves this significance (Saba and Biyase, 2022).

Finally, to determine the causality direction among the variables, this study used the Granger panel causality test, which ascertains if one data series can forecast another within a dataset comprising various entities observed over time. This approach, notably enhanced by Dumitrescu and Hurlin (2012), includes creating a regression model in which previous values of one variable are incorporated to determine if they can help predict the value of another variable. If the inclusion of these values diminishes the prediction errors, then it indicates a Granger causal connection. It should be noted that this study's heterogeneous panel causality test was a modified version of the causality test suggested by Granger (1969). Since the findings from the panel causality test are sensitive to lag length, this study set the maximum lag length to 3.

4. RESULTS

4.1. Panel Unit Root Test

In the Levin, Lin, and Chu (LLC) test, if the null hypothesis is confirmed, then it indicates that the data time series includes a unit root and is nonstationary. Conversely, if the $P < 0.05$, then it means that the variable is stationary. As shown in Table 4, all of the variables are stationary, with a $P < 0.01$.

Table 5: The results of the two-step difference GMM model

Variable	Coefficient	Standard Error	t-Statistic	Prob.
LnREG (−1)	0.642	0.002	241.376	0.000***
LnFDI	−0.033	0.007	−4.390	0.000***
$LnCO_2E$	−0.839	0.037	−22.375	0.000***
LnGDPP	0.124	0.019	6.305	0.000***

***, **, and * represent the 1%, 5%, and 10% significance levels, respectively
Source: Author's calculations

Table 6: Sargan, Arellano-Bond, and Wald test results

Test	Statistic	P-value
Sargan	23.099	0.454
AR (1)	−2.479	0.013**
AR (2)	−0.844	0.398
Wald	186333.905	0.000***

***, **, and * represent the 1%, 5%, and 10% significance levels, respectively
Source: Author's calculations

4.2. Panel GMM Analysis

The results of estimating the effects of FDI, CO_2 emissions, and economic growth on REG by using dynamic panel data and the GMM estimator are presented in Table 5. Based on the findings, all of the variables are statistically significant in the 1% significance level. The coefficient for the lag value of *LnREG* is statistically significant and positive. The 1% increase in the lag value of REG increases such generation by 0.642%, indicating strong persistence in the model. In addition, the REG of the European countries is correlated to such generation in the past.

As for FDI inflows, they negatively and significantly affect REG, with a 1% increase in FDI reducing REG by 0.033%. This indicates that FDI inflows might be directed toward the nonrenewable energy sector. Regarding CO_2 emissions, they have a negative and statistically significant effect on REG, with a 1% increase in CO_2E decreasing REG by 0.839%. Since energy production from renewable sources reduces the need for fossil fuel consumption, the relationship between CO_2 emissions and REG is also negative. Moreover, the significant and positive coefficient for *LnGDPP* suggests that a strong and vibrant economy can lead to higher REG as if a 1% increase in *GDPP* increases REG by 0.124%.

4.3. Sargan, Arrellano-Bond, and Wald Tests

In this study, the model passed the Sargan and Arrellano-Bond tests, confirming the validity and reliability of the model settings. Based on the results of the Sargan test ($0.25 < P = 0.454 < 1.0$), the instrumental variable in the model includes the necessary validity (i.e., there is no relationship between the error terms and the instrument) (Table 6). Thus, the instrumental variable must be

Table 7: Panel causality test results

Null hypothesis	Statistic	P-value
LnFDI↛LnREG	5.079	0.025**
LnREG↛LnFDI	1.302	0.254
$LnCO_2E$↛LnREG	3.429	0.017**
LnREG↛$LnCO_2E$	1.618	0.185
LnGDPP↛LnREG	2.705	0.045**
LnREG↛LnGDPP	0.168	0.917

The null hypothesis in this test is no causality (↛) denotes no causality. ***, **, and * represent 1%, 5%, and 10% significance levels, respectively
Source: Author's calculations

used to control the correlation between the explanatory variables and the error terms.

As for the results of the autocorrelation test between the error terms, they are significant at the 5% level, with no second-order autocorrelation (Table 6). In this case, AR (1) and AR (2) refer to the Arellano-Bond autocorrelation tests for the first- and second-order difference of the error terms, respectively. Specifically, the AR (2) result shows no evidence of second-order serial correlation ($0.05 < P = 0.398$). Regarding the Wald test, which was applied to examine the joint significance of the regressors, the results show that the lag of REG and the independent and control variables are jointly significant to REG ($P = 0.000 < 0.05$).

4.4. Panel Causality Test

Table 7 presents the panel causality test results. This study focused on the causal relationship between REG and each of the possible determinants. Based on the findings, there is unidirectional causality running from: 1) *LnFDI* to *LnREG*; 2) $LnCO_2E$ to *LnREG*; and 3) *LnGDPP* to *LnREG*. This implies that an increase in FDI, CO_2E, and *GDPP* can lead to an increase in REG at the 5% significance level.

5. CONCLUSION

Due to environmental contamination and the lack of nonrenewable resources, the utilization of nonrenewable energy is unsustainable. In this regard, employing renewable energy technology is essential for maintaining environmental sustainability and energy security, with financing through FDI as a suitable tool. However, despite significant research on foreign financing and REG, few studies have examined the relationship between FDI and REG. Thus, this study fills this gap in the literature by applying the GMM/DPD estimation technique to determine the impact of FDI on REG in 27 European economies from 2010 to 2022.

Based on the findings, an increase in FDI inflows decreases the amount of energy produced from renewable sources. This also indicates that FDI inflows are probably directed toward the conventional energy sector. In this regard, it is possible that the energy lobbies are uninterested in going beyond the guaranteed profits of fossil fuels and conventional energy to support and/or develop renewable energies that are costly and time-consuming, with associated financial risks. Thus, policymakers should decide on suitable incentive programs to attract investments in the renewable energy industry. Some suggestions are as follows. First, fiscal incentives, such as feed-in tariffs, electricity purchase agreements, and renewable project tax credits, should be promoted to reduce investment risks and guarantee revenue. Second, competitive auction and bidding systems should be implemented to ensure the allocation of resources at affordable prices and facilitate investment in network modernization and renewable energy integration. Third, fossil fuel subsidies should be gradually removed, forcing energy producers and distributors to allocate a percentage of production and distribution to renewable energy. Fourth, carbon emitters should be taxed, increasing their willingness to invest in renewable energy. Finally, national strategic plans in supporting and allocating funds to research and development sectors should be introduced to accelerate the productivity process. Overall, these approaches might gradually direct FDI from nonrenewable energy sources to the renewable energy sector.

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