Macroeconomic Determinants of Renewable Energy in post-socialist EU Countries

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Abstract

This research paper examines the impact of several economic indicators on renewable energy production, specifically in Central and Eastern Europe. Despite widespread academic interest in renewable energy, this topic has remained largely unexplored. The study focuses on economic factors such as economic development, unemployment, inflation, financial capital, trade balance, and greenhouse gas emissions. Data was obtained from the World Bank development indicators and covers the years 1990-2020. The multivariate regression model was tested using second-generation dynamic panel data tests. The results showed that a growing GDP contributes to higher renewable energy generation while rising unemployment leads to an increase in renewables deployment. Changes in prices trigger inflation and encourage the search for alternative energy sources. An unfavorable trade balance (current account deficit due to dependence on imported oil) is a key factor in the growth of the renewable energy sector. Credits and foreign trade investments are the primary sources of energy investments and lead to a higher share of renewable energy use. For selected groups of countries, renewable energy production is positively stimulated by rising CO2 emission levels.

Keywords: renewable energy, panel data analysis, transition economies

JEL Codes: K32, C33, P2

1. Introduction

The majority of energy consumption relies on nonrenewable fossil fuels, which unfortunately leads to the destruction of our ecological environment through excessive usage. To shift towards a sustainable energy structure, we must explore new driving forces such as renewable options. Nuclear power, while a potential alternative, poses too many risks for society, as evidenced by past disasters like Chernobyl and Fukushima. Renewable sources such as solar, wind, and biological options offer clean and sustainable solutions but require high production costs and advanced technology. Policymakers should prioritize implementing reforms that encourage the development of an energy-conserving society. (Liu, 2022: 2-3).

The purpose of this paper is to shed light on the renewable energy requirements of transition economies in Europe from a macroeconomic perspective. The rationale behind focusing on post-socialist economies is that Europe has proactively tackled energy poverty since 2011, particularly in these countries, by reducing energy costs and providing access to renewable energy sources. In 2020, the European Commission introduced recommendation guidelines for policymakers, which included comprehensive energy poverty indicators and solutions. However, there are not enough research papers available in the literature that address these particular country groups, which is the primary reason for the energy poverty issue in Europe.

Dhabi's (2020) research reveals that sustainable development expenditures have successfully lowered renewable energy costs in recent times. However, the growth of renewable energy usage is subject to multiple factors, such as macroeconomic indicators and natural phenomena. This paper concentrates on quantifiable markers. In the subsequent section, we examine the hypothetical correlation between various economic indicators and the consumption or production of renewable energy. To evaluate the relationship between renewable energy consumption and chosen independent variables, we employ second-generation panel data tests, and the results are computed for each country in both the short and long term. The concluding segment interprets the numerical data economically and provides policy suggestions.

2. Macroeconomic Determinants of Renewable Energy

Economic growth is believed to be a significant factor in promoting the use of renewable energy. According to various studies, there are different theories regarding the relationship between a higher GDP per capita and an increase in renewable energy consumption, or vice versa (Tu et al. 2022:3). Additionally, countries with higher income levels tend to be more aware of the environmental issues associated with fossil fuels and therefore consume more renewable energy (Yüksel and Ubay, 2020:4). The Kyoto Protocol and the Paris Agreement, two climate agreements, have also played a role in promoting the development of the energy sector in advanced economies. A thriving economy plays a vital role in the growth and development of the renewable energy sector (Lin and Moubarak, 2014). In short, the ability to invest in clean technologies, fund research and development initiatives, and build infrastructure for renewable energy production is directly tied to a country's GDP per capita (Alhendawy, 2023: 681).

Renewable energy has been found to have a positive impact on unemployment rates as it creates new job opportunities, according to Hillebrand et al. (2006) and Wei et al. (2010). Additionally, population growth plays a crucial role in employment rates as it affects energy production and consumption in the energy sector, as highlighted by Elmassah (2021). If energy demand is met only through traditional methods, it accelerates climate change by emitting CO_2 (a greenhouse gas). However, renewable energy plays an important role in mitigating carbon emissions.

Investing in renewable energy can be greatly improved by financial investments, which can help to distribute this type of energy from one country to another. Moreover, there is a direct link between financial investments and the transfer of knowledge related to green energy. Therefore, strong economic policies are crucial for financial progress since unexpected financial and economic policies can lead to fluctuation and negatively impact financial growth. (Farouq and Sulong, 2023: 84). Foreign direct investments can have both positive and negative effects on financial development, as noted by Yüksel and Afşar (2023: 186). While Kutan et al. (2018) and Ergun et al. (2019) argue that the consumption of renewable energy has a positive impact on foreign direct investments, Lin et al. (2016) and Kilicarslan et al. (2019) claim the opposite.

According to Kyophilavong et al. (2015), trade openness can help promote the development of renewable energy. In the long run, there is a natural negative relationship between trade current account deficits and energy consumption. For countries that rely on energy imports, using renewable energy sources could be a viable option for improving their current account balance. (Yıldırım and Kaya, 2021: 288).

3. Empirical Literature

Providing a succinct summary, we present an overview of the application of panel data analysis in researching renewable energy within the European Union. In Tsani's (2010) study, the correlation between renewable energy and economic growth in Greece was explored from 1960 to 2006 utilizing the Todo and Yamamato causality test. The results indicate substantiation for both the growth and feedback hypotheses.

Alper and Oğuz conducted a study in 2014 to investigate the relationship between renewable energy consumption and economic growth in various European countries from 1990 to 2009. They utilized Hatemi-J and Asymmetric Causality approaches and discovered that there was no causal relationship between variables in Cyprus, Estonia, Hungary, Poland, and Slovenia. However, in the Czech Republic, the direction of causality was from renewable energy to economic growth, supporting the conservation hypothesis. On the other hand, in Bulgaria, the direction of causality was from economic growth to renewable energy consumption, supporting the growth hypothesis.

Saad and Taleb (2018), Akadiri et al. (2019), and Asiedu, Hassan, and Bein (2021) researched the relationship between economic growth and renewable energy consumption in different European countries. They used Granger Causality to analyze the data and found evidence to support the feedback hypothesis.

Pehlivanoğlu et al. (2021) conducted a study on the feedback hypothesis in 21 European countries from 1995 to 2016 using the Panel Causality Test. Similarly, Piłatowska, Geise, and Włodarczyk (2020) explored the Granger Causality test and discovered partial evidence to support the feedback and growth hypotheses in Spain from 1970 to 2018.

Finally, Tu et al. (2020) examined the drivers of the renewable energy sector in 27 EU members from 2011 to 2020 using the random effects GLS method for the panel data. They found that economic growth and advanced technology were positive drivers, while unemployment negatively impacted them. Additionally, economic freedom and geographical location played important roles.

4. Methodology

The study examines data from the World Bank development indicators for post-socialist European countries between 1996 and 2020. Kosovo, Montenegro, Romania, and Serbia were excluded due to data limitations. The data was analyzed using logarithmic data with Gauss and E-views. In this section, the model is specified and the methodology of the study is described. Panel data analysis was used to take advantage of its benefits, such as the ability to study individual observations at different time points and to compare cross-sections and time differences internationally. (Arellano 2003; Cameron and Trivedi, 2005).

$$REC = \beta_0 + \beta_1\, GDP + \beta_2 BOP + \beta_3 FDI + \beta_4 UNP + \beta_5 INF + \beta_6 CO^2 + \beta_7 CF + u_t \qquad (1)$$

Equation (1) is inspired by the studies of Tu et al. (2020) and Pehlivanoğlu et al. (2021) but this study is different from others due to the increased number of explanatory macroeconomic variables, the use of second-generation tests, and the selected country group.

The following are the variables that will be represented in an orderly manner:

1. REC: Renewable energy consumption as a percentage of GDP,
2. GDP: Gross domestic product per capita, also known as economic growth,
3. BOP: Current Account Balance as a percentage of GDP,
4. FDI: Net inflows of Foreign Direct Investments as a percentage of GDP,
5. UNP: Total labor force as a percentage of modeled ILO estimate,
6. INF: Annual inflation of consumer prices,
7. CO2: Total greenhouse gas emissions in kt of CO2 equivalent, calculated in logarithmic form,
8. CF: Gross fixed capital formation as a percentage of GDP.

The error term, denoted by individual country effects that change across units is defined by u_t. The constant coefficient is represented as "$\beta 0$", whereas "βi" indicates the slope coefficients.

5. Findings

In 2008, a test was conducted in Pesaran and Yamagata to determine the homogeneity of the series. The null hypothesis of this test assumes that the series are all the same. If the null hypothesis is rejected, it means that the series are different from each other. Table 1 (*) shows the significance of probability at a 5% level, where △ represents small samples and Δadj represents big samples. As per the results, the null hypothesis has been rejected, indicating that the variables are heterogeneous.

Table 1: Slope Homogeneity Test Results

Delta Test	T-Statistics	Prob.
$\tilde{\Delta}$	4.411	0.000*
$\tilde{\Delta}_{adj}$	4.690	0.000*

There is a cross-sectional dependence of units, as concluded by Pesaran's (2004) test. The null hypothesis, which assumes no cross-section dependence, has been rejected for all variables at a 5% level of significance (*). This means that there is indeed cross-section dependency, as shown in Table 2.

Table 2: Cross-Section Dependence Test Results for the Model

CD Test	Test Statistics	Prob
LM (Breusch, Pagan 1980)	280.856	0.000*
CD LM 1 (Pesaran 2004)	12.135	0.000*
CD LM 2 (Pesaran2004)	-1.580	0.057*
Bias-adjusted CD (Pesaran et all. 2008)	-0.798	0.787

The Multifactor Error Structure test, introduced by Pesaran et al. in 2013, is an essential pre-test required before applying the CCE (Common Correlated Effects) Model in empirical studies in macroeconomic theory. The primary purpose of this test is to eliminate the error structure of common factors, which is also known as autocorrelation. Two test statistics are estimated: the cross-sectional augmented panel (CIPS) unit root test, introduced by Pesaran in 2007 and later expanded with a new CSB (simple average of cross-sectional augmented Sargan-Bhargava) statistics (Pesaran et al., 2013, 96). The null hypothesis claims that cross-section units have a unit root. The CSB test statistic has been calculated with the stochastic simulation method. Therefore, the calculated test statistics are reliable and superior to CIPS statistics in this respect, regardless of whether the series is linear or has autocorrelation (Pesaran et al. 2013, 99).

Table 3: Multifactor Unit Root Test for all the variables

Variables		Intercept	Pesaran et al. (2013), Table B-3	Intercept and a linear trend	Pesaran et al. (2013), Table B-4
	Lags	Statistics	Critical Value (k=6)	Statistics	Critical Value (k=6)
$CSBm$	0	0.037	0.277	0.039	0.101
REC	1	0.086	0.207	0.054	0.080
	2	0.137	0.146	0.073	0.057*
	3	0.146	0.088*	0.073	0.034*
	4	0.163	0.041*	0.056	0.014*
$CSBm$	0	0.025	0.277	0.024	0.101
GDP	1	0.081	0.207	0.068	0.080
	2	0.083	0.146	0.065	0.057*
	3	0.127	0.088*	0.081	0.034*
	4	0.157	0.041*	0.065	0.014*
$CSBm$	0	0.052	0.277	0.036	0.101
BOP	1	0.109	0.207	0.085	0.080
	2	0.115	0.146	0.072	0.057
	3	0.149	0.088*	0.056	0.034
	4	0.095	0.041*	0.029	0.014*
$CSBm$	0	0.029	0.277	0.027	0.101
FDI	1	0.071	0.207	0.068	0.080
	2	0.087	0.146	0.059	0.057*
	3	0.153	0.088*	0.079	0.034*
	4	0.137	0.041*	0.049	0.014*
$CSBm$	0	0.023	0.277	0.023	0.101
INF	1	0.064	0.207	0.060	0.080

	2	0.108	0.146	0.061	0.057*
	3	0.087	0.088	0.073	0.034*
	4	0.082	0.041*	0.049	0.014*
$CSBm$	**0**	0.078	0.277	0.045	0.101
UNP	**1**	0.077	0.207	0.058	0.080
	2	0.122	0.146	0.082	0.057*
	3	0.257	0.088*	0.101	0.034*
	4	0.165	0.041*	0.058	0.014*
$CSBm$	**0**	0.030	0.277	0.025	0.101*
CF	**1**	0.087	0.207	0.067	0.080
	2	0.074	0.146	0.062	0.057*
	3	0.119	0.088*	0.061	0.034*
	4	0.104	0.041	0.053	0.014*
$CSBm$	**0**	0.027	0.277	0.024	0.101
CO^2	**1**	0.113	0.207	0.086	0.080
	2	0.126	0.146	0.054	0.057
	3	0.154	0.088*	0.078	0.034*
	4	0.075	0.041*	0.047	0.014*

The statistical analysis conducted by Pesaran et al. (2013) utilizes stochastic simulation to determine the significance of variables in regression models. The results for different values of 'k' can be found in Tables B-3 and B-4, which show the intercept only and intercept with a linear trend, respectively, on pages 112 and 114. Table 3 provides critical values at a 5% significance level, where 'k' represents the number of independent variables in the regression. Some of the calculated statistical values exceed the table critical values, particularly for lags 3 and 4 in the intercept model and lags 2-3-4 in the intercept with a linear trend model, indicating that the variables have unit roots at their level but their first differences are stationary. (*) denotes statistical significance.

A test for heterogeneity and cross-section dependence has been suggested by Chang (2004), which uses bootstrap critical values. This test is effective even when the number of observations (N) and the time dimension (T) are small, and it assumes that each unit is stationary after the first difference. Westerlund (2007), the null hypothesis claims that there is no cointegration between variables.

Table 4: ECM Cointegration Test Results

		t-statistics	Boostrap Prob.
g_τ	Group mean	-4.359	0.031*
g_α	Group mean	-4.754	0.015*
p_τ	Panel	-3.328	0.063*
p_α	Panel	-6.709	0.008*

The existence of a co-integrated relationship between cross section units has been proven and the null hypothesis is rejected. This proves the relationship is statistically significant. The CCE mean group estimator will be reported due to heterogeneous cross-units.

Table 5: CCE Mean Group Estimations

y = REC			
Variables	**Coefficients**	**se(NP)**	**t(NP)**
GDP	0.03290	0.033153	0.992524
UNP	-0.45268	0.207156	-2.18525
FDI	-0.17728	0.134505	-1.31802
INF	-0.01371	0.061125	-0.22435
CF	-0.17593	0.093582	-1.88001
CO^2	-61.6210	8.553617	-7.20408
BOP	0.08399	0.100213	0.083811

According to Table 5, there is a negative relationship between the consumption of renewable energy and macroeconomic indicators such as UNP, FDI, INF, CF, and $CO2$, except for BOP and GDP. This means that if the economy is unstable, and these indicators are not positive, the consumption of renewable energy will decrease. However, for the selected period, economic growth and current account balance have positive coefficients, which support the consumption of renewable energy for the selected post-socialist countries.

The significance of the standard deviation (SE) can be found on page 994 of Pesaran's (2006) study, specifically in the full-rank heterogeneous slopes experiment 1A table, for the mean group (for N x T = 15 x 25, bias: 14.21, RMSE: 18.05, size: 34.20, power: 51.30).

The table displays the coefficients for each cross-unit, with (SE) indicating the standard error and (NW) indicating the Newey-West type standard deviation. The period length (T) runs from 1996 to 2020. The conclusion section will provide an interpretation of the findings to ensure statistical and economic integrity.

Table 6: Long-Term Country-Specific Estimations with CCE

ID	GDP	Se(NW)	UNP	Se(NW)	FDI	Se(NW)	INF	Se(NW)	CF	Se(NW)	CO^2	SE(NW)	BOP	SE(NW)	T
Albania	0.394	0.178	0.021	0.198	-0.155	0.150	0.331	0.122	0.112	0.189	-41.218	9.789	0.238	0.093	1996-2020
Bulgaria	0.083	0.029	-0.062	0.040	0.113	0.051	-0.001	0.005	0.005	0.076	-27.642	6.682	0.121	0.078	1996-2020
Croatia	-0.158	0.096	-0.325	0.121	-0.129	0.096	-0.263	0.153	0.834	0.271	-177.919	19.974	0.203	0.196	1996-2020
Czechia	0.071	0.049	-0.491	0.100	-0.046	0.033	-0.004	0.058	0.021	0.120	-39.297	6.371	0.073	0.106	1996-2020
Estonia	-0.055	0.067	0.433	0.163	-0.042	0.051	-0.043	0.086	-0.031	0.159	-28.704	13.836	-0.087	0.058	1996-2020
Georgia	-0.219	0.286	-0.034	0.449	-0.138	0.168	-0.070	0.095	0.290	0.236	-99.981	23.901	0.263	0.218	1996-2020
Hungary	0.002	0.057	0.077	0.121	-0.033	0.019	0.002	0.069	-0.101	0.189	-30.330	8.182	0.250	0.140	1996-2020
Latvia	0.031	0.086	-1.036	0.136	0.261	0.252	0.009	0.078	0.549	0.079	-27.548	34.581	0.177	0.130	1996-2020
Lithuania	-0.010	0.005	0.461	0.058	-0.364	0.114	-0.033	0.044	-0.020	0.011	-37.235	6.280	-0.152	0.054	1996-2020
Moldova	0.018	0.103	-0.063	0.855	-0.457	0.297	0.202	0.076	-0.192	0.259	-24.153	34.419	-0.356	0.161	1996-2020
Macedonia	0.208	0.062	0.485	0.141	0.058	0.095	-0.089	0.072	0.605	0.217	-12.013	9.517	0.637	0.094	1996-2020
Poland	0.121	0.148	0.063	0.129	-0.158	0.155	0.152	0.073	-0.091	0.169	-0.420	14.897	-0.068	0.112	1996-2020
Slovakia	-0.078	0.104	-0.485	0.211	-0.120	0.086	-0.046	0.076	-0.178	0.061	-32.630	13.776	-0.161	0.094	1996-2020
Slovenia	-0.398	0.184	-0.117	0.161	0.221	0.129	0.311	0.287	0.990	0.261	-45.373	23.044	0.237	0.149	1996-2020
Ukraine	0.074	0.036	-0.327	0.190	-0.086	0.030	-0.012	0.005	-0.016	0.119	-24.674	5.792	-0.040	0.016	1996-2020

6. Conclusion

Post-socialist economies are especially vulnerable to energy poverty, which hinders their access to renewable energy sources due to a lack of capacity, infrastructure, and technology.

Investing in Bulgaria, Latvia, North Macedonia, and Slovenia has a positive impact on renewable energy consumption. This type of investment involves multinational companies investing in other countries, bringing capital, technology, and knowledge to the host countries. As a result, it promotes economic growth, creates wealth, and is considered an important factor in the development of economies. Uche et al. (2023) noted the benefits of this type of investment. Renewable energy consumption has decreased in all other countries, with Moldova contributing the most.

Khan and Majeed (2023) have stated that access to energy plays a crucial role in reducing energy poverty and promoting the use of renewable energy. However, our study has discovered that half of the countries in the chosen group have negative economic growth (GDP) coefficients. This contradicts the existing literature, and the growth hypothesis is rejected for Croatia, Estonia, Georgia, Lithuania, Slovakia, and Slovenia. It is crucial to bear in mind that economic growth may not always be the sole driving force behind renewable energy.

According to Von Platten (2022), unemployment can result in a decrease in income and make it challenging to meet basic needs, leading to a lower standard of living and possible energy conservation. Our research findings demonstrate that several post-socialist European countries, except Albania, Estonia, Hungary, Lithuania, Macedonia, and Poland during the selected time frame, are grappling with persistent employment problems, which have a detrimental impact on renewable energy consumption.

Amongst the chosen nations of Estonia, Lithuania, Moldova, Poland, Slovakia, and Ukraine, there exists a trade imbalance stemming from their current account deficits. Overall, it can be observed that the balance of payments (BOP) has a favorable influence on the consumption of renewable energy. This aligns with the findings of Yılıdırm and Kaya (2021), who suggest that utilizing renewable sources of energy may represent a feasible solution for enhancing these countries' current account balances.

Inflation refers to a continuous increase in the overall price level of goods and services, which can result in higher energy bills. According to a report by Simionescu et al. (2023: 182), political conflicts like the Russia-Ukraine war can lead to a rise in energy expenses. As non-renewable resources are limited, any economic disruptions can negatively impact energy access. It is important to note that during the selected timeframe, only Albania, Hungary, Latvia, Moldova, Poland, and Slovenia had positive INF coefficients.

The root cause of global warming is attributed to the use of fossil fuels, which emit greenhouse gases. To mitigate the rise of carbon emissions, it is crucial to shift towards renewable energy sources. CO^2serves as both an economic and environmental indicator, and unfortunately, it possesses entirely negative coefficients for the entire dataset. This indicates that carbon emissions remain a significant challenge for the selected country group, with Croatia, Estonia, and Lithuania being the most negatively impacted.

According to the study by Abbas et al. (2020), investing in fixed capital can lead to economic growth and contribute to sustainable environmental conditions. Our empirical findings suggest that Slovenia, Croatia, Macedonia, and Latvia have provided economic and financial support for green renewable energy sources and clean technology innovation. This is because capital fixed formation has shown the highest positive impact in these countries.

For further research, country groups can be enhanced for all Europeans. In addition to macroeconomic indicators, environmental indicators can be included as separate indexes. The causality between renewable energy and those indexes can then be compared directly.

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