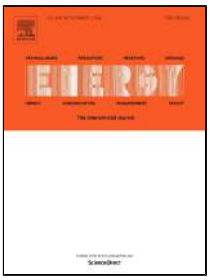

Determinants of renewable energy production in transition economies: A panel data approach

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Determinants of renewable energy production in transition economies: A panel data approach

Abstract

Over the past several years, the analysis of the determinants of renewable energy production has become an increasingly popular topic in academic research and governmental policy around the globe. However, many questions about these factors, especially in the transition economies in Central and Eastern Europe and the Caucasus and Central Asia, remain unanswered. To address this gap, this paper presents novel empirical evidence on the primary economic and political factors shaping transitions to a low carbon economy via renewable energy generation in post-socialist countries. Using extensive data from 27 transition economies over the years 1990-2014, it has been found that higher economic growth and rising level of unemployment and government debt acted as stimulators of renewable energy generation. The implementation of the Kyoto Protocol also led to the significant increase in renewables utilization. Furthermore, increasing CO_2 emissions per capita, the implementation of the competition policy and deteriorating competitiveness within the energy market significantly limited production of energy from renewable sources. The findings also suggest that since the beginning of the last global financial crisis in 2007 reinforcement of competition within energy market and additional public funding had a much stronger role to play as factors stimulating renewables deployment.

Keywords: Renewable energy, transition economies, energy transition

1. Introduction

Today, with the clear identification of a number of global environmental threats, few people seriously deny the urgent need to address climate change. Many ways to do so have been promoted: development of pro-ecological technologies [1], water and energy conservation [2], or improvement of energy efficiency [3]. As a well-accepted solution to mitigate CO_2 emissions, renewable energy generation and consumption also rank highly [4].

Renewable energy constitutes an important component of energy supply which can optimize the existing energy mix and balance market contradictions, while preserving the ecological environment at the same time [5]. Thus, development of renewable energy sources becomes a key question in transformation towards a low-carbon economy at a national and regional level [6]. As such, renewable energy has received a widespread attention in recent years [7].

The quest for renewable energy is becoming a major challenge, as renewable energy sources could meet as much as half of global energy demand by 2050 [8]. The International Renewable Energy Agency even

assumes that renewable energy must account for two-thirds of the world's total energy supply in the year 2050 [9]. A possible future transition to a low carbon economy depends on the substitution away from fossil fuels toward new, renewable sources [10, 11, 12]. The crucial importance of energy generation and consumption for social welfare, the environment, climate change and resource exploitation ensures that these transformation processes feature prominently on the social and political agenda [13].

Although a number of studies have investigated historical energy transitions [14, 15, 16, 17, 18, 19], offering a rich understanding of their nature and implications, only a small number have empirically explored the factors influencing renewable energy generation [7, 20, 21, 22]. To the best of our knowledge, no work has addressed the issue for transition economies in Central and Eastern Europe and the Caucasus and Central Asia (CEECCA). Energy transition in the above group of countries is of particular importance as the transition of post-socialist countries to western-type, liberal capitalism has been interpreted as an important step toward a more ecologically sustainable Europe [23]. Furthermore, transition economies in CEECCA accounted for approximately 10 percent of global greenhouse gas (GHG) emissions in 2012, with only 5.6 percent of the global population and 5.7 percent of global GDP [24]. Finally, the year 2014 marks quarter of a century since the beginning of the post-socialist transformation. All of these conditions make it even more desirable to gain a better understanding of the factors influencing renewable energy generation in the countries of Central and Eastern Europe and the Caucasus and Central Asia.

This study seeks to fill the gap in existing empirical knowledge by examining the effects of several different macroeconomic and institutional characteristics on renewable energy production for 27 post-socialist countries in the years 1990-2014 and offering novel quantitative evidence on the issue. The above approach should contribute to a better and more precise understanding of factors shaping the role of renewables in the low-carbon transformation. It should also enable policymakers in transition economies to make more informed decisions related to renewable energy policy implementation. In particular, this paper addresses the following research question:

What are the main factors affecting renewable energy production during post-socialist transformation?

The obtained results indicate that the higher economic growth, rising level of unemployment, size of general government debt, and implementation of the Kyoto Protocol were all significant positive predictors of renewable energy generation for the countries in the sample over the analyzed period. The results also show that increasing CO_2 emissions per capita, the implementation of the competition policy

and lack of competitiveness within the energy market significantly limited renewable energy sources deployment.

The remainder of this study is structured as follows. Section 2 provides the theoretical framework upon which the empirical work is based and the research hypotheses. Section 3 describes the empirical data and formulates the empirical model. Section 4 presents and discusses empirical results. Section 5 covers robustness checks. Section 6 summarizes main conclusions and provides policy recommendations, as well as makes suggestions for future research.

2. Theory

There are several economic, technical and political factors mentioned in the existing body of literature which might affect renewable energy generation. Economic factors concentrate on economic development, utilization of the labor force, price movements, access to financial capital, trade balance and current greenhouse gas emissions. Technical factors embrace research and development (R&D) capabilities. Political factors involve implementation of competitive markets (e.g. privatization and restructuration), competitiveness within the energy market and participation in international integration and international commitments to emissions reduction.

2.1. Economic factors

2.1.1. GDP growth and renewable energy production

Renewable energy generation capability is inseparable from the level of economic development. Thus, the relationship between GDP and renewable energy production has been widely discussed in the academic literature. Based on the analysis of a different blocks of African countries during the years 1980-2008, Abanda et al. [25] observed that gross domestic product and generation of energy from renewable sources are positively and significantly correlated. Khoshnevis Yazdi and Shakouri [26] also showed that economic growth was favorable for the development of the renewable energy sector in Iran. In their study of bioenergy production drivers in the Organization for Economic Development and Cooperation (OECD) countries, Gan and Smith [27] reported that countries with higher GDP were more concerned with alternative energy supply. Thus, their policies were more focused on developing renewable energy generation capacity. The above phenomenon can be explained by a long-term positive relationship between renewable energy consumption per capita and real GDP per capita found by Apergis and Payne [28]. Finally, Zeb et al. [29] also confirmed that domestic income indeed has a significant impact on

electricity production from alternative sources in Bangladesh, India, Nepal, Pakistan and Sri Lanka over the period of 1975 to 2010. The above findings lead to the first hypothesis:

H1. Renewable energy production is positively influenced by GDP growth

2.1.2. Unemployment and renewable energy production

Renewable energy generation projects may serve as an effective way to reduce excessive unemployment by creating additional job opportunities. Hillebrand et al. [30] analyzed the employment effect of introducing compulsory compensation schemes for electricity produced from renewable energy in Germany. These researchers found that an expansive effect resulting from additional investments leads to an increase in employment of approximately 33,000 new jobs. Similarly, Dvořák et al. [31] analyzed the employment benefits of investment in renewable energy in the Czech Republic. They also found that development of the renewable energy sector had a positive impact on decreasing the unemployment rate, as it succeeded in creating more than 20,000 additional jobs in 2010.

On the basis of an analysis of renewable energy production in the Lodzkie Voivodeship, Igliński et al. [32] stressed that a high unemployment rate supports development of renewable energy sources. The authors not only noted that the renewable energy sector in Poland is one of the few industry sectors experiencing annual growth in employment in the country, but they also indicated that working conditions in the renewable energy sector are safer than in places of non-renewable energy production, such as coal mines. Thus, the second hypothesis is formulated as follows:

H2. Renewable energy production is positively stimulated by a rising unemployment rate

2.1.3. Inflation, domestic credit supply, government debt, foreign direct investments and renewable energy production

Access to financial capital is crucial to successfully accelerate the deployment of renewable energy through diverting additional funds into promising projects in the above area. The above access to financial capital can be driven by several factors. The most important of them are: inflation, domestic credit supply, government debt and foreign direct investments.

Changes in prices can have a profound impact on the structure of energy production. There is widespread evidence that an increase in traditional fuel prices not only negatively affects economic activity but can also cause serious social disruption [33]. In addition, high prices of fossil fuel energy, which usually trigger

inflation, support efforts to find alternative and renewable sources of energy – the historical oil price spikes in the 1970s and 1980s led to a visible increase in R&D expenditures on renewable energy in OECD countries [34]. Additionally, Bird at al. [35] also found that high wholesale electricity prices improve the relative competitiveness of wind energy generation in the United States. Similarly, by analyzing data related to inflation and renewable energy production in the OECD member-countries over the period from 1997 to 2006, Chang et al. [36] suggested that higher consumer price index variation is positively related to the contribution of renewables to energy supply.

Successful development of renewable energy projects requires financial capital, with banking credit being the main source of external financing for energy investments in most countries [37]. The significant role of domestic credit availability in renewable energy development is rather undisputed. Based on an analysis of panel data from 119 non-OECD countries for the years 1980–2006, Brunnschweiler [38] found a positive impact of commercial banking on renewable energy production (especially wind, solar, geothermal and biomass). Best [39] found that larger amounts of domestic credit are connected with a higher share of wind energy in total energy use for the sample of 137 countries over the period 1998-2013. Ang et al. [40], on the basis of analysis of OECD and G20 countries from 2000 until 2014, also confirmed that availability of domestic credit to the private sector is an important factor affecting financing decisions in the context of renewable power generation. In addition to the above, after investigating financial development and energy consumption in Central and Eastern European frontier economies, Sadorsky [41] reported that credit accessibility is critical for explaining national energy consumption patterns. Finally, Corsatea et al. [42] also emphasized the importance of access to credit for renewable energy development.

There is general consensus that central governments have considerable means to support energy transition towards renewable sources by increasing public financing of dedicated projects [43]. Depending on the energy type, enterprises operating in the energy sector may find it easier to access public rather than private sources of finance. A typical example of such a situation is nuclear energy production, which is characterized by the long-term and capital-intensive nature of investment and the necessity of addressing nuclear waste. Geothermal energy is another type of energy that is characterized by the specific combination of resource risk, high capital intensity, and long lead times. Thus, public capital should provide strong support to renewable energy development in the above projects, especially in countries where the energy sector is dominated by state-owned enterprises [39].

An effective system of public funding through direct R&D investments, subsidies and tax-credits that target innovators in the renewable energy sector can accelerate diffusion of renewable energy [44]. Olmos et al. [45] suggested that in case of low liquidity of the capital market, public loans supporting alternative energy projects should replace private ones. The authors further noted that in the case of activities where the public sector is more experienced than the private sector, public financial support might even be more effective than the utilization of private capital.

The significant increase of the renewable energy share in total energy production requires considerable investment in clean energy technologies. These technologies can be effectively supported by FDI inflows, which usually bring not only necessary financial capital to developing countries but also know-how, managerial expertise, a more efficient work culture, and a more diversified skills base and its distribution networks [46, 47, 48]. Cosbey et al. [49] note that FDI inflows, through joint projects, can trigger clean development mechanisms, which are characterized by the positive influence on the human environment, as well as by pro-environmental technological evolution in the host country. Paramati et al. [50] report that foreign direct investments enable hosting country to easily overcome the shortage of capital for the renewable energy generation projects.

In line with the above, Gallagher and Zarsky [51] indicated a positive influence of FDI on energy transition toward renewable sources. The authors noted that the above transition is supported by technology leapfrogging, which occurs as a result of state-of-the-art green generation technologies and best environmental management practices transfer through FDI. The above findings were confirmed by Keeley and Ikeda [52]. On the basis of factor analysis of questionnaires obtained from 225 actors directly engaged in foreign direct investment processes, Kumar and Sinha [53] also found that FDI brings greater energy efficiency, supports the use of renewable sources of energy, reduces the demand-supply gap in the energy sector and improves socio-economic development through dissemination of secure, reliable, clean and affordable energy resources. The above findings lead to the third hypothesis:

H3. Renewable energy production is positively related to inflation, domestic credit availability, government debt and net FDI inflows

2.1.4. Current account balance, greenhouse gas emissions and renewable energy production

Trade balance in not indifferent to the energy production structure. Chang et al. [36] showed that the current account deficit can positively influence renewable energy production. Furthermore, through reduction in import growth, renewable energy generation can substantially improve an unfavorable trade

balance of a given country [54]. Increased dependence on imported oil and a deteriorating trade balance over time may also trigger the development of the renewable energy sector as a way to address possible energy security concerns, particularly in the periods of high fossil fuels prices [27, 39]. The threats of global terrorism, which increases the vulnerability of tankers and pipelines that carry approximately 40% of the world's oil, may also force importers to develop alternative sources of energy [55].

Further, greenhouse gas emissions are also among major economic indicators that might drive renewables capacity. The above is due to the fact that many countries and international organizations view renewable energy as an important factor of large and extensive GHG emissions reduction efforts [56]. For example, Cerdeira Bento and Moutinho [57] found cointegration between CO_2 emissions per capita and per-capita renewable electricity production for Italy from 1960 to 2011. Also Dogan and Seker [58] reported casualty between renewable energy generation and overall level of CO_2 emissions for the European Union over the period 1980–2012. The above findings lead to the fourth hypothesis:

H4. Renewable energy production is positively stimulated by deteriorating current account balance and increasing CO_2 emissions levels

2.2. Technical factors

2.2.1. Research and development capabilities and renewable energy production

Development and deployment of renewable energy require proper technologies, ensuring competitive and cost-efficient energy supply. The above technologies can easily promote and speed up renewable energy generation [59]. They can be stimulated by human capital and knowledge development, strongly affected by the research and development capabilities.

R&D is one of the key factors shaping renewable energy generation capacity. Weak R&D capability usually results in low renewables utilisation and their high development costs, which hinders the practical applications of renewable energy generation [5]. Zaho et al. [60] also name research and development as one of the most important driving factors of renewable energy deployment in China, as strong technology R&D raises the industry standards and market access. Insufficient research and development funding hinders making renewable energies commercially competitive with other energy sources and, as development stage risks are high, furtherly discourages energy firms from spending on renewable projects [61]. Finally, energy sector professionals also state technological barriers, like scarce R&D initiatives, as strongly and negatively influencing the deployment of renewable energy [62]. Thus, the fifth hypothesis is formulated as follows:

H5. Renewable energy production is positively stimulated by rising research and development expenditures

2.3. Political factors

2.3.1. Enterprise restructuring, competition policy implementation, competitiveness within the energy market and renewable energy production

Government policy is a major mechanism to stimulate the creation of new markets connected with renewable energy production. Government policy must properly support firms' entries and the creation of new knowledge and supply of necessary resources [63]. The main aims of energy sector reforms in post-socialist transition countries were to improve its competitiveness and efficiency, expand investments, upgrade technology, and dismantle state-led development model [64].

Painuly [65] indicated that market failures related to government monopolies in the energy sector and restriction of private sector entries are both significant factors hampering renewable energy production. Similarly, Beck and Martinot [66] showed that a monopoly in electricity production and distribution hampers investments in renewable energy facilities by independent power producers. The authors also suggested that the implementation of competitive markets as well as privatization and restructuring of utilities is critical in the promotion of renewable energy production. Also Lin and Omoju [21] confirmed that competitiveness within the energy market, measured by the natural resources rents as a percentage of GDP, encourage investors to engage in a market not dominated by incumbent actors. On the basis of the above our sixth hypothesis is as follows:

H6. Renewable energy production is positively stimulated by enterprise restructuring, competition policy implementation and energy market competitiveness

2.3.2. Integration with the European Union, participation in international commitments to emissions reduction and renewable energy production

There are also other important political factors influencing renewable energy transitions in the context of post-socialist economies – participation in the European Union integration process and eventual accession and international commitments to reduce greenhouse gas emissions and the emission-trading schemes. The EU is widely perceived as the most successful region in the implementation of renewable energy sources, with high and impressive indicators and growth rates for wind, solar photovoltaics, biomass and geothermal electricity production [67]. To reach the ambitious reference targets for the share of national renewable electricity generation, every EU country follows a different promotion strategy [68]. Both the

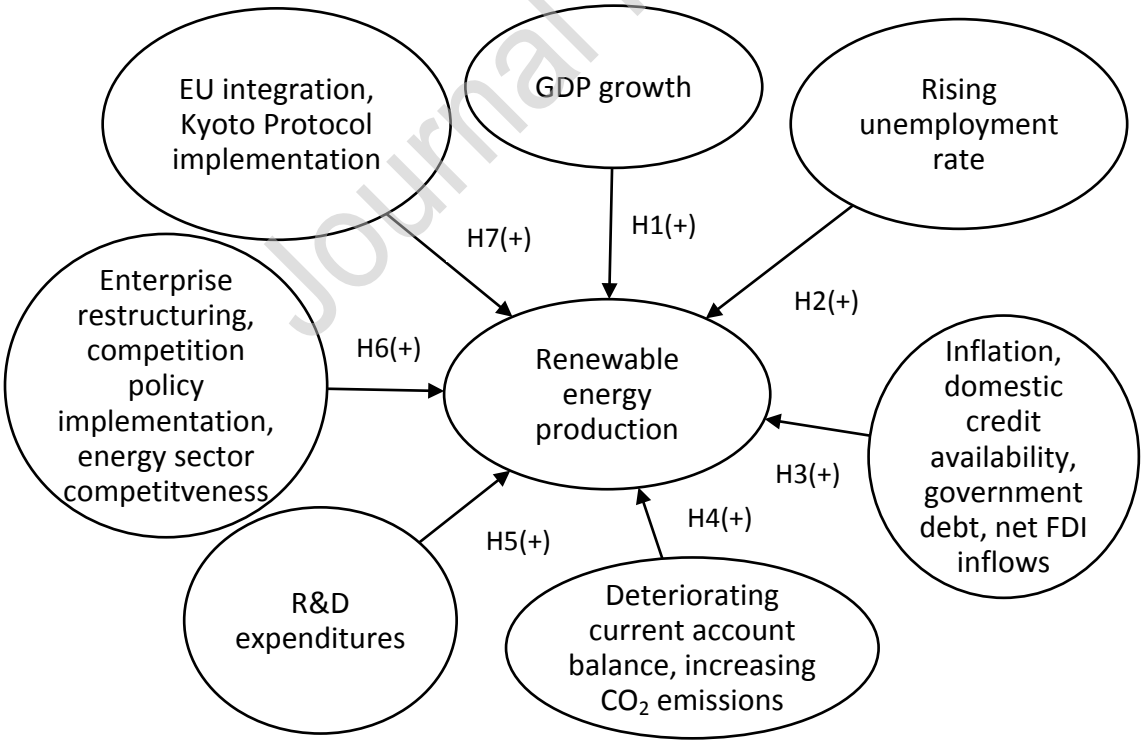
academic literature and governmental and non-governmental reports indicate a significant rise in renewable energy production in the European Union member states as the result of its carefully crafted policy [69, 27].

The Kyoto Protocol signed in 1998 and implemented in 2005 is seen as a key milestone in promoting carbon reduction and increased national commitments of signatories to renewables deployment through renewable energy policies formulation [70]. It fostered a significant change in the way of thinking by the policymakers by restricting greenhouse gas emissions through relevant regulation and contributed to transition to a low-carbon economy. Liu et al. [7] empirically showed that the implementation of the Kyoto Protocol in 2005 had a strong positive impact on renewable energy development for a sample of 29 countries during the period of 2000 to 2015. Thus, the seventh and last hypothesis is formulated as follows:

H7. Renewable energy production is positively stimulated by integration with the European Union and the Kyoto Protocol implementation

Research framework is presented pictorially in Figure 1.

Figure 1. Research framework – factors differentiating renewable energy generation



3. Case study

3.1 Data Description

The data for this study were derived from an investigation of 27 post-socialist countries in Central and Eastern Europe and the Caucasus and Central Asia[1] over the years 1990-2014. Renewable energy production, CO_2 emissions, research and development expenditures and rents from natural resources data for each economy were collected from the World Bank database. Data on GDP growth, unemployment, inflation, governmental debt, domestic credit, foreign direct investment, current account balance, governance and enterprise restructuring and competition policy were derived from the European Bank for Reconstruction and Development (EBRD) database. The International Monetary Fund database served as a supplementary source from which missing data were obtained. The selection of the sample period – years 1990-2014 - was restricted by the availability of data. Specifically, the governance and enterprise restructuring and competition policy indicators were published by EBRD for the last time for the year 2014 and no comparable approach was developed since then. Additionally, no comparable data series for the sample countries on CO_2 emissions (both in absolute terms and per capita) after the year 2014 are available.

The analysis started with an investigation of all potential factors influencing renewable energy generation identified is Section 2. Table 1 presents a summary of descriptive statistics for our sample of countries. Mean electricity production from renewable sources as a percentage of total electricity generation (REN_PROD) [including geothermal, solar, tides, wind, biomass and biofuels] was 27.3%. The average GDP growth rate in % (GDP) was almost 2.04%. The average unemployment rate in % of the labor force (UNEMP) was slightly below 10.3%. The mean annual inflation rate in %, measured as the Consumer Price Index (CPI), was almost 143% and was due to hyperinflation in the early 1990s in all of the countries in the sample (with four-digit annual values of CPI in several cases). The average government debt expressed as a percentage of GPD (GOV_DEBT) was less than 38.5%. The mean annual domestic credit change in % (DOM_CRE) was just over 43.7%. The average net foreign direct investment inflow in millions of USD (FDI) was almost 1,824. The average country in the sample was characterized by the current account deficit of more than 4.6% of GDP (CURR_ACC). The average EBRD transition score[2] in governance and enterprise

[1] Albania, Armenia, Azerbaijan, Belarus, Bosnia and Hercegovina (since 1993), Bulgaria, Croatia (since 1991), Czech Republic, Estonia, FYR Macedonia, Georgia, Hungary, Kazakhstan, Kyrgyz Republic, Latvia, Lithuania, Moldova (since 1991), Mongolia, Poland, Romania, Russian Federation, Slovak Republic, Slovenia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

[2] The average transition score ranges from 1.0 to 4.3, with 1.0 representing little or no progress from a centrally planned economy and 4.3 representing the standards of an industrialized market economy.

restructuring (GER) was almost 2.16, showing moderately tight credit and subsidy policy, together with weak enforcement of bankruptcy legislation and little action taken to strengthen competition and corporate governance. Mean EBRD transition score in competition policy (CP) was just over 2.1, indicating the establishment of competition policy legislation and institutions and some reduction of entry restrictions or enforcement action on dominant firms. The average research and development expenditure was more than 6.1% of GDP (RD_EXP). The average total natural resources rents (from oil, natural gas, coal, mineral, and forest) were almost 6.65% of GDP (NRR_TOT) and coal rents 0.42% of GDP (COALR) respectively. Following existing literature [21, 71], both above measures were used as a proxy of competitiveness within the energy market with rising value representing its lower level. We decided to analyze coal rents separately as coal is the dirtiest of all fossil fuels in terms of carbon emissions. Mean CO_2 emissions per year were around 121,709.3 kilotons (CO2_TOT) and almost 5.7 metric tons per capita (CO2_PC). Analyzed countries were mostly dispersed and skewed in inflation, domestic credit growth, coal rents and net foreign direct investment flows.

Table 1 Summary statistics for all countries in the sample over the years 1990-2014.

	Mean	SD	Min	Max	Skewness	Kurthosis	N
REN_PROD	27.3027	31.2459	0.0000	100.0000	1.1803	0.0092	670
GDP	2.0360	9.2842	-60.0000	86.0000	-0.3023	15.0460	670
UNEMP	10.2538	8.0881	0.0000	44.7700	1.6533	3.4384	670
CPI	142.6254	737.8647	-24.5000	15606.5000	15.1163	295.7282	667
DOM_CRE	43.7256	153.2676	-137.1900	2603.4400	11.0227	155.8828	561
GOV_DEBT	38.4781	29.3730	0.0000	319.7900	2.8147	17.1612	609
FDI	1,823.8089	4,944.7404	-7,335.0000	69,218.8900	8.0328	89.0137	645
CURR_ACC	-4.6229	8.7672	-40.2200	49.5900	0.3157	4.6556	618
GER	2.1578	0.8051	1.0000	3.7000	0.1369	-0.8168	670
CP	2.1040	0.7651	1.0000	3.6700	0.1059	-0.7012	670
RD_EXP	0.6138	0.4481	0.0161	2.5801	1.3680	2.6013	436
NRR_TOT	6.6499	12.0208	0.0000	86.4526	2.8816	9.5730	639
COALR	0.4242	1.5724	0.0000	25.3158	10.3345	134.3464	639
CO2_TOT	121,709.2908	315,749.8168	1,543.8070	2,078,668.2860	4.4107	19.2945	632
CO2_PC	5.6601	3.6082	0.2927	15.9403	0.6186	-0.2167	632

3.2 Empirical Model

Before constructing a formal, multivariate regression model, the potential threat of multicollinearity among some of the previously identified factors influencing renewable energy production (see Table 1) was eliminated by removing those of them from further consideration, which were characterized by pairwise correlation coefficients in excess of 0.5. As a result, the Consumer Price Index, research and development expenditure, and transition score in governance and enterprise restructuring were omitted from the analysis. Table 2 presents the Pearson Correlation Coefficients for all independent variables.

The above adjustments left us with the regression model specified in equation (1), which enabled us to empirically test all the main hypotheses formulated in Section 2. Following the approach used in the majority of existing studies focusing on the relationship between various macroeconomic and institutional factors and renewable energy production discussed in the theoretical framework, we used a panel data analysis.

$$REN\_PROD_{it} = \alpha + \beta GDP_{it} + \gamma UNEMP_{it} + \delta DOM\_CRE_{it} + \theta GOV\_DEBT_{it} + \mu FDI_{it} + \rho CURR\_ACC_{it} + \sigma CP_{it} + \tau NRR\_TOT_{it} + \varphi COALR_{it} + \omega CO2\_TOT_{it} + \vartheta CO2\_PC_{it} + \xi EU\_MEM_{it} + \pi KYOTO_{it} + \varepsilon_{it} \quad (1)$$

where REN_PROD_{it} is renewable electricity production (from geothermal, solar, tides, wind, biomass and biofuels) in % of total electricity production in a given country *i* in year *t*; GDP_{it} is annual growth rate of Gross Domestic Product in % in a given country *i* in year *t*; $UNEMP_{it}$ is unemployment rate in % of the labor force in a given country *i* in year *t*; DOM_CRE_{it} is domestic credit value change in % in a given country *i* in year *t*; GOV_DEBT_{tt} is government debt in % of GDP in a given country *i* in year *t*; FDI_{it} is net foreign direct investment flow in millions of USD in a given country *i* in year *t*; $CURR\_ACC_{it}$ is current account balance in % of GDP in a given country *i* in year *t*; CP_{it} is EBRD transition score in competition policy in a given country *i* in year *t* (with a value from 1.0 to 4.3, with 1.0 representing no competition legislation and institutions and 4.3 representing effective enforcement of competition policy and unrestricted entry to most markets); NRR_TOT_{it} are total natural resources rents (from oil, natural gas, coal, mineral, and forest) in % of GDP in a given country *i* in year *t*; $COALR_{it}$ are coal rents in % of GDP in a given country *i* in year *t*; $CO2\_TOT_{it}$ are total CO_2 emissions in kilotons in a given country *i* in year *t*; $CO2\_PC_{it}$ are total CO_2 emissions per capita in metric tons in a given country *i* in year *t*; EU_MEM_{it} is a dummy variable representing the membership of a given country *i* in year *t* in the European Union, with a value of 1 from the year *t* marking the accession onwards and 0 otherwise; and $KYOTO_{it}$ is a dummy variable representing Kyoto Protocol implementation, with a value of 1 for the implementation countries from 2005 onwards and 0 otherwise.

Table 2 Correlation matrix

	GDP	UNEMP	CPI	DOM_CRE	GOV_DEBT	FDI	CURR_ACC	GER	CP	RD_EXP	NRR_TOT	COALR	CO2_TOT	CO2_PC
GDP	1													
UNEMP	0.124***	1												
CPI	-0.291***	-0.086**	1											
DOM_CRE	-0.282***	-0.100**	0.734***	1										
GOV_DEBT	-0.124***	0.118***	-0.035	-0.029	1									
FDI	0.061	-0.088**	-0.060	-0.057	-0.118***	1								
CURR_ACC	0.030	-0.083**	-0.133***	-0.028	-0.025	0.070*	1							
GER	0.203***	0.151***	-0.241***	-0.276***	-0.044	0.223***	0.038	1						
CP	0.163***	-0.010	-0.194***	-0.168***	-0.057	0.259***	0.088**	0.874***	1					
RD_EXP	-0.269***	-0.156***	-0.021	-0.128***	-0.042	0.140***	0.189***	0.540***	0.563***	1				
NRR_TOT	0.197***	-0.026	0.007	0.111***	-0.176***	0.059	0.363***	-0.345***	-0.292***	-0.286***	1			
COALR	0.067*	-0.053	-0.020	-0.006	0.002	0.075*	-0.070*	-0.047	0.034	-0.120**	0.274***	1		
CO2_TOT	-0.051	-0.119***	0.017	0.029	-0.053	0.443***	0.288***	-0.016	.084**	0.251***	0.127***	0.033	1	
CO2_PC	-0.029	-0.069*	-0.019	0.045	-0.265***	0.325***	0.257***	0.249***	0.282***	0.524***	0.256***	0.126***	0.434***	1

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

The analysis of factors determining renewable energy production in transition countries was based on the data from the same year. This allowed to capture their immediate influence on the possible generation of electricity from renewable, eco-friendly sources. However, to address possible issues of long-term casualty, additional sensitivity analysis for lagged effects was also conducted.

4. Results and discussion

This section examines the effects of different economic and political factors on renewable energy production in transition countries. Table 3 presents the results of Eq. (1) parameters estimation.

Table 3 Renewable energy production model parameters

Variable	Intercept	t-Stat	P-value	VIF
GDP	0.5483***	2.7756	0.0057	1.2915
UNEMP	0.2298*	1.8128	0.0704	1.0934
DOM_CRE	-0.0067	-0.7942	0.4275	1.1149
GOV_DEBT	0.1052***	2.6420	0.0085	1.2965
FDI	-0.00001	-0.0414	0.9670	1.4349
CURR_ACC	-0.0249	-0.1650	0.8690	1.4803
CP	-12.7711***	-5.4765	0.0000	2.6366
NRR_TOT	-0.6189***	-4.9290	0.0000	2.1263
COALR	-1.1495*	-1.7050	0.0888	1.2966
CO2_TOT	0.00001***	3.2239	0.0013	1.6428
CO2_PC	-4.2471***	-10.7233	0.0000	1.9197
EU_MEM	4.0640	1.0738	0.2834	2.2548
KYOTO	13.5088***	5.4056	0.0000	1.5497
R2	0.4595			
Adjusted R2	0.4461			
ANOVA F	34.2003***			
No obs.	7,518			

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Regression analysis provided strong empirical evidence to support Hypotheses 1 and 2 and parcial support for Hypotheses 3, 4, 6 and 7. In particular, in the area of economic factors (Hypotheses 1, 2, 3 and 4), higher economic growth and rising level of unemployment and government debt acted as stimulators of renewable energy production in transition countries over the analyzed period. The above shows that renewable energy generation capability in post-socialist economies is indeed inseparable from the level of economic development and is in line with the existing studies [25, 26]. Only countries with stable and

strong GDP growth paths were able to stay at the forefront of energy transition toward renewable sources by providing enough economic flows for the necessary investment. Furthermore, development of renewable energy sources in CEECCA region was connected with certain employment benefits, which is also in line with existing studies in the area [31, 32]. Thus, the development of renewable energy generation projects was an important way to stimulate labor market growth during the post-socialist transition. The positive and significant result obtained for governmental debt confirms the existence of strong national governments´ financial support for energy transition toward renewable sources [36] and reinforces studies underlining significant role of public financing in the above area [43, 45]. However, such support will only foster renewable energy generation if the correct policies are put in place, otherwise leading to lower capital availability negatively impacting capital intensive projects. The existence of a strong positive relationship between government debt level and energy transition toward renewable sources may also confirm insufficient ability of national governments in the region to attract private investors in the above area, especially that domestic credit expansion generally acted as a factor limiting renewable energy generation, although was not statistically significant. Finally, considering greenhouse gases emissions, increasing CO_2 emissions per capita acted as a significant factor diminishing renewables capacity with the opposite effect for overall CO_2 emissions. This shows that overall carbon footprint measures are much more visible from the international perspective and, as such, treated much more seriously by the national governments in their quest towards cleaner energy technologies utilization, which is in line with existing studies in the area [56, 58]. It also proofs that higher CO_2 emissions intensity per capita strongly deters implementation of renewable energy sources. This finding is in contrast with previous research [57].

In terms of political factors (Hypotheses 6 and 7), the results showed that the introduction of competition policy in the form of increased enforcement actions to reduce abuse of market power and the promotion of a competitive environment acted as a statistically significant factor limiting renewable energy generation. This is quite surprising, as reduction of entry restrictions and enforcement of action on dominant firms connected with a significant rise in the importance of environmental protection policy after the change toward the market economy should trigger the production of energy from renewable sources [65, 66]. It might show the presence of strong support for the old energy economy in transition countries, fueled by powerful oil, coal and natural gas industry lobbies, which are able to successfully shape changing competition regulation in their favor. The above is confirmed by lower competitiveness within the energy market (measured by increased natural resources rents as a percentage of GDP) acting as a factor significantly limiting renewable energy production. The results also showed strong and highly

significant positive relationship between the Kyoto Protocol implementation and renewables capacity in post-socialist countries. This confirms that its validation in 2005 served as a key milestone in energy transition [7]. Surprisingly, the results did not show that accession to the European Union acted as a breakthrough point in transition away from fossil fuels toward renewable sources of energy in analyzed countries. The above finding is not in line with expectations, as fostering the use of renewable energies for power generation is at the heart of the EU's long-term energy policy [55].

The model did not indicate support for Hypothesis 3 in the area of net FDI inflows. It showed that they did not affect renewable energy production among analyzed transition economies. The above is in contrast with the evidence from previous studies suggesting that higher net foreign direct investments flows should positively stimulate renewable energy production [51, 53]. No statistically significant relation found in the above area shows that, as in the case of domestic credit, additional financial capital in the form of FDI is not usually invested in projects connected to the development of alternative energy generation capacity. No evidence to support Hypothesis 4 in the area of current account balance was obtained. Although increased import dependence should trigger the development of local renewable energy generation this was not confirmed by presented empirical findings. Finally, as both inflation and research and development expenditures were eliminated from the empirical model due to their strong collinearity with other independent variables, we were not able to put additional light on their potential significance as factors driving renewable energy generation in analyzed post-socialist countries. To summarize, Table 4 synthesizes the results related to each formulated hypothesis.

Table 4 Synthesis of results for the formulated hypotheses

Hypothesis	Empirical result
H1. Renewable energy production is positively influenced by GDP growth	Supported
H2. Renewable energy production is positively stimulated by a rising unemployment rate	Supported
H3. Renewable energy production is positively related to inflation, domestic credit availability, government debt and net FDI inflows	Supported for government debt
H4. Renewable energy production is positively stimulated by deteriorating current account balance and increasing CO_2 emissions levels	Supported for overall CO_2 emissions
H5. Renewable energy production is positively stimulated by rising research and development expenditures	Not supported
H6. Renewable energy production is positively stimulated by enterprise restructuring, competition policy implementation and energy market competitiveness	Supported for energy market competitiveness
H7. Renewable energy production is positively stimulated by integration with the European Union and the Kyoto Protocol implementation	Supported for the Kyoto Protocol implementation

5. Robustness checks

The existing studies found some significant lagged relationships between different economic and institutional factors and renewable energy generation [7, 72]. Thus, to ensure that the results described above are robust, Eq. (1) parameters were re-estimated using economic and political explanatory variables delayed by one year. Table 5 presents the results of the regression analysis in the above area. It provides evidence that renewable energy supply is also an artifact of previous developments in GDP growth, government debt, CO_2 emissions, competition policy implementation, competitiveness within the energy market, and Kyoto Protocol implementation. Thus, statistically significant associations between renewable energy production and selected independent variables identified in Table 3 are more long term in nature.

Table 5 Renewable energy production model parameters with lagged economic and political effects

Variable	Intercept	t-Stat	P-value	VIF
GDP_{t-1}	0.5027**	2.5294	0.0117	1.2922
$UNEMP_{t-1}$	0.1933	1.5020	0.1337	1.0955
DOM_CRE_{t-1}	-0.0078	-0.9313	0.3521	1.1146
GOV_DEBT_{t-1}	0.1033**	2.5619	0.0107	1.2968
FDI_{t-1}	0.00002	0.1080	0.9141	1.4089
$CURR\_ACC_{t-1}$	-0.0072	-0.0465	0.9629	1.4914
CP_{t-1}	-12.4013***	-5.2023	0.0000	2.5833
NRR_TOT_{t-1}	-0.6120***	-4.8119	0.0000	2.1405
$COALR_{t-1}$	-1.1091	-1.6380	0.1020	1.2912
$CO2\_TOT_{t-1}$	0.00001***	3.0530	0.0024	1.6192
$CO2\_PC_{t-1}$	-4.3132***	-10.5738	0.0000	1.9331
EU_MEM_{t-1}	4.1683	1.0673	0.2864	2.1848
$KYOTO_{t-1}$	13.1567***	5.1184	0.0000	1.5552
R^2	0.4584			
Adjusted R^2	0.4443			
ANOVA F	32.4254***			
No obs.	7,168			

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Next, in order to obtain metric-free results, we adopted standardized coefficients and re-estimated parameters of Eq. (1) for both current and one year lagged explanatory variables. Obtained results presented in table 6 showed that the variables with the strongest positive effect on renewable energy production in transition economies were Kyoto Protocol implementation, GDP growth and absolute CO_2 emissions. On the other end of the spectrum, the variables with the strongest negative effect on renewables deployment were CO_2 emissions intensity per capita, introduction of competition policy and lack of competitiveness within the energy market.

Table 6 Renewable energy production standardized models parameters

	Standardized coefficients				One year lagged standardized coefficients			
Variable	Intercept	t-Stat	P-value	VIF	Intercept	t-Stat	P-value	VIF
GDP	0.1629***	2.7755	0.0057	1.2915	0.1518**	2.5300	0.0117	1.2922
UNEMP	0.0595*	1.8140	0.0702	1.0934	0.0503	1.5005	0.1341	1.0955
DOM_CRE	-0.0327	-0.7945	0.4273	1.1149	-0.0392	-0.9326	0.3515	1.1146
GOV_DEBT	0.0989***	2.6426	0.0085	1.2965	0.0980**	2.5619	0.0107	1.2968
FDI	-0.0014	-0.0406	0.9676	1.4349	0.0039	0.1078	0.9142	1.4088
CURR_ACC	-0.0070	-0.1649	0.8691	1.4803	-0.0021	-0.0472	0.9624	1.4913
CP	-0.3127***	-5.4760	0.0000	2.6368	-0.3003***	-5.2029	0.0000	2.5828
NRR_TOT	-0.2381***	-4.9296	0.0000	2.1263	-0.2378***	-4.8127	0.0000	2.1404
COALR	-0.0578*	-1.7051	0.0888	1.2966	-0.0565	-1.6365	0.1024	1.2912
CO2_TOT	0.1315***	3.2242	0.0013	1.6428	0.1265***	3.0524	0.0024	1.6192
CO2_PC	-0.4904***	-10.7230	0.0000	1.9198	-0.4958***	-10.5724	0.0000	1.9331
EU_MEM	0.0475	1.0735	0.2835	2.2549	0.0472	1.0660	0.2869	2.1844
KYOTO	0.2122***	5.4056	0.0000	1.5497	0.2039***	5.1190	0.0000	1.5551
R^2	0.4595				0.4584			
Adjusted R^2	0.4461				0.4443			
ANOVA F	34.2008***				32.4227***			
No obs.	7,518				7,168			

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

As the recent global financial crisis (GFC), which started in 2007, has brought increased attention to environmental preservation issues and heightened the importance of the necessary change towards renewable energy generation [22, 73], it might have had a profound effect on energy markets in post-socialist economies. Thus, to test if there are any differences in the influence of previously identified economic and political factors on renewables deployment in the analyzed countries we divided the whole period into two sub-periods, 1999–2006 and 2007-2014, and re-estimated Eq. (1) parameters for each. Results presented in table 7 show that there were indeed some important differences in the above area between both subsamples. Specifically, GDP growth was an important factor stimulating renewable energy production only in the first sub-period (1990-2006), while unemployment rate and governmental debt were both significant only during the second sub-period (2007-2014). The above shows that recent GFC and its aftermath, by causing increased unemployment and mobilizing additional public funds, facilitated renewable energy transitions in post-socialist countries. Furthermore, decreasing competitiveness within the energy market was restricting renewable energy deployment much more strongly, while the absolute level of CO_2 emissions acted as its significant stimulator, before the last global financial crisis. Taken together, it shows much lower role of market forces since the beginning of financial turmoil in 2007. Interestingly, being a member of EU rather limited renewable energy generation among transition countries in the sample over the 2007-2014 period, however, without statistical significance.

Table 7 Renewable energy production model parameters for two sub-periods – 1990-2006 and 2007-2014

	1990-2006				2007-2014			
Variable	Intercept	t-Stat	P-value	VIF	Intercept	t-Stat	P-value	VIF
GDP	0.6943***	2.6693	0.0080	1.5256	0.5169	1.4007	0.1629	1.4298
UNEMP	0.1387	0.8799	0.3796	1.2385	0.4643*	1.8130	0.0714	1.2257
DOM_CRE	-0.0041	-0.4774	0.6334	1.1714	-0.0640	-0.9696	0.3335	1.3589
GOV_DEBT	0.0615	1.3837	0.1674	1.3349	0.3699***	3.6637	0.0003	1.3745
FDI	0.0001	0.0691	0.9449	1.4747	0.00001	0.0309	0.9754	2.1117
CURR_ACC	0.1785	0.8454	0.3985	1.5329	-0.2326	-0.8623	0.3896	2.2018
CP	-9.7941***	-3.3466	0.0009	2.1358	-9.0623**	-2.2867	0.0233	3.4922
NRR_TOT	-0.5833***	-4.1288	0.0000	1.7048	-0.3199	-1.1342	0.2581	3.9120
COALR	-7.3071***	-3.2943	0.0011	1.1329	-1.7167*	-1.8940	0.0597	2.0345
CO2_TOT	0.00001***	2.9123	0.0038	1.5004	0.00001	1.1607	0.2472	2.3682
CO2_PC	-4.9844***	-8.6873	0.0000	2.2737	-3.0968***	-4.9153	0.0000	2.0934

EU_MEM	3.0239	0.5126	0.6086	1.4667	-3.5736	-0.5559	0.5789	3.6376
R^2	0.4772				0.4594			
Adjusted R^2	0.4557				0.4258			
ANOVA F	22.2560***				13.6667***			
No obs.	4,634				2,678			

*, **, and *** denote significance at the 10%, 5%, and 1% level, respectively.

Finally, further analysis of collinearity among the economic and political predictors in all the models indicated low variance inflation factors for all independent variables used in the range of 1.0934–2.6368. Thus, multicollinearity did not represent a significant threat to the stability of the estimated parameters. Additionally, to gain a more in-depth understanding of the explanatory capacity of used multivariate regression models, ANOVA analysis was performed for each separate setting, which confirmed all presented results and showed that our models are properly fitted to test the relationship between various economic and political aspects and renewable energy production in post-socialist transition countries.

6. Conclusions

Policy-makers in countries that experienced a transformation from centrally planned systems toward a market economy ought to consider economic and institutional factors related to renewable energy generation, as it would help them to design more effective policies towards achievement of a low-carbon economy. This transition is especially vital now, as almost 30 years have passed since the beginning of post-socialist transformation in Central and Eastern Europe and the Caucasus and Central Asia, and longer term, cross-country datasets are becoming more available.

The reported analysis of factors shaping renewable energy production in post-socialist transition economies provides several insights on how it can be further stimulated and avenues for future research. First, as GDP growth acted as a factor significantly influencing progress in the above area, ensuring stable and reasonable levels of economic growth over time, by making economic resources for investment in alternative energy sources more available, results in a higher renewable energy generation. The above highlights the need for policymakers in transition economies to analyze the solutions to stimulate economic growth applied by top performers in more detail. Second, as a rising level of unemployment positively affects renewables deployment, proper renewable energy promotion has a vital role to play as a potential job creation engine. Thus, the introduction of appropriate financing mechanisms (in the form of feed-in tariffs, capital subsidies, grants, investment tax credits, and sales tax or VAT exemptions) together with market incentives (such as cost-reflective tariffs, green certificates, and carbon taxes)

should play an important role. Furthermore, clear policy targets for renewable energy generation set up at the national level are also vital.

Third, obtained results also showed that governmental financing has a fundamental role to play in effective transition to a low carbon economy in post-socialist countries. Thus, the government's capacity to make effective environmental investments in the area of alternative energy sources in the form of dedicated public loans, direct energy production payments and public competitive bidding are of utmost importance. Fourth, as increasing CO_2 emissions per capita act as a significant factor diminishing renewables capacity, the reduction of national dependence on labour-intensive, high emitting industries and boosting the role of high technology and services sectors is of vital importance for successful energy transition. In close connection with the above point, there is also a need for policymakers to effectively overcome substantial state-owned companies' opposition, which still have a relatively strong economic importance in several countries and usually have vested interests in fossil fuels. This could be done by implementation of dedicated ecological awareness promotion programs throughout the society and stronger cooperation between different levels of government (national, regional, local, different ministries) on long-term ecological issues and environmental risk management.

Fifth, the implementation of the competition policy significantly limited production of energy from renewable sources. Thus, the opportunity remains for future in-depth studies focused on implementation of effective solutions in the area of enforcement of competition policy and unrestricted entry in post-socialist transition countries, which does not harm utilization of alternative energy sources. Additional research could also focus on how to weaken the huge influence of oil, coal and natural gas industry lobby groups, especially that high levels of natural resources rents as a percentage of GDP act as a factor significantly limiting renewable energy production. Sixth, the results highlighted stronger importance of more targeted energy market competition policy focused on a coal sector and mobilization of additional public funds since the beginning of financial turmoil in 2007. Finally, as the implementation of the Kyoto Protocol led to the significant increase in renewable energy generation in post-socialist countries, there is also a strong need for additional multilateral international cooperation and actions among all CEECCA countries. Taking into consideration the current level of political disagreements in the region makes the above need even more pressing.

The method employed in this study has some limitations. Our sample was restricted to transition economies in Central and Eastern Europe and the Caucasus and Central Asia. Therefore, our findings may be peculiar to them and should not be automatically generalized to other, especially more developed

countries. As we only analyzed a selected group of economic and political variables influencing renewable energy generation trajectories, it might be fruitful for future research to examine other unconsidered characteristics (i.e., geographical, historical, and cultural factors). The new EU member states in our sample also have different incentives to implement environmental legislation and renewable energy production goals connected with European Commission demands and monitoring. Thus, an opportunity remains for additional research examining factors influencing electricity generation from alternative sources separately for 11 new EU member states from Central and Eastern Europe (which joined the Community in 2004 and after) and other countries in the Caucasus and Central Asia (including 10 former CIS members). Finally, the presented findings may be affected by the time period of the analysis.

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

- The study provides insights on factors influencing renewable energy generation
- Data from 27 transition countries over the years 1990-2014 were analyzed
- The implementation of the Kyoto Protocol was a milestone in energy transition
- Economic growth, unemployment and rising government debt acted as stimulators
- Deteriorating energy market competitiveness limited renewables deployment