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The impact of agriculture and renewable energy on climate change in Central and East European Countries

Nicoleta Mihaela Florea[1], Roxana Maria Bădîrcea[1], Ramona Costina Pîrvu[2], Alina Georgiana Manta[1], Marius Dalian Doran[1], Elena Jianu[3]*

[1]*Department of Finance, Banking and Economic Analysis, Faculty of Economics and Business Administration, University of Craiova, Craiova, Romania*
[2]*Department of Economics, Accounting and International Business, Faculty of Economics and Business Administration, University of Craiova, Craiova, Romania*
[3]*Department of Finance, Accounting and Economics, University of Pitesti, Pitesti, Romania*

**Corresponding author: nmflorea@yahoo.com*

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Abstract: According to the objectives of the European Union concerning the climate changes, Member States should take all the necessary measures in order to reduce the greenhouse gas emissions. The aim of this study is to identify the causality relations between greenhouse gases emissions, added value from agriculture, renewable energy consumption, and economic growth based on a panel consisting of 11 states from the Central and Eastern Europe (CEECs) in the period between 2000 and 2017. The Autoregressive Distributed Lag (ARDL) method was used to estimate the long-term relationships among the variables. Also a Granger causality test based on the ARDL – Error Correction Model (ECM) and a Pairwise Granger causality test were used to identify the causality relationship and to detect the direction of causality among the variables. The results obtained reveal, in the long term, two bidirectional relationships between agriculture and economic growth and two unidirectional relationships from agriculture to greenhouse gas emissions and renewable energy. In the short term, four unidirectional relationships were found from agriculture to all the variables in the model and one unidirectional relationship from renewable energy to greenhouse gas emissions.

Keywords: Autoregressive Distributed Lag model; Environmental Kuznets Curve theory; greenhouse gas emissions; gross value added from agriculture

The human activity has led to growth of greenhouse gases (GHG) concentration in the atmosphere with direct effects on global warming. As the main environment-related problem, the climate change proved to be a phenomenon residing in the interaction of three main factors: economy (with all its sectors, including agriculture), energy, and environment.

As the other sectors of the economy, the agricultural sector produces greenhouse gases. The emissions from agriculture are generally connected to the management of agricultural soils, animals, rice production, and biomass ignition (Eurostat 2015).

In a report of the Intergovernmental Panel on Climate Change (IPCC) regarding the impact of the global warmth of 1.5°C above the pre-industrial levels and the greenhouse gases emissions associated in the context of consolidating the global answer to the threat of climate changes and sustainable development and the efforts to eradicate poverty, we consider that changing the agricultural practices might be an efficient strategy of adapting to the climate (IPCC 2018). Being the largest source of non-CO_2 emissions (mainly, methane and nitric oxide from livestock production), the

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agricultural sector shall contribute to the reduction of thegreenhouse effects if the target of 1.5°C is reached. Methane and nitrogen oxide emissions from agricultural production represent almost 10–12% of the total anthropic GHG emissions, therefore they are regarded as having an essential role in reaching the target of stabilising the climate at the 1.5°C level (Frank et al. 2019).

On the level of the European Union (EU) the contribution of agriculture to the total emissions have been assessed in a series of studies and reports (FAO 2006) as representing 10.3% of the total EU GHG emissions (Van Doorslaer et al. 2015), the methane from the enteric fermentation representing 32% of total EU agricultural emissions and the management of the manure contributing with 16% to these emissions.

Intensification and specialisation in agriculture led to soil erosion, strong demand for water resources, and severe decline of biodiversity in Europe. On the Central and Eastern European countries (CEECs) level one can notice a better level of biodiversity as compared to the Central Europe (EEA 2003). The main environmental problems identified in the field of agriculture in CEEC were erosion, the water pollution by agricultural chemicals, soil compaction, and manure disposal in the areas with high concentration of livestock production (EC 1998), but there were also new threats caused by excessive grazing and land abandonment.

Production and energy consumption exert significant pressures on the environment in terms of greenhouse gases and atmosphere pollutants emissions, land usage, waste production, and oil spills. These contribute to climate changes, generating damages to natural ecosystems and artificial environment and causing side effects to human health. Renewable energies (wind energy, solar energy, hydroelectric energy, energy of the oceans, geothermal energy, biomass, and biofuels) represent alternatives to fossil fuels and lead to reduction of gases emissions.

In 2017, energy from renewable sources represented 17% of energy consumed in the EU, on the path to reaching the objective of 20% for 2020 (Eurostat 2019), and 32% in 2030 of the consumed energy being from renewable energies (EU 2018). Based on the long-term Strategy of EU economy decarbonization up to 2050 (EC 2018), European Member States will have to completely let go the fossil fuels for the energy generation and rely on renewable energy to the extent of 80%.

This paper concentrates on the impact of the agricultural sector, renewable energy, and economic growth on GHG emissions levels in a panel of 11 Central and Eastern European countries (CEECs) over the period 2000–2017 using the recently developed dynamic panel data methods.

Therefore, the following hypotheses were formulated in order to find answers to the following research questions:

H_1: Is there an impact of the agriculture in greenhouse gas emissions in the CEECs?

H_2: Has the renewable energy consumption any role in decreasing greenhouse gas emissions in CEECs?

H_3: Is the Environmental Kuznets Curve (EKC) theory applying to CEECs?

LITERATURE REVIEW

The relationship between agriculture and environment has been intensively studied, but especially from the point of view of the impact produced by the climate changes on agriculture (Paustian et al. 1998; Simionescu et al. 2019). There is a series of studies regarding the impact of agricultural activity on GHG emissions. Therefore, a study carried out by Tubiello et al. (2013) identified a GHG growth in the agricultural sector of 1.1% each year between 2000 and 2010 on a global level. Paustian et al. (1998) reached the conclusion that agriculture generates significant quantities on carbon dioxide, methane and nitric oxide.

On the EU level, Safwan et al. (2019) pointed out that most of the EU-27 countries registered a significant reduction of the GHG emissions in the agricultural sector, except for Island and Spain, the highest reduction being obtained by the United Kingdom, Germany, and France.

The emission of GHG from agriculture, transportation and international aviation registered a growth in the last five years, according to EEA (2018). Also data reported at the European Union level indicate a slow increase in GHG by 0.6% in 2017 as compared to the previous year, this fact being attributed to the transportation sector. United Nations Framework Convention on Climate Change established in the 2015 Paris Agreement that the GHG emissions from agriculture must be reduced to answer the climate changes (Wollenberg et al. 2016).

Bennetzen et al. (2016) concluded, in a study carried out on a long period of time, that GHG emissions can be reduced only to a certain level, and that simultaneous focus on other parts of the food system is required in order to increase food safety while reducing the emissions.

Starting from the fact that on a global level the energy sectors are considered responsible for more than 66.5% of GHG, while 13.5% of GHG come from the

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agricultural sector (Herzog 2005), this paper analyses the impact of renewable energy on the greenhouse gases in Central and Eastern European countries.

In the reference literature, the relations between economic growth, energy consumption, and its effects on the environment degradation were intensively studied through different methods, data from various groups of countries and periods of time, and varied results, mostly contradictory. As Waheed et al. (2019) pointed out in an extensive analysis of literature from the past two decades in the field of economic growth, energy consumption, and carbon emissions, higher energy consumption is stimulating the economic growth but also leads to a growth of the environment degradation costs.

Saidi and Hammami (2015) analysed the relation between CO_2 emissions, economic growth, and energy consumption in 58 countries and observed that the three indicators are complementary. Sek and Chu (2017) investigated the dynamic relation between the three variables in a country with a high energetic consumption that is China. They noticed a bi-directional relation between energy consumption and greenhouse gases emissions and a uni-directional relation between economic growth and short time energy consumption in China. Also in China, Gessesse (2020) noticed the existence of the EKC hypothesis on a short term, but also of a negative causality between CO_2 emissions and GDP and energy consumption.

Sterpu et al. (2018) pointed out in an analysis carried out on the EU 28 level with the help of two models, quadratic and cubic, that a growth of gross energy consumption leads to a GHG emissions growth while a growth of renewable energy consumption leads to reduction of GHG emissions.

Although for a long period of time, the relations between economic growth, agriculture, energy, and greenhouse emissions had not been an object of analysis. In recent years more and more studies have been oriented towards these relations with an aim to offer recommendations for the decision-making factors regarding economic policy and planning.

Jebli and Youssef (2016) analysed the short and long-term relationships between carbon dioxide, economic growth, renewable and non-renewable energy consumption, commercial opening, and gross added value in agriculture in Tunis in the period 1980–2011. They identified long-term bidirectional relations between all variables taken into consideration, therefore non-renewable energy, trade, and added value in agriculture increase CO_2 emissions.

In another paper, Jebli and Youssef (2017) analysed the causal relations between renewable energy, agriculture, economic growth, and CO_2 emissions in five countries from Northern Africa, pointing out a causality between CO_2 emissions and agriculture and renewable energy, both on a long- and short-term basis.

Liu et al. (2017) investigated relations between the three variables on a level of 4 countries from the Association of Southeast Asian Nations and noticed that a growth of renewable energy and of agriculture determines the lowering of CO_2 emissions, while renewable energy is positively correlated with emissions.

Another study (Berna and Vardar 2020) analysing seven EU countries concludes in a proposal according to which the countries should increase the renewable energy share in order to provide for growth of the agricultural sector, thus reducing fossil energy consumption and environment protection.

On the CEECs level, some studies are worth mentioning in order to better underline the particularities of the countries from this region. Thus, Petrick and Weingarten (2004) emphasized the fact that the agricultural models from EU or those of developing countries can be considered as good practices for CEEC countries. Furthermore, the authors highlight the most important particularity of these countries that is the common past, reflected in a socialist doctrine that was more or less present in all countries. However, in those countries that have retained the large-scale agricultural structures of the collectivist era, agriculture has proven to be more adapted to global competition than in countries where substantial small-scale restructuring has taken place.

Another study (Kantor et al. 2017) makes an overview of specific CEEC political environments that govern economic and environmental policies in order to select several domains representing higher risks to society, environment, and economies of selected countries, together with evaluation of interlinkages between climate change, agriculture, and the water-energy-food nexus.

Furthermore, Banski (2018) reveals important findings concerning the phases to the transformation of agriculture in Central Europe. Therefore, the author emphasizes the significant steps in the transformation of agriculture, the reprivatisation period, and underlines the positive changes that took place after the EU accession. Also, the author makes recommendations concerning possible trends for further changes in the food sector in CEECs in the upcoming years.

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MATERIAL AND METHODS

Data analysis. The main objective of this study is to identify the causality relations between the GHG emissions, the economic growth, agriculture, and renewable energy. Therefore, we used panel data from 11 CEECs (Bulgaria, Croatia, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, and Slovenia), from the period 2000–2017. The choice of the CEECs is motivated by the fact that little attention has been paid to these countries, most articles being focused on developed countries in Central Europe or the European Union as a whole. So, the interest of our analysis is the group of countries and not individual units in the group, which means that very little information is lost by taking the panel perspective. Also, the use of panel to the detriment of time series data is indicated not only by the fact that this increases the number of observations and their variation, but also reduces the noise coming from the individual time series. Therefore, heteroscedasticity is not an issue in panel data analysis. Panel data analysis is best suited where data availability is an issue, particularly for emerging countries, as our case, where short time spans for variables are rampant, often insufficient for fitting time series regressions. In case of the panel data, there is heterogeneity among units in the panel and panel estimation techniques take this heterogeneity into account by allowing for subject-specific variables.

The variables included in this study are: total GHG emissions (*GHG*) collected from European Environment Agency (EEA 2020); agricultural value added per worker (*AGR*) collected from World Development Indicators (The World Bank 2020); renewable energy consumption (*REN*) expressed as a percentage from the total final energy consumption; and real GDP per capita (*GDP*) collected from Eurostat (2020). Annual data used for each variable were collected and processed for the period 2000–2017.

Model and methodology. In researching the causality relation between the variables we start from the following mathematic relation:

$$GHG_{it} = f\left(AGR_{it}, REN_{it}, GDP_{it}, GDP_{it}^2\right) \quad (1)$$

where: *GHG* – total GHG emissions; *AGR* – agricultural value added per worker; *REN* – renewable energy consumption (a percentage from the total final energy consumption); *GDP* – real GDP per capita; $i = 1, 2, ..., 11$ represents each state included in the panel, t – period of time.

Taking into account the characteristics of the data used, it is necessary to make a logarithm. Based on the logarithms, the Equation (1) becomes:

$$\ln GHG_{it} = \alpha_i + \delta_i t + \beta_{1i}\ln AGR_{it} + \beta_{2i}\ln REN_{it} + \beta_{3i}\ln GDP_{it} + \beta_{4i}\ln GDP_{it}^2 + \mu_{it} \quad (2)$$

where: μ_{it} – the residual term; β_i – the associated coefficients for each equation variable; parameters α_i and δ_{it} allow for the possibility of country-specific fixed effects and determining trends.

Panel unit root tests. Before testing the causality relation between the variables, we need to test the stationarity of the data series used within the model. Therefore, we used four unit root tests: Levin-Lin-Chu (LLC) (Levin et al. 2002) to test the common unit root process, and Im-Pesaran-Shin (IPS) (Im et al. 2003), the Fisher augmented Dickey-Fuller (Fisher-ADF) (Maddala and Wu 1999) and the Fisher Phillips-Perron (Fisher-PP) (Choi 2001) tests for the individual unit root process. The null hypothesis for all these tests is the presence of a unit root (non-stationary) and the alternative hypothesis involves the stationarity of the data series.

Panel co-integration tests. The next step involves using the panel co-integration tests to notice whether there is a causality relation between the chosen variables or not. Two co-integration tests specific for the panel data were used within this paper: the Pedroni test based on Engle-Granger (1987) two-step (residual-based) and a Fisher-type test using an underlying Johansen methodology (Maddala and Wu 1999). Pedroni (1999, 2004) proposed in his papers several tests for cointegration that enable heterogeneous intercepts and trend coefficients across cross-sections. Fisher (1932) creates a combined test that uses the results of individual independent tests. Based on Fisher's result, Maddala and Wu (1999) propose an alternative approach for testing for the cointegration in panel data by combining tests from individual cross-sections.

Estimation of long-term relationships. For determination of long-term coefficients, we resorted to the Autoregressive Distributed Lag (ARDL) method for dynamic panel data. We resorted to this method because it is superior to traditional techniques and it has the advantage of not taking into consideration the integration order of the variables. This technique can be used irrespective of the fact that the variables are integrated at I(0), I(1) or mutually integrated (Pesaran et al. 1999).

https://doi.org/10.17221/250/2020-AGRICECON

$$\begin{bmatrix}\Delta\ln GHG_{it}\\ \Delta\ln AGR_{it}\\ \Delta\ln REN_{it}\\ \Delta\ln GDP_{it}\\ \Delta\ln GDP_{it}^2\end{bmatrix}=\begin{bmatrix}\rho_1\\ \rho_2\\ \rho_3\\ \rho_4\\ \rho_5\end{bmatrix}+\sum_{p=1}^{q}\begin{bmatrix}\delta_{11,p}\delta_{12,p}\delta_{13,p}\delta_{14,p}\delta_{15,p}\\ \delta_{21,p}\delta_{22,p}\delta_{23,p}\delta_{24,p}\delta_{25,p}\\ \delta_{31,p}\delta_{32,p}\delta_{33,p}\delta_{34,p}\delta_{35,p}\\ \delta_{41,p}\delta_{42,p}\delta_{43,p}\delta_{44,p}\delta_{45,p}\\ \delta_{51,p}\delta_{52,p}\delta_{53,p}\delta_{54,p}\delta_{55,p}\end{bmatrix}\begin{bmatrix}\Delta\ln GHG_{it-1}\\ \Delta\ln AGR_{it-1}\\ \Delta\ln REN_{it-1}\\ \Delta\ln GDP_{it-1}\\ \Delta\ln GDP_{it-1}^2\end{bmatrix}+\begin{bmatrix}\varphi_1\\ \varphi_2\\ \varphi_3\\ \varphi_4\\ \varphi_5\end{bmatrix}\times ECT_{it-1}+\begin{bmatrix}\mu_{1,it}\\ \mu_{2,it}\\ \mu_{3,it}\\ \mu_{4,it}\\ \mu_{5,it}\end{bmatrix} \quad (4)$$

The equation used in order to test co-integration between the variables of the dynamic panel ARDL model within our analysis is the following:

$$\begin{aligned}\Delta\ln GHG_{it} &= \beta_i + \sum_{j=1}^{n}\alpha_1\Delta\ln GHG_{i,t-j} + \\ &+\sum_{j=1}^{n}\alpha_2\Delta\ln AGR_{i,t-j} + \sum_{j=1}^{n}\alpha_3\Delta\ln REN_{i,t-j} + \\ &+\sum_{j=1}^{n}\alpha_4\Delta\ln GDP_{i,t-j} + \sum_{j=1}^{n}\alpha_5\Delta\ln GDP_{i,t-j}^2 + \\ &+\theta_1\ln GHG_{i,t-j} + \theta_2\ln AGR_{i,t-j} + \theta_3\ln REN_{i,t-j} + \\ &+\theta_4\ln GDP_{i,t-j} + \theta_5\ln GDP_{i,t-j}^2 + \varepsilon_{it}\end{aligned} \quad (3)$$

where: Δ – the first difference operator; θ – the coefficient associated to the variables; ε – the residual term.

Similarly, there are also the equations for the other variables taken as dependent variables. The null hypothesis involves a lack of cointegration, and it is given by the relation $\theta_1 = \theta_2 = \theta_3 = \theta_4 = \theta_5 = 0$. The alternative hypothesis involves the existence of cointegration: $\theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq \theta_5 \neq 0$.

Panel Vector Error Correction model (VECM) Granger causality: short-term and long-term causality tests. If all variables are cointegrated, the next step involves the identification of causality direction in long- and short-term with the help of the Granger test. The equations in the model of this study can be expressed as a system of equations as follows in Equation (4) above.

In Equation (4): ECT_{it-1} – the lagged error correction term; φ – the coefficient associated to the error correction term.

The speed of adjustment is given by the estimated values of *ECT* depending on the sign of the associated coefficient.

EMPIRICAL ANALYSIS AND RESULTS DISCUSSION

Data analysis in CEECs. Most studies researched the impact of agriculture on CO_2 emissions but, to remark how the agriculture of a country affects climate change, other gases such as methane and nitrous oxide must be included in studies, especially in those on agricultural economies.

The highest GHG emissions (Figure 1) are registered in Estonia, with significant fluctuations from one year to another, followed by the Czech Republic: although it was on the top of the countries with the highest GHG emissions, it registered a descending trend. The lowest values for the GHG emissions are registered in Bulgaria and Romania, but this is also due to the low levels of industrial sector in these countries on one hand, but also to the reduction of activity from the agricultural sector on the other hand.

Value added per worker is a measure of labour productivity – value added per unit of input. Value added reveals the net output of a sector after adding up all outputs and subtracting intermediate inputs. As one can notice in Figure 2, in countries like Romania, Poland and Bulgaria, the added value in agriculture registered a constant trend, with no significant fluctuations from one year to another and a lower value, although their geographical potential might allow for a favourable development of agriculture. On the other hand, in countries as Slovakia, Estonia and the Czech Republic, the agricultural sector registered a significant growth with higher added value per worker of more than USD 35 000. In Hungary, agriculture has a significant place among the sectors of economy, but the fluctuations of the added value from agriculture are intense and vary from one year to another.

Renewable energy represents one of the basic pillars of reducing the GHG emissions and a step towards a sustainable development. In Figure 3, we present the renewable energy consumptions as a total percentage from the final energy consumption for the 11 states included in the analysis. Latvia is the country with the highest consumption of renewable energy, expressed as a ratio in the total final energy consumption, and at the same time the country with the lowest GHG emissions, followed by Croatia, Estonia, Romania, Lithuania, and Slovenia. On the opposite pole, there is Slovakia, Poland, the Czech Republic, Hungary, and Bulgaria.

Analysing the GDP evolution per capita, we notice that Slovenia occupied the first position in the top of the states included in the study followed by the Czech Republic, Slovakia, and Estonia. At the end

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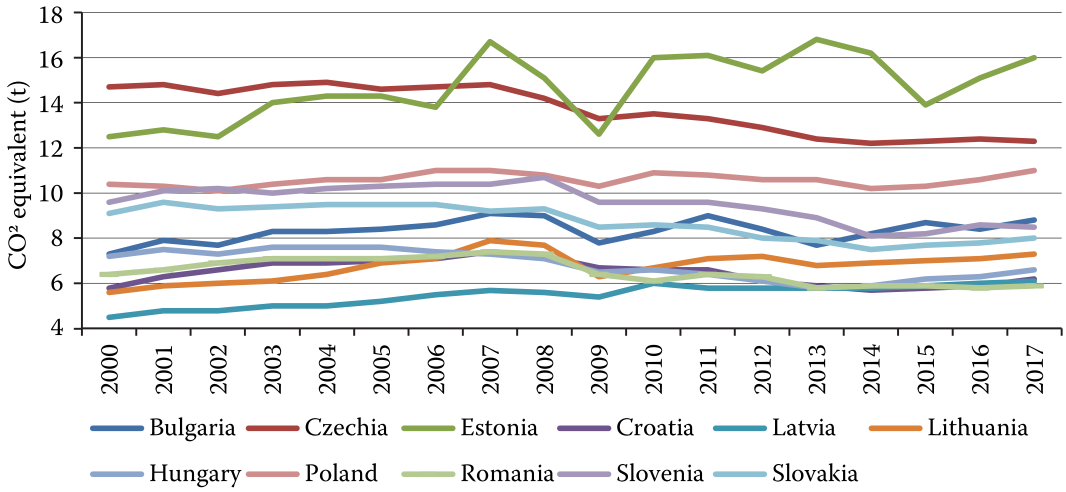

Figure 1. GHG emissions per capita in Central and Eastern Europe (CEECs)

Source: Own calculation based on data from European Environment Agency (2020)

of the classification, there are Bulgaria and Romania, the states joining the EU in 2007 and which are still developing.

If we analyze the evolution of the indicator Real GDP per capita (Figure 4), it is important to notice the fact that some states registered ascending values in the analysed period, except for 2008, the year of the global economic crisis, when the GDP reached significant decreases in all the analysed countries.

Statistical data provided by Food and Agriculture Organization of the United Nations (FAO 2018) highlight the fact that while the average agriculture value added in the CEE region is more than double of that in the EU/Western Europe (Romania, Bulgaria and Hungary are the top three countries), because of the share of industry and mainly of the service sector, it remains under the average of other sub-regions.

Bański (2018) acknowledges that across CEECs, agricultural land accounts for a greater share than any other kind of utilisation. Thus, Eurostat (2018) data show that the figure is around 57% in the case of Hungary, 58% in Romania, 46% in Poland, 53% in Czechia and 39% in Slovakia. Cultivation of crops prevails in this region's agriculture, above all cereals and industrial crops, and this in turn explains the dominance of farmland use by the arable fields' category.

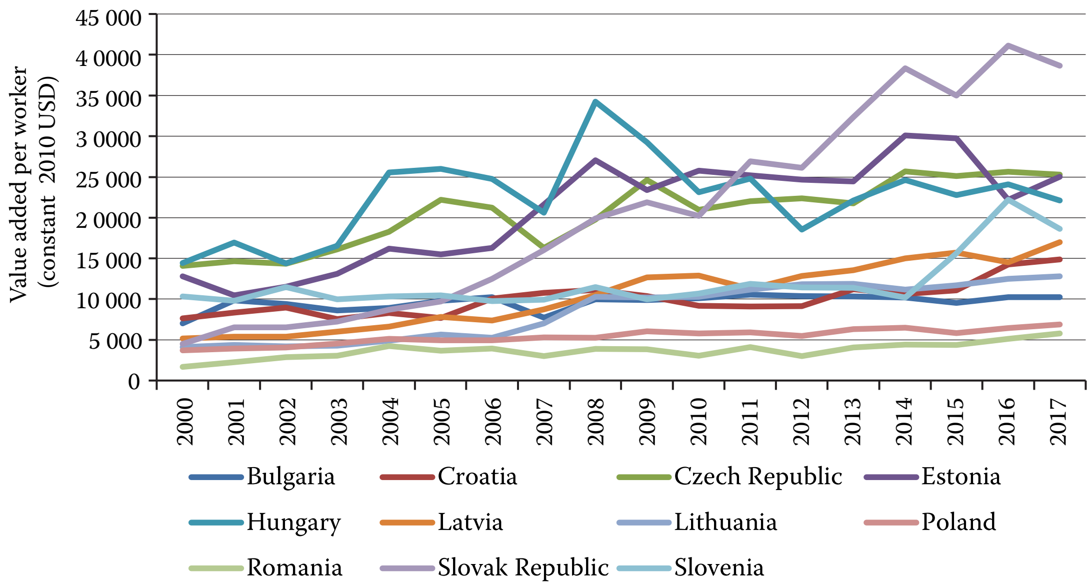

Figure 2. Value added from agriculture in Central and Eastern Europe (CEECs)

Source: Own calculation based on data from World Development Indicators (2020)

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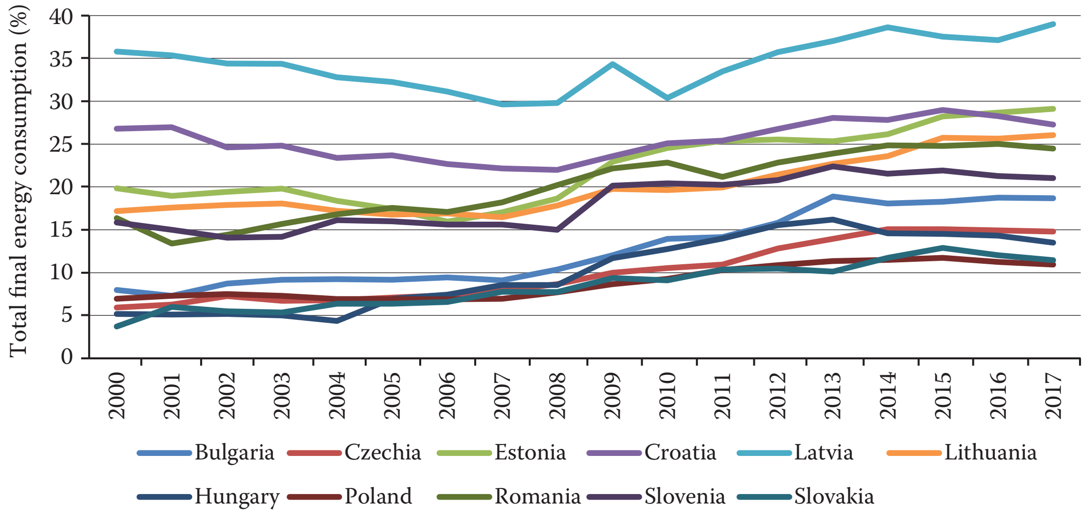

Figure 3. Renewable energy consumption in Central and Eastern Europe (CEECs)

Source: Own calculation based on data from Eurostat (2020)

Some important aspects concerning the country differences are described in the following paragraphs. Thus, according to Runowski (2017) European Union countries differ very much in terms of size and structure of their agricultural output, including crop yields, unit livestock productivity ratios and the size and structure of inputs, and also in economic performance.

Hergrenes et al. (2001) consider that there are many reasons behind the differences in the resource, production, and economic situations of farms. According to Czubak and Pawlowski (2020), Common Agricultural Policy (CAP) instruments are increasingly often the cause of these gaps between countries.

Furthermore, Czubak and Sadowski (2013) also believe that member countries differ in how long they have been covered by CAP instruments (depending on when they joined the EU). Therefore, the newest members (who joined the Community after 2000) mainly include Central and Eastern European countries, who differ from the "old" Union in terms of their agricultural policies and the economic developments experienced in recent years.

In terms of country particularities, it is also worth emphasizing what we have already mentioned above in Figure 2: that according to statistical data provided by FAO (2018) agriculture is a traditionally important sector in the Hungarian economy, as the country has favourable conditions for many types of farming and about 70% of the land area is suitable for agricultural production. Despite these facts, the share of agriculture in the economy has declined. However, Hungary's 4.3% agriculture value added is still the third highest among EU-countries, and the sector employs 5.2% of the work force.

In case of Romania, FAO (2018) states that 87% of agricultural land covers almost 60% of the country. The share of agriculture in Romanian economy is approximately 6%, one of the highest in Europe. Farm-

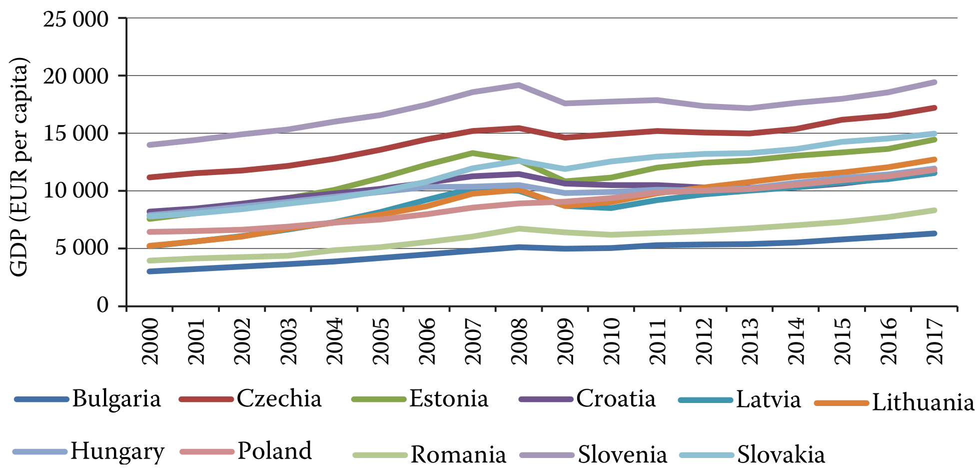

Figure 4. Real GDP per capita in Central and Eastern Europe (CEECs)

Source: Own calculation based on data from Eurostat (2020)

https://doi.org/10.17221/250/2020-AGRICECON

ing structures are polarized, due to the huge number of small, subsistence farms: the average farm size is 3.4 ha. Agriculture still provides one third of total employment in the country.

On the opposite side, the agriculture sector in Slovakia does not play a very important role in Slovakian economy. However, the information society development indicators are favourable to help the sector further increase its efficiency.

Also, Slovenia is one of the smaller European countries, with a territory of 20 273 km^2 and with a population of around 2 million people, according to FAO (2018). The role of agriculture in the economy is limited for many reasons, mainly due to the unfavourable environmental conditions for farming: the majority of the country is covered by mountains and forests and more than three-quarters of the surface belong to areas classified as less favoured (LFA). Agricultural land use (23% of the whole territory) is dominated by permanent grasslands and livestock production.

Therefore, although sharing the legacy of communist agricultural policy, national economic development outcomes varied among states with geography playing an important role.

Testing cross section dependence. Analysis of the correlation matrix (Table 1) among the four variables of the model indicates a positive correlation of agriculture and economic growth with greenhouse gases emissions, situation which is normal because in CEE, many sectors of the economy have not reached a development level allowing for orientation towards alternative solutions for energy consumption and for eliminating the harmful substances for the environment. Negative correlation between renewable energy consumption and greenhouse gases emissions is intuitive.

Panel unit root tests. Table 2 presents the results of unit root tests for the panel variables. For both common (LLC) and individual unit root process (IPS, Fisher-ADF and Fisher-PP), the results are significant at 1% level in the first difference which means that, in the first difference, the variables are all stationary. So, the alternative hypothesis for all variables is accepted and the null hypothesis of unit root is rejected.

Cointegration test should be performed on the level form of the variables and not on their first difference. The log-transformation of the raw variables can also be used, as in this model. Considering the stationarity of all variables on the first difference, co-integration tests were made in order to check if there is along-term cointegration relation among the variables of the model.

Table 1. The correlation matrix of growth rate in panel (2000–2017)

Correlation probability	*GHG*	*AGR*	*REN*	*GDP*
GHG	1.0000 –			
AGR	0.3405 0.0000	1.0000 –		
REN	–0.3568 0.0000	–0.1128 0.1138	1.0000 –	
GDP	0.4160 0.0000	0.5533 0.0000	0.0202 0.7778	1.0000 –

GHG – total GHG emissions; *AGR* – agricultural value added per worker; *REN* – renewable energy consumption; *GDP* – real GDP per capita

Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

Panel cointegration tests. Pedroni is one of the most important and widely used tests of cointegration for panel data. The results of the test presented in Table 3 show that in the within-dimension part, four of the eight statistic tests reject the null hypothesis, while for the between-dimension part, two of the three statistic tests accept the alternative hypothesis. This fact indicates the existence of a long-term cointegration relation among the variables of the model.

In order to provide for accuracy and robustness of these results, we performed an additional Johansen-Fisher test, were the null hypothesis states that there is a cointegration relation, whereas the alternative hypothesis involves the existence of a cointegration relation among variables. The results from Table 4 point out the existence of a strong co-integration relation among the variables.

Estimation of a long-term relationship. In order to examine the existence of a long-term coexistence relation between the selected variables, the long-run estimates of Equation (2) are calculated by ARDL method. Table 5 presents the long-term parameters of agricultural value added, renewable energy consumption, real *GDP* per capita and real GDP^2 per capita regarding the dependent variable, greenhouse gas emissions.

Starting from the fundamentals of the EKC theory and taking into account the negative coefficient of the linear term (*GDP*) and the positive one of the nonlinear term (GDP^2), this panel of 11 CEECs is on the U-shape curve (conventional EKC) in the long run. This result does not support Environmental Kuznets Curve Theory accord-

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Table 2. Panel unit root tests

Methods LLC		Common unit root process	Individual unit root process		
			IPS	Fisher-ADF	Fisher-PP
ln*GHG*	statistic	–1.0763	–0.1654	21.6486	35.7506
	P-value	0.1409	0.4343	0.4810	0.0323
dln*GHG*	statistic	–6.7514	–6.1759	79.6999	133.8250
	P-value	0.0000	0.0000	0.0000	0.0000
ln*AGR*	statistic	–2.3721	0.0472	18.2436	33.4470
	P-value	0.0088	0.5188	0.6914	0.0559
dln*AGR*	statistic	–8.1132	–7.4044	92.9149	408.0790
	P-value	0.0000	0.0000	0.0000	0.0000
ln*REN*	statistic	–1.3318	1.7780	8.9294	8.3988
	P-value	0.0915	0.9623	0.9937	0.9959
dln*REN*	statistic	–1.7183	–3.8259	52.3907	122.5670
	P-value	0.0429	0.0001	0.0003	0.0000
ln*GDP*	statistic	–2.6889	0.1544	16.0756	21.4261
	P-value	0.0036	0.5614	0.8121	0.4960
dln*GDP*	statistic	–6.1025	–3.3190	45.5048	44.2823
	P-value	0.0000	0.0005	0.0023	0.0033
lnGDP^2	statistic	–2.4617	0.3432	15.1057	19.4245
	P-value	0.0069	0.6343	0.8577	0.6190
dlnGDP^2	statistic	–6.1949	–3.4388	46.8528	45.5193
	P-value	0.0000	0.0003	0.0015	0.0023

GHG – total GHG emissions; *AGR* – agricultural value added per worker; *REN* – renewable energy consumption; *GDP* – real GDP per capita; LLC – Levin-Lin-Chu test; IPS – Im-Pesaran-Shin; ADF – augmented Dickey-Fuller test; PP – Phillips-Perron test
Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

ing to which greenhouse gas emissions increase within the first phase of the economic growth and decrease after reaching a certain threshold, but this is explained by the fact that all countries included in the panel are developing countries with economic growth based on fossil fuel consumption. Therefore, the hypothesis H_3 is not validated in the case of the 11 countries panel. Improving the renewable energy consumption and the efficient use of energy may solve this situation of sustainable economic growth. The results from Table 5 point out the existence of a long-term cointegration relation among the selected variables. Therefore, the growth of the add-

Table 3. Pedroni co-integration test (alternative hypothesis: common autoregressive coefficients – within-dimension)

		Statistic	Probability	Weighted	
				statistic	probability
Alternative hypothesis: common autoregressive coefficients (within-dimension)					
Panel	*v*-statistic	–0.859353	0.8049	–1.273910	0.8987
	rho-statistic	1.090102	0.8622	1.299396	0.9031
	PP-statistic	–5.341780	0.0000	–5.037319	0.0000
	ADF-statistic	–3.418231	0.0003	–3.525703	0.0002
Alternative hypothesis: individual autoregressive coefficients (between-dimension)					
Group	rho-Statistic	2.100980	0.9822	–	–
	PP-Statistic	–7.754327	0.0000	–	–
	ADF-Statistic	–2.194453	0.0141	–	–

ADF – augmented Dickey-Fuller test; PP – Phillips-Perron test
Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

https://doi.org/10.17221/250/2020-AGRICECON

Table 4. Johansen Fisher panel cointegration test

Hypothesized number of CEECs	Fisher statistics*			
	trace test	probability	max-eigen test	probability
None	430.0	0.0000	329.4	0.0000
At most 1	297.2	0.0000	222.5	0.0000
At most 2	118.1	0.0000	91.2	0.0000
At most 3	51.4	0.0004	49.3	0.0007
At most 4	26.4	0.2325	26.4	0.2325

*Probabilities are computed using asymptotic Chi-square distribution; CEECs – Central and Eastern European Countries
Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

ed value in agriculture involves a simultaneous growth of the GHG emissions, while the growth of the renewable energy consumption determines a decrease in the GHG emissions. Consequently, these results support the hypothesis H_1 and H_2 that are thus validated.

Also, it is worth noting that the particularities of these post-communist countries consist of being very polluting countries before the socioeconomic transition in early 1990's. Therefore, these countries have this relatively high level of GHG emissions.

Short-term and long-term causality tests. If there is at least one cointegration relationship detected in the model, there must also be a causal relationship among the variables. In this study, the Granger test based on VECM was used to identify the causality relationship between the variables included in the model. The purpose of applying this test is to identify if there is a short-run, long-run and strong causality between the variables. The *t*-statistics of the ECT explain the long-run causal relationship. A negative value of *t*-statistics implies a long-term relationship among variables. As for the short-term relation among the variables, this is given by the *P*-value for the coefficients given for each variable. Therefore, if the *P*-value is lower than 0.5 then the null hypothesis is rejected for the existence of a short-term causality relation among the variables of the model.

From Table 6, we can notice that in the short-term, there is causality relation between the agricultural added value and the greenhouse gases emissions, but also between the renewable energy consumption and these emissions. At the same time, in the short term we also notice a causality relation between the agricultural added value and the renewable energy consumption. Moreover, we can notice the existence of a strong causal relationship between the agricultural added value and *GDP* and GDP^2, meaning that the agricultural sector has a significant importance for economic growth in the analysed states.

In the long term, the values of *t*-statistic point out the existence of a causality relation among the variables of the model. The previous results were connected with the results of applying Pairwise Granger causality test to detect the direction of causality between variables (Figure 5). In the long-term, we notice the existence of two, bi-directional causality relations between agriculture and *GDP*, and agriculture and GDP^2, the agricultural sector characterising these economies, which currently could be considered a subsistence one, being able to represent an important sustainable economic growth factor. At the same time, we identified a uni-directional causality relation from agriculture to the GHG emissions and from agriculture to the renewable energy consumption. Using the renewable energy

Table 5. Autoregressive Distributed Lag (ARDL) long-term estimates

Variable	Coefficient	Standard error	*t*-statistic	Probabilities*
Long run equation				
ln*AGR*	0.083374	0.029428	2.83315	0.0058
ln*REN*	–0.288139	0.014651	–19.66624	0.0000
ln*GDP*	–3.640854	0.972081	–3.74542	0.0003
$\ln GDP^2$	0.220706	0.054231	4.06970	0.0001

*Probabilities must be below 0.05 to be significant
Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

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Table 6. Vector Error Correction model (VECM) Granger causality test

		d(ln*GHG*)	d(ln*AGR*)	d(ln*REN*)	d(ln*GDP*)	d(lnGDP^2)
ECT(–1)	coefficient	–0.002372	–0.001430	–0.001739	–0.000860	–0.008914
	t-statistics	(–1.12716)	(–0.25434)	(–0.56112)	(–0.58591)	(–0.32840)
d(ln*AGR*(–1))	coefficient	–0.068618	–	0.105497	–0.077985	–1.417324
	P-value	0.0112		0.0081	0.0000	0.0001
d(ln*REN*(–1))	coefficient	–0.091093	–0.051461	–	–0.025813	–0.458278
	P-value	0.0711	0.7025		0.4633	0.4812
d(ln*GDP*(–1))	coefficient	–0.026331	–8.147805	–0.601011	–	54.059210
	P-value	0.9925	0.2778	0.8845		0.1360
d(lnGDP^2(–1))	coefficient	–0.000747	0.476064	0.028836	–0.158029	–
	P-value	0.9961	0.2460	0.8985	0.1405	

ECT – the lagged error correction term; *AGR* – agricultural value added per worker; *REN* – renewable energy consumption; *GDP* – real GDP per capita
Source: Own processing using Eviews 9.0 software based on EEA (2020), The World Bank (2020) and Eurostat (2020)

consumption in agriculture (biomass, solar, wind, and hydro power) can do a lot to mitigate climate change and replace the use of non-renewable energy.

In the short term, agriculture generates effects on all variables included in the model, identifying the four causality relations from agriculture towards the other four variables, and from the renewable energy consumption just a unidirectional causality relation towards the GHG emissions. These results confirm the fact that the agricultural activities represent an important factor in the evolution

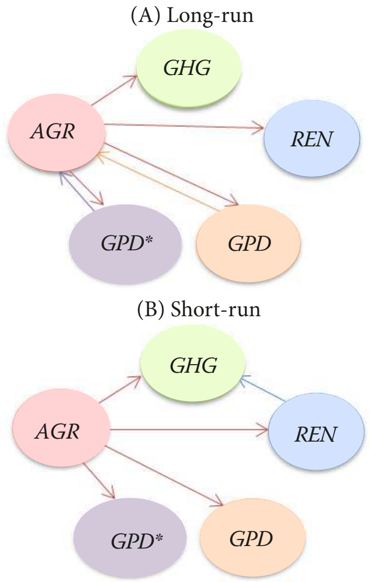

Figure 5. Causality relationship among the model

AGR – agricultural value added per worker; *REN* – renewable energy consumption; *GDP* – real GDP per capita
Source: Own representation based on results from Eviews

of the GHG emissions, the need for using environmental-friendly technologies in agriculture, and the rational use of pesticides and fertilizers. Any change of the renewable energy consumption determines changes in the GHG emissions. That is why we can consider the use of a significant quantity of renewable energy as a method to reduce the emissions. The growth of the renewable energy consumption in the total consumption of energy has as positive impact on the GHG emissions, in the sense that an increase in the level of consumption of renewable energy by a percentage point will determine a decrease in the level of GHG emissions by 9 percentage points. The same situation is encountered in the case of the impact of agriculture on *GHG*.

The results mentioned above once again validate the hypotheses H_1 and H_2.

CONCLUSION

The research reveals important information on the interaction of each variable to another (one-way or two-way relation) which provides guidelines/recommendations for the policymakers in effective policy decision-making and economic planning, taking into consideration the environmental issues, energy conservation, and agriculture for sustainable growth.

The purpose of this paper is to identify the causality relations between agriculture, renewable energy, economic growth, and greenhouse gases based on a dynamic panel ARDL model. This analysis supports a better understanding of the linkage between renewable energy, agriculture, and GHG emissions, and examines the ex-

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istence of the environmental Kuznets curve (EKC) hypothesis in CEECs. Overall, all the hypotheses are validated through the achieved results.

The research methodology consisted in using a dynamic panel ARDL model to test the cointegration relationship between the GHG emissions, agriculture, renewable energy, *GDP*, and GDP^2. First a dynamic ECM was used to integrate the short-term and long-term causality relationships. Second, two Granger causality tests were used to identify the short-term and long-term causalities between the variables and the direction of causality.

As for the relation between GHG and economic growth, the results indicate the position of CEECs on the U-shapes EKC in the long-term pointing out the fact that the fast economic growth in these states causes deterioration of the environment because it relies on the fossil fuel consumption. Hence, our recommendation is that the policy makers should act to improve the efficient use of energy and consider energy saving and decarbonized economic structure.

The results of the econometric analysis reveal that agriculture is a sector which might play an important role in CEECs because it influences all the variable included in the model and it should to be redesigned to reduce GHG emissions. That is why we underline the recommendation that policy makers should follow the model of states with a developed agriculture relying on ecologic agriculture systems and on less environmentally aggressive technologies. As a consequence of the identified causality relations we can say that agriculture determines not only the development of renewable energy sources but also the reduction of GHG emissions and implicitly the improvement of climate changes.

In the countries included in the analysis, although they have a significant potential for renewable energy, this is not exploited either due to lack of investment funds or due to lack of interest of the decisive factors. Therefore, another recommendation that we support is that the CEEC governments should grant funds for the development of the renewable energy infrastructure.

Food and Agriculture Organization of the United Nations (FAO) (2018) helps the CEECs countries in addressing the problems that are confronting. Another matter pointed out by FAO is the transition to e-agriculture and implementation of such strategies. Our recommendation is that CEECs should focus on e-agriculture strategies in order to ease the adaptation to innovation process and consequently to an environmentally sustainable and climate change resilient agriculture. Also, another recommendation is that CEECs should strive to abandon forever the socialist shells and to set ambitious sustainable targets in agriculture in order to adapt to the climate change events.

Moreover, the results of the study also suggest that individual countries of the studied region of Europe are not homogeneous in terms of greenhouse gas emissions, level of agricultural development, or energy efficiency. This diversity can be noted in the climate change targets and policies for individual countries. Thus, concerning the long-term targets of climate change policies to achieve, the EU countries seem not to be so ambitious. According to the report of CANE (2018), the rankings that assess both the role that Member States have in setting ambitious climate and energy targets, show that all EU countries have not succeeded in fulfilling the target.

As for the panel of countries analysed in this study, Estonia and Slovenia should take action and promote more high-aimed climate and energy policies and targets, both at national and at EU level. Furthermore, most CEEC countries are not making important steps in terms of climate policies. Some of these countries achieved high scores in the rankings according to CANE (2018). In this situation we find Lithuania in 10th place and Latvia in 12th place because of low climate and energy targets received due to their low average income. Furthermore, they usually have low energy consumption and greenhouse gas emission numbers due to their economic situation. Slovenia, Slovakia (18th place each) and the Czech Republic, Romania (20th place each), Hungary (22nd place) are one step ahead from this point of view. Moreover, Bulgaria (26th place), Estonia (27th place) and Poland (29th place) rank lowest due to their disagreements to climate action both at country and at EU level.

In our future research we intend to extend the analysis period by several years, as the lack of data is the main limitation of the present study, in order to generate more robust results. In addition, in a future research, the non-renewable energy consumption and environmental technologies variables will also be included to obtain more reliable results.

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