International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2021, 11(4), 362-373.

The Relationships between GDP growth, Energy Consumption, Renewable Energy Production and CO_2 Emissions in European Transition Economies

Klodian Muço[1], Enzo Valentini[2]*, Stefano Lucarelli[3]

[1]Catholic University "Our Lady of Good Counsel," Albania, [2]Department of Political Science, Communication and International Relations, University of Macerata, Italy, [3]University of Bergamo, Italy. *Email: enzo.valentini@unimc.it

Received: 08 Feburary 2021 **Accepted:** 29 April 2021 **DOI:** https://doi.org/10.32479/ijeep.11275

ABSTRACT

The objective of the analysis is to study the relationships between GDP, energy consumption, renewable energy production, and CO_2 emissions in some European transition economies in the period 1990-2018. We use the growth rates of per capita values, in a panel VAR approach where all variables are typically treated as endogenous, allowing some inference on the causality of the relationships. The decision to focus on European transition countries is motivated by the fact that a significant part of the future of the green economy in Europe depends on the environmental and energy policies that will be implemented by these countries. In the transition economies (and years) included in the analysis, our findings suggest that investing in energy efficiency is good for the competitiveness of economies (in terms of effects on GDP growth) and is good for the environment (in terms of diminishing CO_2 emissions). Finally, an increasing production of renewable energies reduces CO_2 emissions.

Keywords: Energy Consumption, Economic Growth, Renewable Energy, CO_2 Emissions, Transition Countries
JEL Classifications: O44, Q43

1. INTRODUCTION

Energy plays an important role in the supply chain as it is a non-durable consumption good for consumers and an input into the production processes of firms (Sari et al., 2008), Sharma (2010), (Magazzino, 2012).

The importance of energy draws the attention to the relationship between energy consumption and economic growth, since higher economic growth leads to a higher level of energy consumption. At the same time the emissions of gasses are derived mainly from the consumption of oil energy, and the increasing use of energy may have a negative effect on the ever-increasing amount of carbon dioxide (CO_2), the dominant contributor to pollution and climate change (Soytas and Sari, 2007), Zhang and Cheng (2009), (Lu, 2017). Some researchers have pointed out that even developing countries should sacrifice some economic growth to protect the environment (Harrison and Eskeland, 2003), (Coondoo and Dinda, 2020).

The nexus between energy consumption, economic growth and environmental pollutant has been the subject of considerable academic research over the past few decades in different countries. The empirical evidence remains controversial and ambiguous. Different studies employ different empirical models and different data periods (Ang, 2007).

According to empirical approach they can be classified in three groups: (1) studies on the (causal) links between energy consumption and economic growth (e.g.: Kraft and Kraft, 1978), Chiou-Wei et al. (2008), Ozturk (2010), (Yoo and Lee, 2010), Payne (2010), Tsani (2010), Tang and Tan (2012), Kasman and Duman (2015), Tang et al., 2016; (2) studies on the (causal) relationship between economic activity and CO_2 and/or greenhouse gas emissions e.g.: Grossman and Krueger (1991), Harrison and Eskeland, 2003, Richmond and Kaufmann (2006), Ozturk and Oz (2016), Antonakakis et al., 2017; and finally, (3) studies on the (causal) links between energy consumption, greenhouse gas emissions and economic growth (e.g: Ricci, 2007), Soytas et al. (2007), Ang (2008), Zhang and Cheng (2009), Apergis and Payne (2009), Soytas and Sari (2009), Halicioglu, 2009.

On this background, we attempt to shed more light on the intricate and complex relationships between economic growth, energy consumption, renewable energy and CO_2 emissions in fourteen European Transition countries (Albania, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, North Macedonia, Poland, Romania, Slovak Republic, Slovenia, Ukraine). The decision to focus on these nations is motivated by the fact that a significant part of the future of the green economy in Europe depends on the environmental and energy policies that will be implemented by these countries. It should also be noted that there are still few specific studies on this subject and on these countries. Therefore, our article aims to fill this gap and to stimulate further investigation on an area where renewable energy production could be strategic in the near future.

The findings of this study can help to better understand the context in which define and implement the appropriate energy development policies in this area.

We use a panel VAR approach in which all variables are typically treated as endogenous, allowing some inference on the causality of the relationships.

The remainder of this paper is organized as follows: Section 2 briefly reviews the empirical literature. Section 3 discusses the econometric methods and the data used. Section 4 provides empirical findings. Section 5 presents conclusions and policy implications.

2. THEORETICAL BACKGROUND AND LITERATURE REVIEW

The exploration of the link between economy-energy-environment has attracted the attention of a growing number of researchers and the great amount of literature on this subject bears witness to this fact.

The literature on the subject is so boundless that it is impossible to present it all here in an exhaustive way. The aim of our review is to show that research in this field is very extensive, but it produces extremely heterogeneous results. This suggests three important considerations: the results depend very much on the data and methodology used; in different economic-social contexts the relationship between economy-energy-environment can be different; this topic deserves to be deepened with studies on specific territories and different methodologies.

All previous empirical results concerning the countries covered by our analysis are presented together in section 2.3.

2.1. Energy Consumption and Economic Growth

Besides the impact of energy on the economic development and on the environment (Brown et al., 2011), several studies show that energy consumption and economic growth are intricately linked, although the direction of causality remains ambiguous. Different studies present conflicting results, and there is no consensus neither on the existence nor on the direction of the causality. Bouoiyour et al. (2014) proposed a meta-analysis over a sample of 43 empirical studies, emphasizing the great variety of results regrading the economic growth-energy consumption nexus.

The possible direction of this relationship may be divided into four types, each of which might be important for energy policy implications (Ozturk, 2010), (Soytas and Saru, 2009): (1) unidirectional causality which runs from GDP to energy consumption (conservation hypothesis); (2) unidirectional causality which runs from energy consumption to GDP (growth hypothesis); (3) lack of correlation between GDP and energy (neutrality hypothesis); (4) bidirectional causality between GDP and energy consumption (feedback hypothesis). In addition, it is also possible to classify studies with reference to a single country or a group of countries.

The analyses on the relationship between energy consumption and economic growth are based on the pioneering study of Kraft and Kraft (1978). The authors study the relationship between the gross energy inputs and GNP in the USA for the period 1947-1974 and they find a unidirectional positive causality from GNP to energy consumption. Other scholars confirm these results analyzing several time series in the USA (Abosedra and Baghestani, 1989; Ajmi et al. 2013), and countries like India, Bangladesh and Taiwan (Ghosh, 2002; Mozumder and Marathe, 2007; Pao, 2009).

On the contrary, some studies found a positive causality running from energy consumption to GDP but not vice versa in Greece, China, Turkey, Hong Kong and Korea (Shiu and Lam, 2004; Altinay and Karagol, 2005; Ho and Siu, 2007; Tsani, 2010).

Finally, a bidirectional causality between energy consumption and economic growth has been shown for Canada, France, Japan, South Korea, Italy, and low-income countries (Yoo, 2005; Ozturk et al., 2010; Magazzino, 2012; Ajmi et al., 2013).

Regarding the studies focused on group of countries, a positive unidirectional causality from GDP to energy consumption is supported for Asian countries (Chen et al., 2007). A statistically significant inverted-U-shaped relationship between electric energy consumption and GDP has been showed for OECD and developed countries, with data from 1975 to 2004 (Yoo and Lee, 2010).

In Middle Eastern countries a 1% increase in electricity consumption results to be associated to an increase of GDP equal to 0.04% and a 1% increase in GDP leads to a 0.95% increase in electricity consumption (Narayan and Smyth, 2009). Bouoiyour and Selmi (2013) studied a panel of twelve MENA countries over the period 1975-2010 and showed that 16.66% of MENA countries are in line with the growth hypothesis, 25% with the conservation hypothesis, 33.33% with the feedback hypothesis and 25% with the neutrality hypothesis.

Other scholars underline that the relationships between electricity consumption and economic growth is overly sensitive to regional differences, countries' income levels, urbanization rates and supply risks (Narayan and Prasad, 2008).

In this field, OPEC countries represent a particular field of analysis: a study suggests that economic growth is dependent on electricity consumption in five countries, less dependent in three countries, and independent in three others (Squalli, 2007). A study on seventeen African countries finds a long-run relationship between electricity consumption per capita and real GDP per capita for only nine of them; moreover, Granger causality test shows a significative causality only for twelve countries. For six nations there is a positive unidirectional causality running from real GDP per capita to electricity consumption per capita, an opposite causality for three countries, and finally, bidirectional causality for the three remaining ones (Wolde-Rufael, 2006). An analysis on the causal relationship between GDP and different types of energy consumption for five countries of the Indian subcontinent (Pakistan, India, Sri Lanka, Bangladesh and Nepal) produced different results for each country (Asghar, 2008). Studying the cointegration between GDPs per capita and energy consumption per capita in 88 emerging economies, it emerged a two-way short-run, long-run and strong positive causality between the growth of GDP and growth of energy consumption (Sinha, 2009).

Ahmed and Azam (2016) investigated 119 countries from all over the world by employing Granger-causality in the frequency domain, and their results suggest that 18 countries confirm the feedback hypothesis, 25 countries the growth hypothesis, 40 countries the conservation hypothesis and 36 countries the neutrality hypothesis.

Again, the heterogeneity of the results seems to be the only sticking point.

2.2. Energy Consumption and CO_2 Emissions

The relationship between economic growth and environment is based on the hypothetical Kuznets curve (Kuznets, 1955). According to Kuznets there is an inverted "U" shape relationship between income inequality and economic growth. In the 90s this hypothesis was reformulated as the Environmental Kuznets Curve in order to study the relationship between GDP per capita and environmental quality (expressed by CO_2 equivalent emissions). The growth of GDP per capita at the first stage of development leads to the increase in CO_2 emissions per capita. Once income reaches a certain level there is a gradual reduction in CO_2 emissions per capita since the sensitivity of the individuals to the environment increases gradually leading to a reduction of environmental degradation. Empirical research has failed to verify this the existence of the Environmental Kuznets Curve (Stern, 2004).

The internationalization of markets and the outsourcing of production to developing countries complicates the discussion of this issue. Scholars are concerned whether multinationals are flocking to developing country "pollution havens" (Harrison and Eskeland, 2003). Thus, in developing countries, apart from the positive impact that they have on the economic growth, multinationals stimulate an increase of CO_2 emissions. Moreover, precisely the most polluting companies may tend to move towards developing countries to avoid the stringent environmental regulations (Jensen, 1996; Hoffmann et al., 2005). In the case of Turkey, Kizilkaya (2017) shows the opposite: the multinationals tend to transfer their "clean" technology to host developing countries.

As in the energy consumption-economic growth relationship also in the economic growth-environment relationship the empirical results are ambiguous, and the outcomes depend not only on the countries considered, but also on the method employed and on the period covered by the analysis.

Several studies show that the consumption of energy leads to an increase in CO_2 emissions, with a unidirectional causal relationship running from economic growth to polluting emissions. These results emerge for heterogeneous groups of developed countries, USA, Asia, Middle East (Ricci, 2007; Soytas et al., 2007; Lean and Smyth, 2010; Al-mulali, 2012).

Opposite results (a not significant correlation between economic growth and environment pollution overall) have emerged from other studies concerning other countries (Akbostanci et al., 2009; Ozturk and Oz, 2016). Finally, for MENA countries has been suggested the existence of a bidirectional causal relationship between economic growth and polluting emissions (Omri, 2013).

Economic growth might stimulate pollution. In order to prevent the increase of pollution, the economic growth should be accompanied by the promotion of environment-friendly technological progress Ricci (2007). Some scholars underline the ethical dilemma "between high economic growth rates and unsustainable environment and low or zero economic growth and environmental sustainability" (Antonakakis et al., 2017. p. 808).

2.3. Transition Economies

As mentioned in the introduction, there are few contributions on this issue concerning European transition economies. The reason is quite obvious: an analysis of these countries necessarily requires considering only the period starting from 90s, because only in these years these economies can be defined as "transition." In most cases, data relating to the variables used in studies on this subject are annual. This fact places limits on the methodologies that can be used. For example, a serious and robust cointegration analysis requires many observations. As we will see later, this argument influences the choice of the methodology used in the present contribution. Nevertheless, some published studies exist. These empirical researches refer to different periods, and are also very distant from each other. This may be an even more relevant issue in the case of transition economies, due to the radical changes they have experienced. Even with this warning, we think it useful to present them, also to show the variety of results in relation to the methodologies, countries and periods considered.

In terms of energy consumption and economic growth: a unidirectional causality running from electricity consumption to economic growth has been found in Belarus and Bulgaria; the opposite unidirectional causality running from economic growth to electricity consumption has been found in the Czech Republic, Latvia, Lithuania and the Russian Federation; a bidirectional causality emerges in Ukraine while no Granger causality in any direction results for Albania, Macedonia, Moldova, Poland, Romania, Serbia, Slovak Republic and Slovenia (Wolde-Rufael, 2014).

The panel analysis presented by Antonakakis et al. (2017) on European countries including some, but not only, transition countries (Bulgaria, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia) over years 1988-2009 shows a high significant positive impact of economic growth on CO_2 emissions. A strong relationship between economic growth and total emissions is highlighted for the period 1980-2016 also by another panel study on 28 European countries which again includes transition economies (Haller, 2020).

Other contributions, covering not only countries in transition, analyze them individually and therefore provide more interesting information on our topic. In a study on various European countries, no long-run relationship has been found for Hungary, in the period 1960-2005, between carbon dioxide emissions, energy consumption, and economic growth by using ARDL bounds testing approach of cointegration (Acaravici and Ozturk, 2010). Kablamaci (2017) found a causality running from economic growth to energy use has been found for Albania and Bulgaria. Investigating the causal relationship between energy and economic growth in Albania, Bulgaria, Hungary and Romania from 1980 to 2006, evidence has emerged of a two-way (bidirectional) strong Granger causality only in Hungary, while no cointegration was found for Albania, Bulgaria and Romania (Ozturk and Acaravici, 2010).

Finally, Marinaş et al. (2018) tested the correlation between economic growth and renewable energy consumption for ten European Union (EU) member states from Central and Eastern Europe (CEE) in the period 1990-2014. Using Auto-regressive and Distributed Lag (ARDL) they showed that, in the short run, GDP and Renewable Energy Consumption dynamics are independent in Romania and Bulgaria, while in Hungary, Lithuania and Slovenia an increasing renewable energy consumption improves the economic growth. The hypothesis of bi-directional causality between renewable energy consumption and economic growth is validated in the long run for both the whole group of analyzed countries as well as in the case of seven CEE states which were studied individually (Bulgaria, Estonia, Latvia, Lithuania, Poland, Slovakia and Slovenia).

3. MATERIALS AND METHODS

The objective of the analysis is to study the relationships between GDP per capita (constant international dollars, World Bank), energy consumption per capita (kg of oil equivalent, Eurostat), renewable energy (% of energy production, Eurostat), and total CO_2 emissions per capita (kt of CO_2 equivalent, Our World in Data, which combines two sources: the Global Carbon Project and Carbon Dioxide Analysis Center) in European transition economies since 1990.

The choice to merge different sources follows the attempt to have as many countries as possible in the analysis and at the same time long series in order to include the most recent years (2018) thus running an up to date analysis.

With reference to European transition countries as a whole, the research hypotheses we want to test are based on the ones of previous literature and can be described as follows.

About the relationship between energy consumption and GDP, the previous literature about European Transition countries has produced very diverse results. As mentioned above, the literature identifies four possible cases: unidirectional causality which running from GDP to energy consumption (conservation hypothesis); unidirectional causality running from energy consumption to GDP (growth hypothesis); lack of correlation between GDP and energy (neutrality hypothesis); bidirectional causality between GDP and energy consumption (feedback hypothesis).

About the consequences of economic growth and energy use on CO_2 emissions: our hypothesis is that economic growth and more use of energy will both (ceteris paribus) cause an increase of CO_2 emissions as literature suggests for European transition countries.

About renewable energy: does economic growth cause a relative increase in renewable energy production? Can a dynamic renewable energy sector have positive effects on economic growth? The literature does not give unequivocal indications, so we will try to give a contribution to answer these questions. Thanks to the pvar approach, in which all variables are endogenous and can influence each other we can also check if the growth of renewable energy (as a percentage of total energy production), ceteris paribus, leads to a decrease in CO_2 emissions (as one would expect).

We identify European transition economies referring to IMF and World Bank for the period 1990-2018. (International Monetary Fund, 2000), (World Bank, 2002). As a result of data availability, the countries included in the analysis are: Albania, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Latvia, Lithuania, North Macedonia, Poland, Romania, Slovak Republic, Slovenia, Ukraine.

As mentioned earlier, most existing literature generally supposes that economic growth would likely lead to changes in CO_2 emissions. It has also been established that energy consumption is often a key determinant of carbon emissions. It is therefore worth investigating the interrelationships between the three variables by considering them simultaneously in a unique modeling framework.

The methodologies used for this type of analysis are generally VECM, ARDL, or VAR on individual countries, to analyze short-and long-term causality. In our case, this is not possible because for the analyzed countries the historical series would be too short to provide reliable and robust results. We have therefore opted for a panel VAR approach that allows us to work with more observations (Holtz-Eakin et al., 1988). Another option would be the use of VECM panels, which can distinguish short- and long-term effects. However, this estimation method is only appropriate for large panels (Shin et al., 1999). A panel is large if the number of cross-sectional units and the number of time periods is going to infinity. Our choice is to privilege the robustness of the econometric analysis, based on the availability of data at the moment.

A requirement for the VAR panel analysis is that all variables are stationary. In our case, some variables are I(1) and others I(0) in levels, and these characteristics are not homogeneous across countries. Hence, the variables will all be expressed in terms of growth rates to make sure we work with stationary variables we verified it through panel unit root tests, in particular by using the Im-Pesaran-Shin test, in view of the fact that we use an unbalanced panel (Im et al., 2003). The fact that some series are I(0) in levels further explains why we cannot do a cointegration analysis (panel VECM).

Even more reason, our approach can only be relevant as a short-term analysis. We will take this into account when interpreting the results. We are aware that in this way we can not give interpretations about the long-term relationships, but we think that at this level the short analysis is the only possible and it is still a beginning of a research that can be expanded over time. On the other hand, the use of a new methodology (suggested by the characteristics of the available data) could highlight aspects that have so far been overlooked.

The last limitation of our analysis is that, by using a panel approach, we estimate average parameters (and relationships) for the group of countries considered. But it is the first time that this is done with specific reference to European transition countries.

In a panel VAR system, all variables are typically treated as endogenous. Our estimates and inference are based on the generalized method of moments (GMM) (Abrigo and Love, 2016). We consider a panel VAR with panel-specific fixed effects represented by the following reduced form:

$$Y_{i,t}=\Lambda(L)\, Y_{i,t} + u_i + e_{i,t} \tag{1}$$

where Y_{it} is a (1xk) vector of stationary dependent variables, $\Lambda(L)$ is a polynomial matrix in the lag operator with $\Lambda(L)= \Lambda_1 L^1+ \Lambda_2 L^{2+}+\Lambda_3 L^3+\ldots+\Lambda_p L^p$, u_i is a vector of country fixed effects and e_{it} is a vector of idiosyncratic errors.

Panel-specific fixed effects are removed using forward orthogonal deviation or Helmert transformation forward orthogonal deviation (FOD) (Arellano and Bover, 1995): "Instead of using deviations from past realizations, it subtracts the average of all available future observations, thereby minimizing data loss. Because past realizations are not included in this transformation, they remain valid instruments. Potentially, only the most recent observation is not used in estimation" (Abrigo and Love, 2016. p. 780). In order to remove the fixed effects, all variables in the model are transformed in deviations from forward means. Let $\overline{y_{it}^m} = \sum_{s=t+1}^{T_i} y_{st}^m / \left(T_i - t\right)$ defines the means of the future values of y_{it}^m, a variable of the vector $Y_{i,t} = \left(y_{it}^1, y_{it}^2, \ldots, y_{it}^M\right)'$ where T_i indicates the last period for a given country series (Boutbane et al., 2012).

Similarly, $\overline{e_{it}^m}$ indicates the mean obtained by the future values of $e_{i,t} = \left(e_{it}^1, e_{it}^2, \ldots, e_{it}^M\right)'$. As a consequence, we obtain the transformed variables:

$$\overline{y_{it}^m} = \eta_{i,t}\left(y_{it}^m - \overline{y_{it}^m}\right) \widetilde{e_{it}^m} = \eta_{i,t}\left(e_{it}^m - \overline{e_{it}^m}\right) \tag{2}$$

where $\eta_{it} = \sqrt{\left(T_i - t\right)/\left(T_i - t + 1\right)}$. I is not possible to calculate forward means for the observation of the last available year, hence it is not used in the estimates.

The final model is:

$$\overline{Y_{i,t}} = \Lambda\left(L\right)\overline{Y}_{i,t} + \overline{e_{i,t}} \tag{3}$$

where $\overline{Y_{i,t}} = \left(\overline{y_{it}^1}, \overline{y_{it}^2}, \ldots, \overline{y_{it}^M}\right)$ and $\overline{e_{i,t}} = \left(\overline{e_{it}^1}, \overline{e_{it}^2}, \ldots, \overline{e_{it}^M}\right)'$. The transformed model preserves homoscedasticity and does not induce serial correlation (Arellano and Bover, 1995). This approach allows the use of lagged values of regressors as instruments, and estimates the coefficients by the generalized method of moment (GMM).

Common time fixed effects are removed by subtracting from each variable in its cross-sectional mean before estimation.

A precondition of the var estimates (and panel VAR) is the choice of the optimal lag. We anticipate here that in our case the selection has followed the overall Coefficient of Determination (CD) criterion, because we are dealing with a just identified model. The Coefficient of Determination captures the proportion of variation explained by the panel VAR model. In the case of our analysis, the optimal lag is always 1. This greatly facilitates the presentation of results and reasoning in terms of Granger causality (Granger, 1969). Finally, we estimate cluster robust standard errors, and after the estimates we check for residual autocorrelation (and do not find evidence of it) by graphs of their distribution and by performing the test suggested by Wooldridge (2002. pp. 176,177).

Data cover the period from 1990 to 2018. Thus, for some countries the period includes the EU membership: Bulgaria (from 2007), Estonia (2004), Latvia (2004), Lithuania (2004), Polonia (2004), Czech Republic (2004), Romania (2007), Slovak Republic (2004), Slovenia (2004), Hungary (2004).

In Appendix we present, through graphical representations (Figure A1 and Figure A2), all the data we use in the analysis, since the presentation of simple descriptive statistics could lead to losing sight of the great volatility over years that characterizes the data (understandably, given that these are economies in transition that suffered various shocks during the analyzed period). To make it easier to read the data, we have also separated the graphs of countries that present data at vastly different "scales/levels" from those of other countries.

Here, we want to draw attention in particular to Figure A1, which already at first glance suggests the presence of common movements between the growth rates of GDP, Energy Use and CO_2 emissions, while the trends in renewable energy seem more erratic.

4. RESULTS AND DISCUSSION

Table 1 shows the results of the panel-VAR analysis. The first and last year is 1992 because starting from the original data (1990-2018) we work in growth rates (1990 is lost), with one lag (1991 is lost) and with Helmert transformation forward orthogonal deviation for fixed effects (2018 is lost).

The first results concern the causal relationship between GDP and energy consumption growth rates: in these countries, on average, higher economic growth implies (other things being equal) a higher growth in the energy used. This is quite obvious. But the GDP-energy relationship seems not to be symmetrical, in the sense that a growth in energy use, ceteris paribus, seems to cause a decrease in GDP growth.

With reference to the hypotheses we formulated following the literature about GDP and energy consumption, our results support the "feedback hypothesis" and "bidirectional causality."

The novelty of our results lies in the fact that the relationship seems to be not symmetrical: an increase in the GDP growth rate causes an increase in energy consumption, but ceteris paribus an excessive increase in energy consumption can negatively affect the GDP growth rate. An intuitive interpretation of these results

Table 1: Panel VAR model results

Variables	Dep: GDP	Dep: Energy use	Dep: Renewable energy	Dep: CO_2 Emission
GDP (t-1)	0.463***	0.213***	-0.080	0.174**
	(0.107)	(0.063)	(0.494)	(0.076)
Energy use	−0.055*	0.064	0.338	0.289***
(t-1)	(0.033)	(0.043)	(0.304)	(0.108)
Renewable	−0.011	−0.001	0.001	−0.034**
energy (t-1)	(0.012)	(0.018)	(0.039)	(0.015)
CO_2	0.027	0.036	−0.323	−0.143***
Emission	(0.030)	(0.060)	(0.354)	(0.053)
(t-1)				

Coefficient of Determination: 0.87. Number of Countries: 14; Observations: 343; t min – t max: 1992-2017. All variables: growth rates. Panel-specific fixed effects removed using forward orthogonal deviation (Helmert transformation). Common time fixed effects removed by subtracting from each variable in its cross-sectional mean before estimation. Cluster-robust standard errors in brackets. *p<0.1,**p<0.05,***p<0.01. Stability condition verified (all the eigenvalues lie inside the unit circle)

is that a growing economy requires more energy, but if energy use grows too much it means that the country is not efficient in energy use and this affects production costs, the competitiveness of the economy and the GDP growth rate.

In terms of contribution to the literature on this topic, it is useful to highlight the following: the use of a different methodology (suggested by the characteristics of the data and based on growth rates) than usual makes it possible to highlight an aspect that seems quite rational (the relationship between energy use and competitiveness), but that long-term analysis on levels tends to leave out. This occurs because the analysis moves from being absolute to being relative. Therefore, the use of a different methodology should not be considered as a criticism of those usually used.

The second result concerns CO_2 emissions growth rate, which result to be positively affected by GDP growth rate and energy consumption growth rate. This is coherent with the findings of previous literature for European transition economies. Our analysis also shows that the CO_2 emissions growth rate decrease when the production of renewable energy growths, in line with our hypothesis.

The results seem to indicate that there is no causality relationship going from the other variables (including GDP growth) to renewable energy (in % of energy production). This result is probably the more affected by the limitation of our "short-run" approach: it is highly unlikely that one-period lagged growth rates in GDP, energy use or emissions have important short-run effects on growth in renewable energy production. As mentioned in the hypotheses, the research works on transition economies considering renewable energy are few and with not univocal results. Our results, unfortunately, do not add anything in this sense. At the present time it does not seem to be possible to say that there exists any "endogenous" mechanism that leads to invest more in renewables as a consequence of economic growth.

The growth rate of per capita GDP is positively correlated with its lag, indicating an unsurprising form of GDP growth persistence. The negative relationship between the growth rate of CO_2 emissions per capita and its lag indicates that, all other things being equal (and in our case, particularly with a given GDP growth and energy consumption growth), the per capita level of emissions would tend to stabilise.

Since the results for the variable "renewable energy" are mostly insignificant, we re-estimate the model without this variable in order to verify the robustness of the results of the other three variables. The results shown in Table 2 confirm those of the first model. In addition, the significance of the causal relationship from the growth rate of energy use to the growth rate of GDP increases in the new specification.

With reference to this second model, after the panel VAR estimate, we checked the stability condition by calculating the modulus of each eigenvalue of the fitted model. A VAR model is stable if all module of the companion matrix is strictly less than one (Hamilton, 2004; Lütkepohl, 2005). Our panel model results to be stable and, hence, invertible and has an infinite-order VMA representation which allows to go on with orthogonalized impulse-response.

Simple IRFs have no causality interpretation. Orthogonalized IRFs require a specification of the Cholesky ordering of the endogenous variables. "The ordering constrains the timing of the responses: shocks on variables that come earlier in the ordering will affect subsequent variables contemporaneously, while shocks on variables that come later in the ordering will affect only the previous variables with a lag of one period" (Abrigo and Love, 2016. p. 794). In our case, also based on the results of the model estimation, the following order can be assumed: GDP, Energy use, CO_2 emissions.

Table 2: Panel VAR model (2) results

Variables	Dep: GDP	Dep: Energy use	Dep: CO_2 emission
GDP (t-1)	0.465***	0.213***	0.181**
	(0.107)	(0.062)	(0.080)
Energy use (t-1)	−0.070**	0.063	0.248***
	(0.028)	(0.049)	(0.108)
CO_2 Emission (t-1)	0.036	0.036	−0.118**
	(0.031)	(0.068)	(0.052)

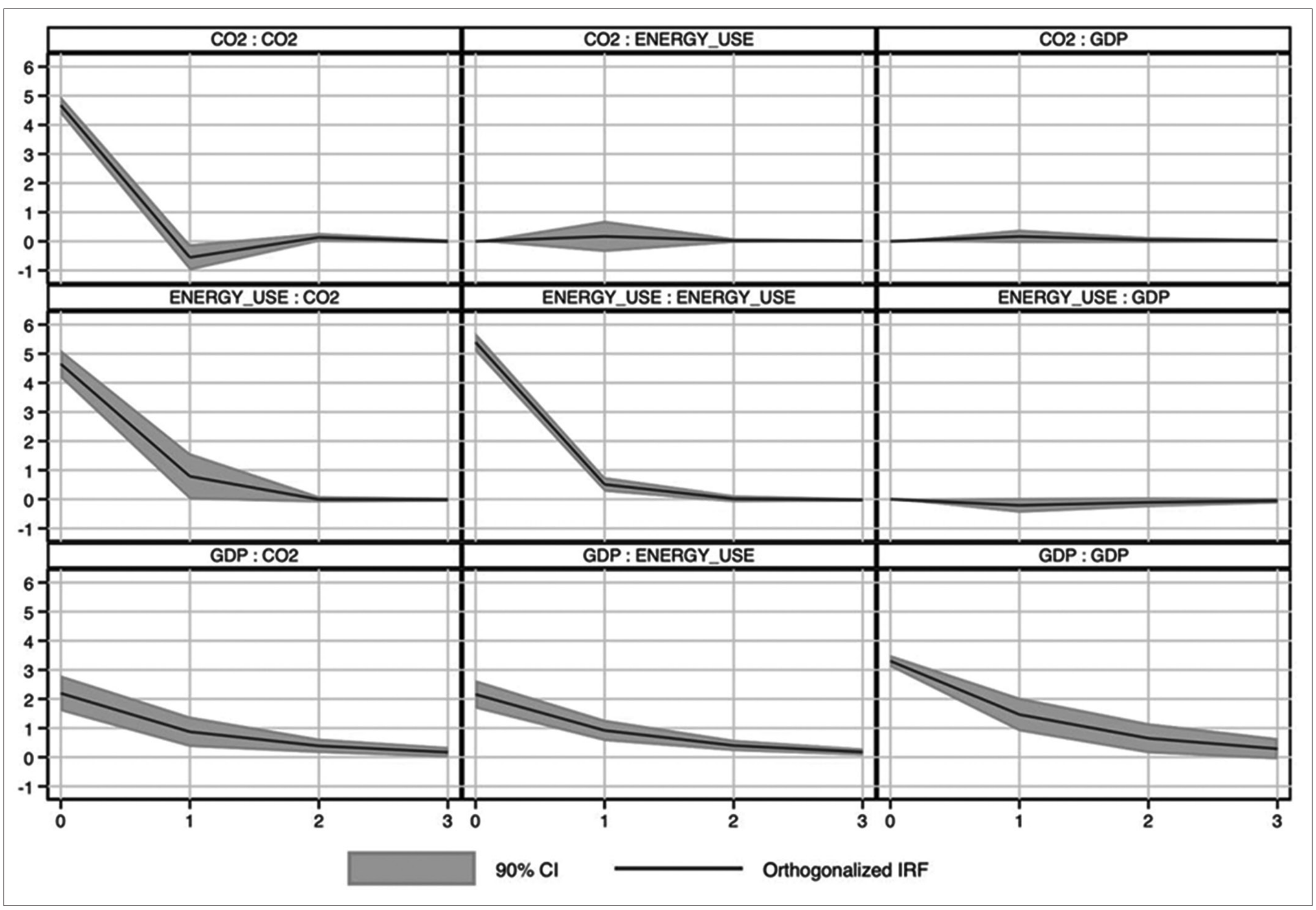
Coefficient of Determination: 0.87. Number of Countries: 14; Observations: 343; t min – t max: 1992-2017. All variables: growth rates. Panel-specific fixed effects removed using forward orthogonal deviation (Helmert transformation). Common time fixed effects removed by subtracting from each variable in its cross-sectional mean before estimation. Cluster-robust standard errors in brackets. *$p<0.1$,**$p<0.05$,***$p<0.01$. Stability condition verified (all the eigenvalues lie inside the unit circle)

Figure 1 shows the results of orthogonalized IRF (confidence intervals are computed using 200 Monte Carlo draws based on the estimated model).

The first row shows that a shock on the growth rate of CO_2 emissions has no significant effects (in subsequent periods) on GDP and energy consumption growth rates. In turn (second row), a shock on the growth rate of energy use leads to a contemporary increase in emissions and has a negative effect on the potential for GDP growth (with a lag of delay). The third row shows that a shock on GDP growth rate positively influences the growth rates of energy consumption and CO_2 emissions (in the same period, because of our Cholesky ordering).

Obviously, the impulse-response graphical representation does not allow to add much to the comments already made to the results of the panel var (Tables 1 and 2). However, they show that the negative effect of the growth rate of energy consumption on the growth rate of GDP is very small, as could be expected in the short term.

Figure 1: Impulse response analysis



5. CONCLUSIONS

In this contribution, we study the causal relationship between GDP growth, energy consumption, renewable energy production and CO_2 emissions in some European transition economies.

In 2011, the European Commission published a roadmap for moving to a competitive low-carbon economy in 2050. The European transition countries' that we have considered in our study are very integrated in the production processes of the EU countries with higher manufacturing specialization. It can be assumed that some of these economies have completed their transition phase. But there is no doubt that the European transition economies face an own trajectory of development, different from that of other European countries and still based on manufacturing industry (Compagnucci et al., 2020). For this reason, analyzing the interactions between these economies and the environment is useful for the purposes of European objectives. The CO_2 reduction necessary to transform the EU into a competitive low carbon economy must necessarily affect (and pass through) European economies in transition. Although our approach can only give indications on the short term, it is still the first attempt to specifically analyze European transition countries.

One cannot underestimate the results may be influenced by the fact that, as already mentioned, during the period considered some countries joined the European Union, characterized by specific regulations and objectives in terms of environmental policy and emissions. We verified that by introducing an exogenous dummy indicating the EU membership the results do not change substantially (here we have preferred to focus on variables that can all be considered "endogenous"). Unfortunately, the introduction of an interaction between our endogenous variables and a dummy for EU-membership would increase too much the number of parameters to be estimated in relation to the available observations.

Here, we briefly summarize our results (in section 3 they are already commented with direct reference to our hypothesis, formulated on the basis of the results of the previous literature): our findings show that a growing GDP implies a growing energy use but also suggest that investing in energy efficiency is good for the competitiveness of transition countries (we found that*, ceteris paribus*, an high growth of energy use can negatively affect GDP growth rate) and is good for the environment (we found that, ceteris paribus, an higher use of energy implies higher CO_2 emissions).

Our results also confirm that a growing use of renewable energies reduces CO_2 emissions. Finally, as the previous literature suggests, our results confirm that, at the moment, it cannot be said that there is an endogenous mechanism linking economic growth to increasing investment in renewable energy.

Despite all the precautions deriving from the methodology, our work suggests a consideration that deserves to be deepened in further research: public interventions are important because energy efficiency is crucial and because there may not be any endogenous mechanism associating GDP growth with an increase of renewable energy sources. These considerations suggest an additional benefit of EU membership, given the resulting incentives for energy saving and emission reduction policies. In the near future, policy makers in a growing economy should aim to reduce wasted energy and to improve the power infrastructures for the economy. Energy saving and renewable energy need to be boosted through specific fiscal and administrative measures and policies, with possible positive effects for the economy and the environment.

For future research, the availability of more abundant and accurate data will be essential to allow the applicability of quantitative methodologies capable of giving more precise policy indications.

REFERENCES

Abosedra, S., Baghestani, H. (1989), New evidence on the causal relationship between United States energy consumption and gross national product. The Journal of Energy and Development 14(2), 285-292.

Abrigo, M.R., Love, I. (2016), Estimation of panel vector autoregression in Stata. The Stata Journal 16(3), 778-804.

Acaravci, A., Ozturk, I. (2010), On the relationship between energy consumption, CO_2 emissions and economic growth in Europe. Energy, 35(12), 5412-5420.

Ahmed, M., Azam, M. (2016), Causal nexus between energy consumption and economic growth for high, middle and low income countries using frequency domain analysis. Renewable and Sustainable Energy Reviews, 60, 653-678.

Ajmi, A.N., El Montasser, G., Nguyen, D.K. (2013), Testing the relationships between energy consumption and income in G7 countries with nonlinear causality tests. Economic Modelling, 35, 126-133.

Akbostanci, E., Türüt-Aşik, S., Tunç, G.İ. (2009), The relationship between income and environment in Turkey: Is there an environmental Kuznets curve? Energy Policy, 37(3), 861-867.

Al-mulali, U. (2012), Factors affecting CO_2 emission in the Middle East: A panel data analysis. Energy, 44(1), 564-569.

Altinay, G., Karagol, E. (2005), Electricity consumption and economic growth: Evidence from Turkey. Energy Economics, 27(6), 849-856.

Ang, J.B. (2007), CO_2 emissions, energy consumption, and output in France. Energy Policy, 35(10), 4772-4778.

Ang, J.B. (2008), Economic development, pollutant emissions and energy consumption in Malaysia. Journal of Policy Modeling, 30(2), 271-278.

Antonakakis, N., Chatziantoniou, I., Filis, G. (2017), Energy consumption, CO_2 emissions, and economic growth: An ethical dilemma. Renewable and Sustainable Energy Reviews, 68, 808-824.

Apergis, N., Payne, J.E. (2009), CO_2 emissions, energy usage, and output in Central America. Energy Policy, 37(8), 3282-3286.

Arellano, M., Bover, O. (1995), Another look at the instrumental variable estimation of error-components models. Journal of Econometrics, 68(1), 29-51.

Asghar, Z. (2008), Energy-GDP relationship: A causal analysis for the five countries of South Asia. Applied Econometrics and International Development, 8(1), 167-180.

Bouoiyour, J., Selmi, R. (2013), The nexus between electricity consumption and economic growth in MENA countries. Energy Studies Review, 20(2), 25-41.

Bouoiyour, J., Selmi, R., Ozturk I. (2014), The nexus between electricity consumption and economic growth: new insights from meta-analysis. International Journal of Energy Economics and Policy, 4(4), 621-635.

Boutbane, E., Coulibaly, D., Rault, C. (2012), Immigration, Growth and Unemployment: Panel VAR Evidence from OECD Countries. IZA

Discussion Papers No. 6966.

Brown, J.H., Burnside, W.R., Davidson, A.D., DeLong, J.P., Dunn, W.C., Hamilton, M.J., Zuo, W. (2011), Energetic limits to economic growth. BioScience, 61(1), 19-26.

Chen, S.T., Kuo, H.I., Chen, C.C. (2007), The relationship between GDP and electricity consumption in 10 Asian countries. Energy Policy, 35(4), 2611-2621.

Chiou-Wei, S.Z., Chen, C.F., Zhu, Z. (2008), Economic growth and energy consumption revisited evidence from linear and nonlinear Granger causality. Energy Economics, 30(6), 3063-3076.

Compagnucci, F., Gentili, A., Valentini, E., Gallegati, M. (2020), Technical progress, structural change, and robotisation: Insights from the growth patterns of the "Visegrád" countries. Economia e Lavoro, 1, 13-29.

Coondoo, D., Dinda, S. (2020), Causality between income and emission: A country group-specific econometric analysis. Ecological Economics, 40(3), 351-367.

Ghosh, S. (2002), Electricity consumption and economic growth in India. Energy Policy, 30(2), 125-129.

Granger, C.W. (1969), Investigating causal relations by econometric models and cross-spectral methods. Econometrica, 37(3), 424-438.

Grossman, G.M., Krueger, A.B. (1991), Environmental Impacts of a North American Free Trade Agreement. NBER Working Paper No. 3914 1991, National Bureau of Economic Research.

Halicioglu, F. (2009), An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. Energy Policy, 37(3), 1156-1164.

Haller, A. (2020), From classical and neoclassical economic growth to degrowth in Europe. Challenges for Public Administration. Administratie si Management Public, 34, 150-170.

Hamilton, J.D. (1994), Time Series Analysis. Princeton, NJ: Princeton University Press, US.

Harrison, A.E., Eskeland, G. (2003), Moving to greener pastures? Multinationals and the pollution-haven hypothesis. Journal of Development Economics, 70(1), 1-23.

Ho, C.Y., Siu, K.W. (2007), A dynamic equilibrium of electricity consumption and GDP in Hong Kong: an empirical investigation. Energy Policy, 35(4), 2507-2513.

Hoffmann, R., Lee, C.G., Ramasamy, B., Yeung, M. (2005), FDI and pollution: A granger causality test using panel data. Journal of International Development: The Journal of the Development Studies Association, 17(3), 311-317.

Holtz-Eakin, D., Newey W., Rosen, H.S. (1988), Estimating vector autoregressions with panel data. Econometrica, 56, 1371-1395.

Im, K.S., Pesaran, M.H., Shin, Y. (2003), Testing for unit roots in heterogeneous panels. Journal of Econometrics, 115(1), 53-74.

International Monetary Fund. (2000), Transition Economies: An IMF Perspective on Progress and Prospects. Available from: https://www.imf.org/external/np/exr/ib/2000/110300.htm.

Jensen, V. (1996), The Pollution Haven Hypothesis and the Industrial Flight Hypothesis: Some Perspectives on Theory and Empirics. Centre for Development and the Environment, University of Oslo Working Paper, No. 5.

Kablamaci, B. (2017), A re-examination of causal relation between economic growth and energy consumption: Evidence from 91 countries. Economics Bullettin, 37(2), 790-805.

Kasman, A., Duman, Y.S. (2015), CO_2 emissions, economic growth, energy consumption, trade and urbanization in new EU member and candidate countries: A panel data analysis. Economic Modelling, 44, 97-103.

Kizilkaya, O. (2017), The impact of economic growth and foreign direct investment on CO_2 emissions: The case of Turkey. Turkish Economic Review, 4(1), 106-118.

Kraft, J., Kraft, A. (1978), On the relationship between energy and GNP. The Journal of Energy and Development, 1978, 401-403.

Kuznets, S. (1955), Economic growth and income inequality. The American Economic Review, 45(1), 1-28.

Lean, H.H., Smyth, R. (2010), CO_2 emissions, electricity consumption and output in ASEAN. Applied Energy, 87(6), 1858-1864.

Lu, W.C. (2017), Renewable energy, carbon emissions, and economic growth in 24 Asian countries: Evidence from panel cointegration analysis. Environmental Science and Pollution Research, 24(33), 26006-26015.

Lütkepohl, H. (2005), New Introduction to Multiple Time Series Analysis. Germany: Springer Science and Business Media, Springer Nature.

Magazzino, C. (2012), On the relationship between disaggregated energy production and GDP in Italy. Energy and Environment, 23(8), 1191-1207.

Marinaş, M.C., Dinu, M., Socol, A.G., Socol, C. (2018), Renewable energy consumption and economic growth. Causality relationship in Central and Eastern European countries. PLoS One, 13(10), e0202951.

Mozumder, P., Marathe, A. (2007), Causality relationship between electricity consumption and GDP in Bangladesh. Energy Policy, 35(1), 395-402.

Narayan, P.K., Prasad, A. (2008), Electricity consumption real GDP causality nexus: Evidence from a bootstrapped causality test for 30 OECD countries. Energy Policy, 36(2), 910-918.

Narayan, P.K., Smyth, R. (2009), Multivariate Granger causality between electricity consumption, exports and GDP: Evidence from a panel of Middle Eastern countries. Energy Policy, 37(1), 229-236.

Omri, A. (2013) CO_2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models. Energy Economics, 40, 657-664.

Ozturk I., Acaravci, A. (2010), The causal relationship between energy consumption and GDP in Albania, Bulgaria, Hungary and Romania: Evidence from ARDL bound testing approach, Applied Energy, 87(6), 1938-1943.

Ozturk, I. (2010), A literature survey on energy growth nexus. Energy Policy, 38(1), 340-349.

Ozturk, I., Aslan, A., Kalyoncu, H. (2010), Energy consumption and economic growth relationship: Evidence from panel data for low- and middle-income countries. Energy Policy, 38(8), 4422-4428.

Ozturk, Z., Oz, D. (2016), The Relationship between energy consumption, income, foreign direct investment, and CO_2 emissions: The case of Turkey. Çankırı Karatekin Üniversitesi İİBF Dergisi, 6(2), 269-288.

Payne, J.E. (2010), A survey of the electricity consumption-growth literature. Applied Energy, 87(3), 723-731.

Ricci, F. (2007), Channels of transmission of environmental policy to economic growth: A survey of the theory. Ecological Economics, 60(4), 688-699.

Richmond, A.K., Kaufmann, R.K. (2006), Is there a turning point in the relationship between income and energy use and/or carbon emissions? Ecological Economics, 56(2), 176-189.

Sari, R., Ewing, B.T., Soytas, U. (2008), The relationship between disaggregate energy consumption and industrial production in the United States: an ARDL approach. Energy Economics, 30(5), 2302-2313.

Sharma, S.S. (2010), The relationship between energy and economic growth: Empirical evidence from 66 countries. Applied Energy, 87(11), 3565-3574.

Shin, Y., Pesaran M.H., Smith, R.P. (1999), Pooled mean group estimation of dynamic heterogeneous panels. Journal of the American Statistical, 94(446), 621-634.

Shiu, A., Lam, P.L. (2004), Electricity consumption and economic growth in China. Energy Policy, 32(1), 47-54.

Sinha, D. (2009), The Energy Consumption-GDP Nexus: Panel Data Evidence from 88 Countries. MPRA Paper, No. 18446. Germany: University Library of Munich. Avaialble from: .https://www.mpra.ub.uni-muenchen.de/id/eprint/18446

Soytas, U., Sari, R. (2007), The relationship between energy and production: Evidence from Turkish manufacturing industry. Energy Economics, 29(6), 1151-1165.

Soytas, U., Sari, R. (2009), Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. Ecological Economics, 68(6), 1667-1675.

Soytas, U., Sari, R., Ewing, B.T. (2007), Energy consumption, income, and carbon emissions in the United States. Ecological Economics, 62(3-4), 482-489.

Squalli, J. (2007), Electricity consumption and economic growth: Bounds and causality analyses of OPEC members. Energy Economics, 29(6), 1192-1205.

Stern, D.I. (2004), The rise and fall of the environmental Kuznets Curve. World Development, 32(8), 1419-1439.

Tang, C.F., Tan, B.W., Ozturk, I. (2016), Energy consumption and economic growth in Vietnam. Renewable and Sustainable Energy Reviews, 54, 1506-1514.

Tang, C.F., Tan, E.C. (2012), Electricity consumption and economic growth in Portugal: Evidence from a multivariate framework analysis. The Energy Journal, 33(4), 23-48.

The World Bank. (2002), *The First Ten Years. Analysis and Lessons for Eastern Europe and the Former Soviet Union.* Washington, DC: The International Bank for Reconstruction and Development/The World Bank.

Tsani, S.Z. (2010), Energy consumption and economic growth: A causality analysis for Greece. Energy Economics, 32(3), 582-590.

Wolde-Rufael, Y. (2006), Electricity consumption and economic growth: A time series experience for 17 African countries. Energy Policy, 34(10), 1106-1114.

Wolde-Rufael, Y. (2014), Electricity consumption and economic growth in transition countries: A revisit using bootstrap panel Granger causality analysis. Energy Economics, 44, 325-330.

Wooldridge, J.M. (2002), Econometric Analysis of Cross Section and Panel Data. Cambridge, MA: MIT Press.

Yoo, S.H. (2005), *Electricity consumption and economic growth: Evidence from Korea.* Energy Policy, 33(12), 1627-1632.

Yoo, S.H., Lee, J.S. (2010), *Electricity consumption and economic growth: A cross-country analysis.* Energy Policy, 38(1), 622-625.

Zhang, X.P., Cheng, X.M. (2009), *Energy consumption, carbon emissions, and economic growth in China.* Ecological Economics, 68(10), 2706-2712.

APPENDIX A

Figure A1: GDP per capita (World Bank), Energy consumption per capita (Eurostat), CO_2 emissions per capita (Our World in Data); growth rates

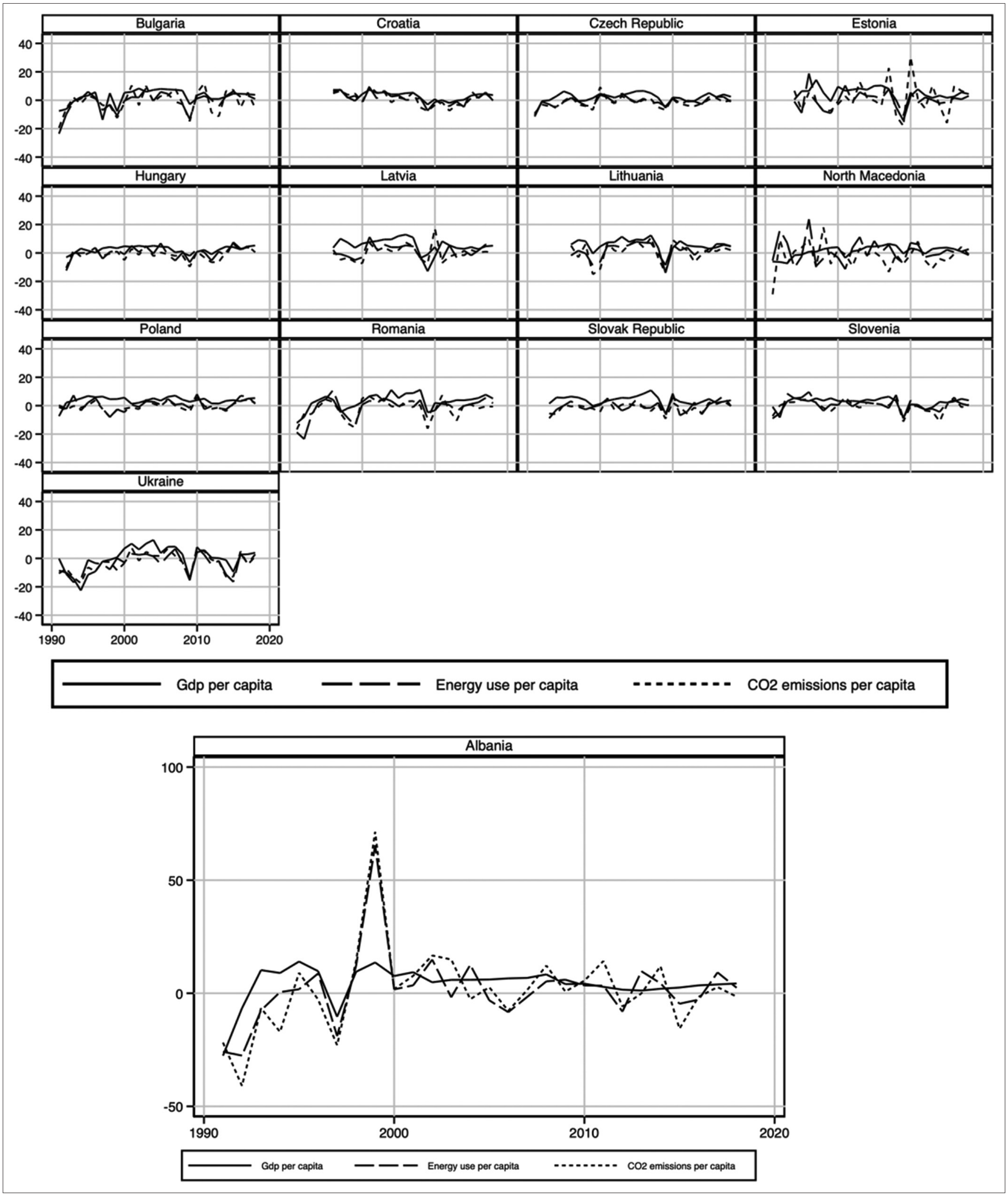


Figure A2: Renewable Energy (% of energy production), growth rates, source Eurostat