Associate Professor Ioana Teodora MEȘTER, PhD (corresponding author)
E-mail: imester@uoradea.ro
Department of Economics and Business
Faculty of Economic Sciences, University of Oradea, Romania

Associate Professor Liana Eugenia MEȘTER, PhD
E-mail: lmester@uoradea.ro
Department of International Business
Faculty of Economic Sciences, University of Oradea, Romania

Lecturer Andreea Florina FORA, PhD
E-mail: afora@uoradea.ro
Department of International Business
Faculty of Economic Sciences, University of Oradea, Romania

EXPLORING THE RELATIONSHIP BETWEEN ECONOMIC GROWTH, TRADE OPENNESS, CO_2 EMISSIONS, AND RENEWABLE ENERGY: EVIDENCE FROM EASTERN EUROPEAN COUNTRIES

Abstract. *The objective of this paper is to investigate the relationship between economic growth, CO_2 emissions, trade openness index, as well as the renewable energy consumption in Eastern European countries. The panel ARDL approach is used to reveal the long- and short-run impact of the selected variables on GDP per capita. Stationarity tests reveal that variables are I(0) and I(1), panel cointegration test confirm the long-run equilibrium between the variables, which enables us the use of panel ARDL methodology. The model reveals that in the long run there is a significant relationship between the dependent variable and all the exogenous ones for the selected countries. The Dumitrescu Hurlin causality test confirms the feedback causality between economic growth and trade openness, renewable energy consumption, and economic growth and unilateral causality running from CO_2 emissions to economic growth.*

Keywords*: panel cointegration, economic growth, GDP, CO_2 emissions, trade openness, renewable energy, long-run equilibrium*

JEL Classification: C50, F43, P18

1. Introduction

The study of the economic growth and its determinants has old implications. An analysis of relevant literature shows that there is a series of empirical studies that have analysed, tested, and explained the correlation between the dynamics of economic growth and its determinants.

DOI: 10.24818/18423264/57.2.23.14

Achieving or maintaining a sustained growth rhythm represents a major objective of macroeconomic policies. The concern for the study of economic growth has existed beginning with the representatives of the classical school and continuing with the Keynesists, Neo-Keynesists, and the neo-classics. A series of empirical studies has tested the dynamics of the different factors and the economic growth process using econometrical models and statistical approaches.

Energy is fundamental for sustainable development, and until recently, fossil fuel energy has been the major component used worldwide. However, the global economy has expanded so much that it led to the depletion of the most accessible energy resources. In addition, the problem of global warming and CO_2 emissions generated by all the economic activities generated a major alarm sign – renewable resources must be appropriately managed for a sustainable growth. Renewable energy is clean, as it is generated from solar, wind, geothermal, tide and wave, waste, and biomass. It is undeniable that renewable energy sources play a major role in reducing greenhouse emissions.

Regarding the openness of trade, it plays an essential role in the 'cleaning' of the energy sector. It should ease the transfer of modern technologies that support the renewable energy production.

A series of empirical studies tested the correlation between the process of economic growth and the dynamics of renewable energy consumption, trade openness, and CO_2 emissions. Most of these researches are based on econometrical methods including panel data approach, cointegration, and Granger causality analysis.

The objective of our paper is to investigate the short- and long-run nexus between the GDP per capita as a nexus for economic growth, CO_2 emissions, trade openness index as well as the renewable energy consumption in Eastern European countries. For this purpose, we will use an Auto Regressive Distributed Lag model based on panel data. This approach has the advantage that it allows including both time and spatial dimension in the analysis, which increases the number of observations and increases the degrees of freedom and reduces the chances of multicollinearity.

Our investigation seeks to contribute to the literature both from a theoretical and empirical point of view. First, the survey of the relevant papers allowed us to assess the correlation between the selected variables. Second, the empirical analysis based on dynamic models and panel data enables the investigation of short- and long-run effects of determinants over the endogenous variable – the international tourism development index. Third, the analysis reveals some policy implications and further research directions to be followed in the future.

The rest of our paper is organised as follows. Section 2 reviews the previous literature on the nexus between growth, CO_2 emissions, trade openness, and renewable energy consumption. Section 3 presents the data and methodology; Section 4 is dedicated to the empirical analysis. Finally, Section 5 presents a detailed discussion, policy, and practical implications.

2. Literature review

Over the years, the relationship between economic growth and trade openness has been the subject of study by several specialists in the economic field. The results of studies carried out in countries from various corners of the world and in different periods indicated that there is a close and direct connection between economic growth and trade openness (Leitão and Balsalobre-Lorente, 2020; Jebli et al., 2019; Hye and Lau, 2015; Pilinkienė, 2016; Islam et al., 2022, Çevik et al., 2019).

The studies carried out by Leitão and Balsalobre-Lorente (2020) and Balsalobre-Lorente and Leitão (2020) between 1995 and 2014, within 28 EU member countries, highlighted that among the 28 analysed countries, economic growth was influenced by trade openness. Furthermore, these studies demonstrated that trade openness, through the standard commercial policy carried out at the EU level, encourages environmental sustainability through a negative association between climate change and trade openness.

In a study carried out between 1995 and 2010 in 22 states of Central and South America by Jebli et al. (2019), the results of econometric studies highlighted a bidirectional causal relationship between economic growth and trade openness and between FDI and trade openness.

Some studies (Çevik et al., 2019; Hye and Lau 2015; Islam et al. 2022; Louardy and Moussamir 2022) analysed the relationship between economic growth and trade openness over more extended periods of time – exceeding 30 years and reaching up to 50 years. Using various econometric techniques, such as the ARDL bounds test of cointegration, the rolling window regression, the Granger causality tests, as well as the Toda-Yamamoto causality tests, the authors revealed different correlations between the economic growth and trade openness in the short-run. The results of studies by Hye and Lau (2015) in India, Louardy and Moussamir (2022) in Morocco, and Çevik et al. (2019) in Turkey confirmed that in the short-run economic growth is positively influenced by trade openness; trade openness had a negative impact on economic growth in the case of the three states in the long-run.

The case study of Saudi Arabia by Islam et al. (2022), during the period 1985-2019, highlighted that trade openness positively influences economic growth, both in the short- and long-run.

Pilinkienė (2016) conducted a study in which he analysed the link between economic growth and trade openness in 11 countries in Central and Eastern Europe from 2000-2014. The vector autoregression (VAR) model and the Granger-causality tests confirmed a statistically significant correlation between trade openness and economic growth; moreover, economic growth would improve trade openness.

Economists have also studied the relationship between economic growth and CO_2 emissions over the years. Most studies indicate that economic growth also implies an increase in CO_2 emissions (Nguyen et al., 2022; Jayasinghe and

Selvanathan, 2021; Wang et al. 2016; Mikayilov, et al. 2018; Antonakakis et al. 2015; Obradović and Lojanica, 2017; Onofrei et al. 2022).

On the other hand, the results of other studies have demonstrated that economic growth is possible with the reduction of CO_2 emissions (El Hedi Arouri et al., 2012; Aslan et al., 2021; Raihan and Tuspekova; 2022).

Studies conducted in Vietnam by Thi Nguyen et al. (2022) in the period 1980-2018, in India by Jayasinghe and Selvanathan (2021) in the period 1991-2018, in China by Wang et al. (2016) in the period 1990-2012, in Azerbaijan by Mikayilov et al. (2018) in the period 1992-2013, and in Greece and Bulgaria by Obradovik and Lojanica (2017), in the period 1980-2010 which were based on econometric models clearly showed that there is a causal relationship between economic growth and CO_2 emissions.

The study undertaken by Antonakakis et al. (2016), in the period 1971-2011, the authors investigated the correlation between economic growth and CO_2 emissions in 106 countries grouped by the degree of development and using a panel vector autoregression model (PVAR). The empirical results showed that the continuous process of economic growth amplifies the phenomenon of greenhouse gas emissions.

Onofrei et al. (2022) in their study on 27 EU countries during the period 2000-2017 conclude that an average increase of 1% in GDP leads to an increase of 0.072% in CO_2 emissions.

On the other hand, the result of the study conducted in Singapore by Raihan and Tuspekova (2022) indicates that an economic growth of 1% is possible, simultaneously with a reduction of CO_2 emissions by a percentage of 0.99%.

Also, the study performed by Arouri et al. (2012) in 12 countries in the Middle East and North Africa in the period 1981-2005 revealed that economic growth was possible during the analysed period, with a simultaneous reduction of the CO_2 emissions.

As regards the correlation between trade openness and the economic growth, we have identified country-specific as well as regional studies. Ocal and Aslan (2013) investigate the causal relationship between renewable energy use and economic growth in Turkey, the results confirming a unidirectional causality from economic growth towards renewable energy consumption. Pao and Fu (2013) investigate the causal relationship between renewable energy consumption and economic growth in Brazil. In their research, they use annual data for GDP and four types of renewable energy consumption. The results are mixed, but the authors point out the importance of renewable energy in the process of economic growth.

In most cases, regional studies (Tugcu et al., 2012; Sadorsky, 2009; Menegaki, 2011; Apregis and Payne, 2011) also confirm the cointegration in the short – as well as in the long-run between the economic growth and renewable energy consumption.

We will issue the following research hypothesis to be investigated:

Research hypothesis H1: At the level of Eastern European countries, there is a short-run relationship between GDP per capita and trade openness.

Research hypothesis H2: At the level of Eastern European countries, there is a short-run relationship between GDP per capita and renewable energy consumption.

Research hypothesis H3: At the level of EU countries, there is a short-run relationship between tourism and CO_2 emissions.

Research hypothesis H4: At the level of Eastern European countries, there is a long-run relationship between economic growth, CO_2 emissions, trade openness and renewable energy consumption.

Research hypothesis H5: At the level of Eastern European countries, there is feedback causality between GDP per capita, trade openness, CO_2 emissions, and renewable energy consumption.

3. Methodology

3.1. Data and sample

The objective of this paper is to investigate the economic growth measured trough the GDP per capita, CO_2 emissions, trade openness index as well as the renewable energy consumption in Eastern European countries. Our empirical analysis comes to enrich the literature and to validate or not the results obtained by in previous analysis.

For this purpose, we will use the Autoregressive Distributied Lag (ARLD) model based on panel data.

Table 1. Data

Variable	Source	Code
GDP per capita (current international US$)	World Bank	GDP
CO_2 Emissions (metric tons per capita)	World Bank	CO_2
Trade Openness (%)	World Bank	TO
Renewable energy consumption (% of total energy consumption)	World Bank	REC

Yearly data were collected from the World Bank database for all the variables and for nine Eastern European countries. Given the limited data available for CO_2 emission as and renewable energy consumption, we used data for the 1995-2019 period. Trade openness index was computed by the authors as a ratio between the total value of exports and imports of each country and the total GDP.

Table 1 presents the acronyms used for each variable, the data sources, as well as the measurement units. GDP per capita is expressed in current international US$, trade openness index and renewable energy consumption are coefficients and can be expressed as percentages, the CO_2 emissions are measured in metric tons

per capita. The values are diverse, which is why there is a need to put the data on the same measurement scale. Before starting our empirical analysis, we will compute the log of each variable, this way we will also eliminate possible trends.

3.2. ARDL model

The variables used in our model are the GDP growth rate as a proxy for the economic growth, CO_2 emissions, trade openness index, as well as the renewable energy consumption. The choice of the appropriate model will be made after an analysis of the characteristics of the data. We will begin with an investigation of the Bounds Test proposed by Pesaran and Shin (1999) and Pesaran et al. (2001). Dickey Fuller (1979), Phillips and Perron (1988), and Levin and Lin and Choo (2002) unit root tests will be used to test the integration order of the variables.

The multicolinarity between the dependent variables will be checked using the variance inflation factor (VIF) test.

Residual Cointegration tests (Pedroni, 1999; Pedroni, 2004) will be used to investigate the long-run relationship in panel data. In order to choose the best estimator for the model, we will employ the Hausmann test (1978); it will indicate if the fixed effects model or the random effects model is appropriate.

We will then estimate the parameters of an ARDL(p,q,q,...q) model that can be written as follows:

$$y_{it} = \sum_{j=1}^{p} \delta_j y_{i,t-j} + \sum_{j=0}^{q} \beta_{ij}^{'} X_{i,t-j} + \varphi_i + e_{it} \quad (1)$$

where yit is the dependent variable, Xit is a k x 1 vector of independent variables, δ_j is the coefficient of the lagged dependent variable, $\beta_{ij}^{'}$ is a k x 1 coefficient vector , φ_i is the unit specific fixed effects, $i = \overline{1,N}$, $t = \overline{1,T}$, p and q are optimum lag orders and *eit* is the error term.

Starting from the initial model, a re-parametrised ARDL(p, q, q, ...q) error correction model will be specified as:

$$\Delta y_{it} = \theta_i ECT + \sum_{j=1}^{p-1} \xi_{ij} y_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij}' \Delta X_{i,t-j} + \varphi_i + e_{it} \quad (2)$$

that will reveal the long run relationship between the variables.

Here:

$\theta_i = -(1 - \delta_i)$ group specific speed of adjustment

λ_i' = vector of longrun relationship

ECT = $\left[y_{i,t-1} - \lambda_i' X_{i,t}\right]$ - the error correction term

ξ_{ij} and β_{ij}' are the short run dynamic coefficients.

Diagnostic tests will confirm the validity of the model. The Dumitrescu-Hurlin (2012) panel causality test will be used to investigate the bidirectional causality between the variables and to confirm or reject our research hypothesis.

4. Results

4.1. Descriptive statistics

We will begin the investigation of the data with a summary of the descriptive statistics computed for the variables included in our model. As seen in Table 2, we have computed the main statistical indicators of the primary variables, before them being detrended. The summary statistics reveal the basic features of the data. The central tendency is revealed by the mean and the median, variability of the series is measured by the standard deviation, the form and asymmetry of the distribution is revealed by the skewness and kurtosis coefficients, while the amplitude of the variation is measured by the minimum and maximum of each variable.

Table 2. Descriptive statistics

Indicator	Renewable energy consumption	GDP per capita	CO_2 emissions	Trade openness
	(% of total energy consumption)	current international US$	metric tons per capita	%
Mean	9.81	280305342765.27	6.23	110.23
Median	7.32	395887.50	5.97	107.81
Std. Dev.	6.25	760230986128.56	2.26	33.29
Pearson's var. coeff.	63.71%	271.21%	36.27%	30.2%
Skewness	0.86	2.64	0.73	0.23
Kurtosis	-0.1	5.37	0.52	-0.57
Minimum	0.89	6147.43	2.29	43.72
Maximum	26.07	3075100758400	12.36	189.8
Observations	225	225	225	225

Source: Authors' calculation

As seen in Table 2, there are some significant differences between the mean and the median values of GDP per capita, which reveals a significant heterogeneity between values, as well as between countries. Pearson's variation coefficient is also a measure of homogeneity. The threshold of 40% is used in the literature for distinguishing between the homogenous and heterogeneous variables. Trade openness and CO_2 emissions are the two homogenous variables, for which the average value is representative as a measure of tendency; GDP per capita and renewable energy consumption are the heterogeneous variables included in our analysis. All the variables are asymmetrical; GDP per capita has the most asymmetrical distribution. In what regards the kurtosis, two of the variables are platykurtic (GDP per capita and trade openness), the other two are leptokurtic; GDP per capita is again the variable most biased from the normal or Gaussian curve.

4.2. ARDL model

Our empirical analysis will be based on a three-stage procedure. First, the stationarity of the variables will be investigated. Second, the long-run equilibrium among the variables will be tested based on the ARDL approach, and in the end the causal relationship between the variables will be investigated using the Dumitrescu-Hurlin cointegration tests.

According to the ARDL / Bounds Testing methodology proposed by Pesaran and Shin (1999) and Pesaran et al. (2001), all the variables should be either stationary or integrated of first order I(1). Also, some studies (De Vita et al., 2006) recommend that the dependent variable is I(1). This is not a mandatory condition widely accepted in the literature, but in our case it is observed.

Before investigating the stationarity of each variable, we analysed their pattern and checked for the presence of a trend and/or a constant coefficient in each unit root regression. Dickey Fuller (1979) and Phillips and Perron (1988) unit root tests confirmed that all the variables are either I(0) or I(1). Levin, Lin and Choo (2002) unit root test was also employed to investigate the presence of a common unit root process.

Table 3 presents the results of these tests as well as the models employed for testing the stationarity of each variable, for example, tests for GDP per capita, CO_2 emissions, and renewable energy consumption were run under the assumption of the presence of an intercept and deterministic trend. The results allow us to apply the bound test for cointegration.

Table 3. Panel data unit root tests

	Renewable energy consumption Trend, constant		GDP per capita Trend, constant		CO_2 Emissions Trend, constant		Trade Openness Constant	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LLC	0.16 (0.56)	-2.99 *(0.00)	0.04 (0.51)	-2.53* (0.00)*	-0.64 (0.26)	-3.59* (0.00)	-2.99* (0.00)	-
ADF	-3.87* (0.01)	-	-1.79 (0.7)	-14.95 (0.00)	-2.7 (0.23)	-14.62* (0.00)	-3.68 (0.02)	-
PP	-4.07* (0.00)	-	13.31 (0.77)	53.3* (0.00)	20.58 (0.30)	121.15* (0.00)	38.38* (0.00)	-

The null hypothesis states that the unit root exists. The asterisks *"the rejection of the null hypothesis at the 0.01 level I(0) indicates at the level and I(1) at first diference."
Source: Authors' calculation using Eviews 10

The multicoliniarity between the independent variables might affect the results of our empirical analysis. Variance inflation factor (VIF) is a measure of the amount of multicoliniarity that is often employed in the literature. The higher the VIF value, the greater the correlation of the variable with the others considered. A good value for VIF is below 10, but some researchers state that if the value is above 5 the regression is highly correlated. Results indicate that there is no multicolliniarity between the independent variables considered for our model - GDP growth rate, CO_2 emissions, trade openness, as well as the energy efficiency. All the centered VIF values are below 2.5, which is a threshold accepted for the absence of multicoliniarity. Spearman's rho rank order correlation coefficients were also computed; the results confirmed that that there is no multicolliniarity between the selected variables. The Pesaran and Shin (2001) bound test confirmed the presence of a long-run relationship between the variables.

In order to choose the lag length, we have employed an unrestricted VAR model, and most of the information criteria indicated an optimal lag length equal to 1.

Pedroni (1999, 2004) Residual Cointegration test was used for investigating the long-run relationship in panel data, because it takes care of cross-sectional dependence, by allowing considerable heterogeneity. The outcome of the test is presented in Table 4. The test was run under the assumption of no deterministic trend. As seen, 6 of the 11 statistics are significant at the 5% level and indicate the rejection of the null hypothesis of no cointegration.

The results confirmed the existence of a long-run cointegration relation between the GDP growth rate, CO_2 emissions, trade openness, and the renewable energy consumption. This means that their correlation is not a short-lived, but a permanent one, and one that can be recovered every time there is a perturbation.

Table 4. Data cointegration analysis

		Statistic	Prob.	Statistic	Prob.
Panel v-Statistic		13.12389	0.0000	12.43560	0.0000
Panel rho-Statistic		0.525806	0.7005	0.876689	0.8097
Panel PP-Statistic		-1.726345	0.0469	-0.927696	0.1768
Panel ADF-Statistic		-2.412438	0.0079	-2.262172	0.0118
Alternative hypothesis: individual AR coefs. (between-dimension)					
		Statistic	Prob.		
Group rho-Statistic		1.718227	0.9571		
Group PP-Statistic		-0.693033	0.2441		
Group ADF-Statistic		-2.912056	0.0018		

Source: Authors' calculation using Eviews 10

The next step in our analysis was to choose between the fixed effects model and the random effects model. Hausmann test (1978) revealed the presence of random effects, which means the PMG – Pooled Mean Group estimator is best to be used when estimating our ARDL model.

We will estimate the coefficients of the ARDL model that reveal the short- and long-run correlations between the variables.

Table 5. Panel ARDL model estimations

Long run coefficients			**Short-run coefficients**		
Variable	**Coeff.**	**–Prob.**	**Variable**	**Coeff.**	**–Prob.**
LOGTO	0.2147*	0.00	COINTEQ01	-0.3088*	0.00
LOG_REC	0.2355*	0.00	D(LOGTO)	-0.0055***	0.06
LOGCO2	0.5367*	0.00	D(LOG_REC)	0.0255	0.22
			D(LOGCO2)	0.1511***	0.07
			C	3.9707*	0.00
			@TREND	0.0147*	0.00

***Coefficient is significant at the 0.01 level (2-tailed). ** Coefficient is significant at the 0.05 level (2-tailed). *Coefficient is significant at the 0.1 level (2-tailed).

Source: Authors' calculation using Eviews 10

The findings presented in Table 5 suggest that, in the short-run, renewable energy consumption does not influence economic growth in Eastern European countries, but trade openness (p = 0.06) and CO_2 emissions (p = 0.07) have a statistically significant impact on GDP per capita at the level of 0.01.

As a result, we can decide on our research hypothesis as follows:

Research hypothesis H1: At the level of Eastern European countries, there is a short-run relationship between GDP per capita and trade openness – is validated.

Research hypothesis H2: At the level of Eastern European countries, there is a short-run relationship between GDP per capita and renewable energy consumption – is not validated.

Research hypothesis H3: At the level of EU countries, there is a short-run relationship between tourism and CO_2 emissions – is validated.

Regarding the long-run results, all variables taken into account have a statistically significant impact on the economic growth measured by GDP per capita: CO_2 emissions are positively correlated with growth, an increase in renewable energy consumption and trade openness will have a positive impact on long-term economic growth.

Research hypothesis H4: At the level of Eastern European countries a long-run relationship between economic growth, CO_2 emissions, trade openness and renewable energy consumption is validated.

The error correction term from the long run representation is statistically significant at the 0.01 level and its sign is negative, which confirms the correct specification of the model.

Table 6. Cross section short run coefficients

	COINTEQ01		TO		CO_2		REC	
Country	Coefficient	Prob	Coefficient	Prob	Coefficient	Prob	Coefficient	Prob
BG	**-0.368864**	0.0019	-0.008784	0.1571	**0.175124**	0.0002	**0.320370**	0.0010
CZ	**-0.468129**	0.0000	**-0.033047**	0.0025	**-0.035729**	0.0128	**-0.047607**	0.0345
HU	**-0.383149**	0.0000	**0.067507**	0.0001	**0.017974**	0.0002	**0.086975**	0.0007
PL	**-0.354769**	0.0000	**0.006880**	0.0246	**0.062395**	0.0002	**-0.128139**	0.0000
RO	**-0.377764**	0.0001	-0.017167	0.1101	**0.015360**	0.0693	0.023404	0.3769
SK	**-0.183459**	0.0002	**0.102758**	0.0005	**-0.003983**	0.0631	**0.052400**	0.0331
MD	**-0.449130**	0.0001	**-0.019608**	0.0871	**0.020064**	0.0011	-0.041001	0.1110
UKR	**-0.248156**	0.0002	**-0.240324**	0.0000	**0.006997**	0.0038	**0.561596**	0.0000
BL	**-0.053351**	0.0001	**0.091508**	0.0000	**-0.027930**	0.0137	**0.532022**	0.0001

***Coefficient is significant at the 0.01 level (2-tailed). ** Coefficient is significant at the 0.05 level (2-tailed). *Coefficient is significant at the 0.1 level (2-tailed).

Source: Authors' calculation using Eviews 10

The analysis of the cross section results on the short-run has revealed a different situation from that presented at the panel level (Table 6).

CO_2 emissions have a significant short-run impact on the economic growth measured by GDP per capita in all Eastern European countries cases. Trade openness has a significant short-run influence on the index in most cases (except Bulgaria and Romania). In the Czech Republic, Moldova, and Ukraine, trade openness negatively influences the economic growth while the in Hungary, Poland, Slovakia is direct. Renewable energy consumption has a statistically significant short-run impact on the economic growth in most countries, except Romania and Moldova. In Bulgaria, Hungary, Slovakia, Ukraine and Belarus, the renewable energy consumption has a positive impact on the short run, while in Czech Republic and Poland it has a negative impact on the economic growth measured by GDP per capita.

The diagnostic tests confirm that the model fulfills the requirements for a valid one. The Jarque Bera test for normality revealed the lack of normality, but Thadewald and Bunning (2007) suggest that the findings are not prejudiced.

There are several causality tests that are used in the literature, the most known being the Granger (1969) test, as well as the Dumitrescu and Hurlin (2012) test.

Table 7. Dumitrescu Hurlin Panel Causality Test

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
LOGTO does not homogeneously cause LOGGDP	1.36063	-1.04580	0.0957
LOGGDP does not homogeneously cause LOGTO	5.29173	3.57674	0.0003
LOG_REC does not homogeneously cause LOGGDP	7.98288	6.74124	2.E-11
LOGGDP does not homogeneously cause LOG_REC	11.1406	10.4543	0.0000
LOGCO2 does not homogeneously cause LOGGDP	4.28095	2.38818	0.0169
LOGGDP does not homogeneously cause LOGCO2	3.44542	1.40569	0.1598

Source: Authors' calculation using Eviews 10

As seen in Table 7, Dumitrescu Hurlin causality test confirm feedback causality between economic growth and trade openness, as well as economic growth and renewable energy consumption and unilateral causality running from CO_2 emissions to economic growth.

In conclusion, the research hypothesis H5: At the level of Eastern European countries, there is feedback causality between GDP per capita, trade openness, CO_2 emissions and renewable energy consumption is partially validated.

5. Concluding remarks

The relationship between economic growth, the environment and trade openness has a high degree of complexity. The impact of economic activities on the environment can have several policy implications.

Greater focus by policymakers on promoting economic growth could encourage innovation, and investment in renewable energy technologies. Also, in order to mitigate the negative impacts of economic activities on the environment, while promoting economic growth in the sector, a series of policy implications could be mentioned such as: the adoption of sustainable practices, encouraging the use of renewable energy sources that are more clean and do not have a negative impact on the environment.

The purpose of this paper was to investigate the causal relationship between economic growth, trade openness, CO_2 emissions, as well as renewable energy consumption in Eastern European countries. To our knowledge, there is no similar study that considered the Eastern part of Europe as a whole.

The empirical evidence from the ARDL approach indicates that CO_2 emissions, trade openness and renewable energy consumption are correlated in the long-run. In the short-run, renewable energy consumption do not influence economic growth in Eastern European countries, but trade openness and CO_2 emissions have a statistically significant impact on GDP per capita. The Dumitrescu Hurlin causality test confirm feedback causality between economic growth and trade openness, as well as economic growth and renewable energy consumption, and unilateral causality running from CO_2 emissions to economic growth.

These findings reveal that an increase in income is a key factor in encouraging the renewable energy sector. Trade openness enables Eastern European countries to benefit from the green and clean technologies. The policy implications of this relationship include the need for countries to pursue policies that promote trade openness while supporting and encouraging the import of modern technologies that support the energy sector.

REFERENCES

[1] **Antonakakis, N., Ioannis, C., Filis, G. (2017),** ***Energy Consumption, CO2 Emissions, and Economic Growth: An Ethical Dilemma.*** *Renewable and Sustainable Energy Reviews*, 68, 808–824;

[2] **Antonakakis, N., Dragouni, M., Filis, G. (2015*), How Strong Is the Linkage between Tourism and Economic Growth in Europe?*** *Economic Modelling*, 44, 142–155;

[3] **Arouri, M., Youssef, B.A., M'henni, H., Rault, C. (2012*), Energy Consumption, Economic Growth and CO2 Emissions in Middle East and North African Countries.*** *Energy Policy*, 45, 342–349;

[4] **Balsalobre-Lorente, D., Leitão, N.C. (2020),** ***The Role of Tourism, Trade, Renewable Energy Use and Carbon Dioxide Emissions on Economic Growth: Evidence of Tourism-Led Growth Hypothesis in EU-28.*** *Environmental Science and Pollution Research*, 27(36), 45883–45896;

[5] **Ben Jebli, M., Youssef, S., Apergis, N. (2019),** ***The Dynamic Linkage between Renewable Energy, Tourism, CO2 Emissions, Economic Growth, Foreign Direct Investment, and Trade.*** *Latin American Economic Review*, 28(1), 2;

[6] **Çevik, E.İ., Atukeren, E., Korkmaz, T. (2019),** ***Trade Openness and Economic Growth in Turkey: A Rolling Frequency Domain Analysis.*** *Economies*, 7(2), 41;

[7] **De Vita, G., Endresen, K., Hunt, L.C. (2006),** ***An Empirical Analysis of Energy Demand in Namibia.*** *Energy Policy*, 34(18), 3447–3463;

[8] **Dickey, D.A., Fuller, W. (1979),** ***Distribution of the Estimators for Autoregressive Time Series With a Unit Root.*** *Journal of the American Statistical Association*, 74(366), 427;

[9] **Dumitrescu, E., Hurlin, C. (2012),** ***Testing for Granger Non-Causality in Heterogeneous Panels.*** *Economic Modelling*, 29(4), 1450–1460;

[10] **Granger, C.W.J. (1969),** ***Investigating Causal Relations by Econometric Models and Cross-Spectral Methods.*** *Econometrica*, 37(3), 424;

[11] **Hausman, J.A. (1978*), Specification Tests in Econometrics.*** *Econometrica*, 46(6), 1251;

[12] **Hye, Q.M.A., Lau, W. (2015),** ***Trade Openness And Economic Growth: Empirical Evidence From India.*** *Journal of Business Economics and Management*, 16(1), 188–205;

[13] **Islam, M.S., Alsaif S.S., Alsaif, T. (2022),** ***Trade Openness, Government Consumption, and Economic Growth Nexus in Saudi Arabia: ARDL Cointegration Approach.*** *SAGE Open*, 12(2), 215824402210966;

[14] **Jayasinghe, M., Selvanathan, E.A. (2021),** ***Energy Consumption, Tourism, Economic Growth and CO $_2$ Emissions Nexus in India.*** *Journal of the Asia Pacific Economy*, 26(2), 361–380;

[15] **Leitão, N.C., Balsalobre Lorente, D. (2020),** ***The Linkage between Economic Growth, Renewable Energy, Tourism, CO2 Emissions, and International Trade: The Evidence for the European Union***. *Energies,* 13(18), 4838;

[14] **Levin, A., Lin, C., Chu C.S. (2002),** ***Unit Root Tests in Panel Data: Asymptotic and Finite-Sample Properties***. *Journal of Econometrics,* 108(1), 1–24;

[15] **Louardy, H., Moussamir, A. (2022), Analysis Of The Impact Of Trade Openness On Economic Growth: The Case Of Morocco.** *Acta logistica*, 09(04), 417–431;

[16] **Mikayilov, J.I., Galeotti, M., Hasanov, F.J. (2018),** ***The Impact of Economic Growth on CO2 Emissions in Azerbaijan***. *Journal of Cleaner Production,* 197, 1558–1572;

[17] **Nguyen, H.T. et al. (2022),** ***The Nexus between Greenhouse Gases, Economic Growth, Energy and Trade Openness in Vietnam***. *Environmental Technology & Innovation*, 28, 102912;

[18] **Obradović, S., Lojanica. N. (2017),** ***Energy Use, CO2 Emissions and Economic Growth – Causality on a Sample of SEE Countries***. *Economic Research-Ekonomska Istraživanja*, 30(1), 511–26;

[19] **Onofrei, M., Vatamanu, A.F., Cigu, E. (2022),** ***The Relationship Between Economic Growth and CO2 Emissions in EU Countries: A Cointegration Analysis***. *Frontiers in Environmental Science*, 10, 934885;

[20] **Pedroni, P. (1999),** ***Critical Values for Cointegration Tests in Heterogeneous Panels with Multiple Regressors***. *Oxford Bulletin of Economics and Statistics,* 61(s1), 653–70;

[21] **Pedroni, P. (2004),** ***Panel Cointegration: Asymptotic and Finite Sample Properties of Pooled Time Series Tests. with an Application to the PPP Hypothesis.*** *Econometric Theory*, 20(03);

[22] **Pesaran, M.H., Shin, Y., Smith, R. (2001),** ***Bounds Testing Approaches to the Analysis of Level Relationships.*** *Journal of Applied Econometrics, 16(3), 289–326;*

[23] **Pesaran, M.H., Shin, Y., Smith, R. (1999),** ***Pooled Mean Group Estimation of Dynamic Heterogeneous Panels.*** *Journal of the American Statistical Association,* 94(446), 621–34;

[24] **Phillips, P.C.B., Perron, P. (1988),** ***Testing for a Unit Root in Time Series Regression***. *Biometrika*, 75(2), 335–46;

[25] **Pilinkienė, V. (2016),** ***Trade Openness, Economic Growth and Competitiveness. The Case of the Central and Eastern European Countries.*** *Engineering Economics,* 27(2), 185–94;

[26] **Raihan, A., Tuspekova, A. (2022),** ***The Nexus between Economic Growth, Energy Use, Urbanization, Tourism, and Carbon Dioxide Emissions: New Insights from Singapore.*** *Sustainability Analytics and Modeling*, 2, 100009;

[27] **Thadewald, T., Büning, H. (2007),** ***Jarque–Bera Test and Its Competitors for Testing Normality – A Power Comparison.*** *Journal of Applied Statistics,* 34(1), 87–105;

[28] **Wang, S., Li, Q., Fang, C., Zhou, C. (2016),** ***The Relationship between Economic Growth, Energy Consumption, and CO2 Emissions: Empirical Evidence from China.*** *Science of The Total Environment,* 542, 360–71.