INNOVATION, EXPORT, CO2 EMISSION AND ECONOMIC GROWTH: A PANEL ANALYSIS OF SELECTED CENTRAL AND EASTERN EUROPEAN COUNTRIES

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Abstract: *The article presents an effort to examine the development patterns of the Central and Eastern European countries (CEEC), considering notable macroeconomic relations amongst export intensity, energy use, innovation capacity, and economic growth. From that perspective, the main objective of the article is to identify the significance and impact of prior mentioned macroeconomic features on economic growth, as well as the dynamics of CO2 emission in the CEEC. The Panel Auto Regressive Distributed Lag (ARDL) is utilized as the central model for examining the long-term and short-term relations among economic growth, technological innovations, export intensity, and CO2 emission. Based on the Pooled Mean Group (PMG) estimator, outcomes exhibit that the export intensity and the dynamics of CO2 emission have a notable impact on economic growth in the long term, while the impact of export intensity becomes irrelevant to explain the movement of economic growth in the short term. Innovation capacity has no significant impact on economic growth trends in the long or the short term. The different outcomes are obtained regarding the influence of the specified variables on the dynamics of CO2 emission. Trends in economic growth, in the long run, moderately determine the dynamics of CO2 emission. The innovation capacity and the export intensity have a significant negative impact on the movement of CO2 emission dynamics in the long run, although the dynamics of CO2 emissions remain determined only by innovation capacity in the short term.*

Keywords: *Innovation, Export, CO2 Emission, Economic Growth, Panel ARDL*

JEL classification: *C33, F10, O11*

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INTRODUCTION

In contemporary economic circumstances, it is important to comprehend the patterns of economic movement under the influence of various factors. Growing economies face the necessity to find out new technological and innovative solutions to foster a more efficient level and functioning of the economy. Active participation in international markets requires economic openness and their positioning in the world market by stimulating export, as a necessary determinant of economic growth. Economic activity is also strongly linked to energy use and CO_2 emissions (Tang & Tan, 2013). In addition to contributing to economic growth, innovation and economic openness also affect energy consumption, so there is a strong relationship between innovation, exports, CO_2 emissions, and economic growth (Fan & Hossain, 2018). The effects of these variables and their interaction with the degree of economic growth depend on a particular economy and its economic structures.

CEEC region has reached a certain level of development but still lag behind the most developed European Union (EU) countries. Reducing the backwardness, compared to the most developed EU countries, can largely depend on innovation and the intensification of export (Damijan, Kostevc, & Rojec, 2017). It is also important to establish the relationship between innovation, export, CO_2 emission, and economic growth in the example of CEEC. This article tries to complement the literature gap in this respect and to indicate the interrelationship among variables. The main objective of the article is to identify the significance and impact of prior mentioned macroeconomic features on economic growth, as well as the dynamics of CO_2 emission in the CEEC. The aim is to examine the development patterns of selected CEEC, considering notable macroeconomic relations amongst export intensity, energy use, innovation capacity, and economic growth.

The rest of the article is organized as follows: Section 2 presents the review of the past literature. Section 3 illustrates the used methodology and hypotheses. Section 4 provides results and discussion. At last, conclusions are summarized, and some basic policy recommendations are offered in section 5.

LITERATURE REVIEW

Numerous studies have analyzed the impact of innovation, economic openness, and CO_2 emissions on economic growth. The main intention is to identify the pattern and intensity of influence of those variables on the economic growth in individual economies and to understand the economic growth and its determinants through different perspectives. On the opposite, some efforts were made to identify basic economic determinants of CO_2 emission.

The development of new technologies and innovations can be considered as a key factor in the development of economic activities through the creation of knowledge and an innovation-based economy (Oulton, 2012). The contribution of innovation, as well as investment in research and development, provides a positive stimulus to the economy in the long run by creating the concept of "smart growth", which is based on knowledge and innovation (Rodriguez-Pose, & Bilbao-Osorio, 2004; Capello & Lenzi, 2013). Maradana, Pradhan, Dash, Gaurav, Jayakumar, and Chatterjee (2017) analyzed the long-term link between innovation and economic growth, based on the example of 19 European countries from 1989-2014. Using the cointegration technique and the Granger causality test, the study provides evidence of the long-term link between innovation and sustainable economic growth in most cases. Nazir and Tan (2018) have proven the positive attitude and importance that financial innovation has in the short and long term on economic growth. The authors also point out that the openness of the economy plays an important role in stimulating economic growth.

When it comes to the openness of the economy and its impact on economic growth, most studies have shown a positive impact. Using the ARDL model based on Toda and Yamamoto Granger causality approach, the significant impact of trade, energy, and financial development on economic growth was identified (Kumar R.R, Stauvermann, Loganathan, & Kumar R.D., 2015). Export can play a significant role in stimulating economic growth, especially in the case of developed and developing countries, while the effects of exports do not show a positive influence on economic growth in underdeveloped countries (Were, 2015). Analyzing the impact of exports and foreign direct investments, Sunde (2017) also confirmed the positive influence of economic openness on economic growth using the ARDL model approach.

The third variable, whose movement and impact on economic growth, can also be observed is air pollution followed through CO2 emissions. The demand for more intense economic growth can neglect the pollution effects that the development of industry causes. Consequently, it is essential to determine the effects of increased pollution in the short and long term. A review of the literature in this field shows that there are a positive cause and effect relationship between the two variables, but their intensity depends on the degree of development of the economy (Bengochea-Morancho, Higón-Tamarit, & Martínez-Zarzoso, 2001). Attiaoui, Toumi, Ammouri, and Gargouri (2017), using the panel ARDL-PMG approach, expose a positive impact between CO2 emissions and GDP, while a study conducted by Saidi and Hammami (2015) on the example of 58 countries also proves that economic growth and CO2 emissions are complementary. Al-Mulali and Ozturk (2016) find that economic growth leads to an increase in CO2 emissions only in the long run, while on the other hand, the openness of the economy leads to a decrease.

Fan and Hossain (2018) analyzed all four variables on the example of China and India, using the panel ARDL model. The findings show that innovation, trade openness, and CO2 emissions, have a significant positive impact on economic growth in China in the long run. In the case of India, trade openness and CO2 emission have also a significant positive impact in the long-run, but CO2 emission harms economic growth, in the short-run. Innovation does not have a significant impact on economic growth in the short term. Sohag, Begum, Abdullah, and Jaafar (2015) concluded that economic growth increases energy consumption, with the effect being more significant in the long run. Trade openness also increases energy consumption as measured by CO2 emissions in the long run, while innovation plays an important role in reducing energy consumption and contributing to long-term economic growth. Destek, Balli, and Manga (2016) proved the long-run cointegrated relationship between CO2 emission, energy consumption, urbanization, and trade openness. Research conclusion, on the example of 10 selected CEEC, indicates that an increase in energy consumption by 1 percent leads to an increase in CO2 by 1.0863 percent while, on the other hand, an increase in trade openness by 1 percent leads to a 0.0686 percent decrease in CO2 emissions.

Based on the above, the subsequent hypotheses are tested in the article:

- H_1: Increase in innovation capacity, export dynamics, and CO2 emission incites economic growth.
- H_2: Intense economic growth spurs the scope of CO2 emissions.
- H_3: Increased export activities and well-activated innovation capacity reduce the intensity of CO2 emission.

METHODOLOGY

To achieve the main objective, panel data series with an annual frequency range between 2002 - 2017 have been used in the article. The examination includes eight Central and Eastern European countries (i.e., the Republic of Bulgaria, the Republic of Croatia, the Czech Republic, Hungary, the Republic of Poland, Romania, the Slovak Republic, and the Republic of Slovenia), and incorporates the following variables:

- Gross domestic product per capita (variable gdp_pc);
- Number of patents per million inhabitants (variable patent_inhab);
- Export as a percentage of gross domestic product (variable export_gdp_ratio);
- All sectors and indirect CO2, excluding LULUCF and memo items (variable CO2_emission)

The statistical office of the European Union (Eurostat) served as the origin of data. Descriptive statistics of the variables and correlation matrix are exhibited in Table 1 and Table 2, respectively. The Jarque-Bera statistic shown in Table 1 reveal the absence of normal distribution for all series except the series of gdp_pc. The cause might be a cross-sectional and heterogeneous characteristics of the data, which are corrected through the examinations in panel data analysis.

Table 1 Descriptive statistics of the variables

	gdp_pc	patent_inhab	export_gdp_ratio	CO2_emission
Mean	10143.98	15.33633	57.17500	88840.76
Median	10135.00	8.395000	57.15000	50010.76
Maximum	20810.00	69.10000	95.10000	336556.8
Minimum	2220.000	0.520000	24.00000	13524.34
St. Dev.	4352.857	17.07405	19.75955	95078.62
Skewness	0.304273	1.728708	0.149425	1.785211
Kurtosis	2.432549	4.959268	1.855718	4.880611
Jarque-Bera	3.692420	84.22644	7.459686	86.85125
Probability	0.157834	0.000000	0.023997	0.000000
Obs.	128	128	128	128

Source: Author's calculations

Concerning the further aspects of the series, it is necessary to show the correlation between the selected variables. As pointed in Table 2, innovation capacity and the export intensity have a strong relation with economic growth, while the dynamics of CO2 emissions have a weak and negative correlation. A moderate negative correlation is detected between innovation capacity and the dynamics of CO2 emissions, also between the export intensity and CO2 emissions.

Table 2 Correlation matrix of the variables

	gdp_pc	patent_inhab	export_gdp_ratio	CO2_emission
gdp_pc	1			
patent_inhab	0.79	1		
export_gdp_ratio	0.62	0.44	1	
CO2_emission	-0.18	-0.23	-0.34	1

Source: Author's calculations

All variables, besides export_gdp_ratio, are represented using logarithmic expressions and can be perceived as elasticities.

The initial step that has to be taken in panel data analysis is to test whether cross-section units are cross-sectionally dependent or cross-sectionally independent. Cross-sectional dependence is a significant matter, and overlooking it might lead to biased and inconsistent estimates (Dong, Sun, Li, & Liao, 2018). For that purpose, two tests are utilized in the article, Breusch–Pagan LM test and the Pesaran-scaled LM test. Lagrange multiplier revealed by Breusch and Pagan (1980) is adequate for panel with N being comparatively small and T amply large (which is the case in the examination: N=8 T=16). The test is based on the following LM statistic:

$$LM = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} T_{ij}\, \hat{p}_{ij}^2 \rightarrow x^2\, \frac{N(N-1)}{2} \qquad (1)$$

Where $\hat{p}_{ij}$ is the correlation coefficient of residuals, as well as in Pesaran-scaled LM test, which can be estimated as:

$$LM_{pesaran} = \sqrt{\frac{1}{N(N-1)}} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} (T_{ij}\hat{p}_{ij}^2 - 1) \rightarrow N(0,1) \qquad (2)$$

Considering the high degree of interactivity in the functioning of economies of the examined countries, spatial spillover effects, which is one of the causes of cross-section dependence, become more apparent. Since it is profoundly presumable that the panel data in the examination will be identified by cross-sectional dependence, the following step determines the selection of the second generation unit root tests, which assumes that cross-section units are cross-sectionally dependent, to perceive the nature of the stationarity of the series. Pesaran (2007) introduced a unit root test marked as cross-sectionally augmented IPS test which can be expressed as:

$$CIPS(N,T) = N^{-1} \sum_{i=1}^{N} t_i\, (N,T) \qquad (3)$$

Furthermore, the panel ARDL formulated as an error correction model is used to examine the long and short term relations among economic growth, innovation capacity, export intensity, and dynamics of $CO2$ emission. The procedure is applicable because it can examine possible associations irrespective of the integration order of the selected variables. The model's imperative is that the series cannot be integrated of order two. Besides, this method proposes convenient and useful estimators because it reduces the obstacles appearing from endogeneity by including lag length for both endogenous and exogenous variables (Attiaoui et al. 2017).

Pesaran and Smith (1995) and Pesaran, Shin, and Smith (1999) proposed two different estimators as the solutions to heterogeneity bias produced by heterogeneous slopes in dynamic panels - Mean Group (MG) and Pooled Mean Group (PMG). The MG procedure permits the coefficients to be heterogeneous in the short run and long run, while the PMG procedure implies heterogeneity of the short-term coefficients, whereas the long-term coefficients are homogeneous (Sohag, Nabilah, & Begum, 2015). The decision between MG and PMG estimators is based on the Hausman test. If the Hausman test fails to reject the long-run homogeneity restriction, then the PMG estimator is more suitable, and vice versa.

RESULTS AND DISCUSSION

Observed from the perspective of strong intra-economic linkages of macroeconomic data, the premise of cross-sectional independence among different groups cannot be assumed, rather the premise necessitates to be questioned. The results of cross-sectional independence tests are presented in Table 3. The assumption of cross-sectional independence amongst groups is rejected according to to the Breusch–Pagan LM test and Pesaran-scaled LM test, considering that p-values are less than 0.05.

Table 3 Cross-sectional dependence tests results

Test	Statistic	P-value
Breusch–Pagan LM	144.6735	0.0000
Pesaran-scaled LM	15.59116	0.0000

Source: Author's calculations

Rejecting the assumption of cross-sectional independence requires utilizing the second generation unit root tests to examine the stationarity of the variables. As observed in Table 4, all variables are not stationary at level besides the innovation capacity (variable patent_inhab). Nevertheless, every of nonstationary variables (gdp_pc, export_gdp_ratio, CO2_emission) become stationary after the first difference, respects to CIPS test. The presence of a mixed order of integration supports to use panel ARDL model.

Since the Hausman test explicated that the PMG estimator is more suitable for producing further panel analysis, the following table exhibits the outcomes of the PMG estimator as well as the results of the Hausman test.

The Hausman test failed to reject the long-run homogeneity restriction, implying the appropriateness of the PMG estimator when economic growth is observed as a dependent variable. The same results of the Hausman test occur when the dynamics of CO2 emission are placed as a dependent variable.

The results from Table 5 manifest a positive influence of export dynamics and the boost of CO2 emission on economic growth (a 1 percent increase in export value and the CO2 emission enhances economic growth by 0.0325 percent and 3.7553 percent, respectively). From the short-term perspective, results reveal that a 1 percent rise in CO2 emission magnifies economic growth by 0.2944 percent while the impact of export intensity is irrelevant to explain the movement of economic growth in the short run. Nevertheless, the outcome of the same analysis indicates that innovative activities do not represent a significant pillar of economic growth in the long or the short term.

Table 4 Panel unit root test results

Variables	CIPS
gdp_pc	-2.384
patent_inhab	-2.819
export_gdp_ratio	-0.993
CO2_emission	-1.843
Δgdp_pc	-3.522
Δpatent_inhab	/
Δexport_gdp_ratio	-2.857
ΔCO2_emission	-3.387

Δ - is the first difference operator
*CVs are -2.21, -2.34, -2.60 at 10%, 5% and 1% levels of significance, respectively
*CVs for Δ are -2.22, -2.37, -2.66 at 10%, 5% and 1% levels of significance, respectively

Source: Author's calculations

Inevitably, economic development, to a greater or lesser extent, causes increased CO2 emissions. Within the analyzed group of countries, dynamizing economic growth encourages the use of CO2 (1 percent rise in economic growth fosters CO2 emission by 0.0635 percent over the long run, and 0.4543 percent over the short run). From a different perspective, one of the essential preconditions for establishing the so-called green economy is the emergence of new technological solutions. Fostering the innovation capacity represents a serious impetus to creating an economic structure based on sustainable development. This is in line with the hypothesis of Soete (2007), who outlined the necessity of simultaneous competitiveness development and quality of social and environmental conditions. The main findings administrate that innovations reduce CO2 emissions (a 1 percent increase in innovation capacity decreases CO2 emission by 0.1466 percent over the long run). Since the aggregate level of CO2 emissions is observed, evaluating the real impact of the progression of innovation on CO2 emission requires a lengthier period. Consequently, the outcomes obtained in the short term can be held as irrelevant. Further conclusions of this part of the examination concern the impact of exports on CO2 emission. Specifically, the results show that the rise in export adversely affect CO2 emissions, which may be explained by the fact that open trade regimes are more capable to gain a lower level of pollution because they invest in industries that use modern technology and cause less polluting (Danchev, 1994). To some extent, a mentioned outcome can partly be justified by the relatively successful adoption and implementation of new technological solutions for those industries that are export-oriented. However, there is still not strictly determined regularity in defining the impact of trade openness on CO2 emissions. Market size, industrialization level, and various additional institutional characteristics should also be considered when evaluating the effects of trade liberalization on environmental outcomes (Zugravu-Soilita, 2018).

Table 5 Pooled Mean Group Regression results

Dependent variable	gdp_pc ARDL(1 0 0 0)	CO2_emission ARDL (1 1 1 0)
	Long-run coefficient	
gdp_pc		0.0635*
patent_inhab	0.5225	-0.1466***
export_gdp_ratio	0.0325***	-0.0029***
CO2_emission	3.7553***	
	Short-run coefficient	
ECT	-0.141048***	-0.3568538***
Δgdp_pc		0.4543***
Δpatent_inhab	-0.0163	0.0385**
Δexport_gdp_ratio	-0.0051	0.0020
ΔCO2_emission	0.2944***	
Hausman test value	2.36	1.49
P-value	0.5004	0.6847
Notes: * indicate significance (* at 10%, ** at 5% and *** at 1%)		
The optimal lag length is determined by Schwarz Information Criterion		

Source: Author's calculations

Within both instances, the ECT has a negative sign and is statistically notable at a 1 percent level of significance, implying a stable long-term association among the variables. As previously stated, the PMG procedure indicates the heterogeneity of the short-term coefficients as well as the heterogeneity of the dynamic adjustment process (Demetriades & Hook-Law, 2006). The subsequent table exhibits the error correction terms for each country. The outcomes indicate that error correction terms have a corresponding negative sign and are significant in most of the examined countries. The examples of countries where ECT has a corresponding negative sign, but statistically insignificant, are the Republic of Croatia (when the dynamics of CO2 emission is considered as a dependent variable), Hungary, and Romania (the case when the gdp_pc is the response variable), the Republic of Poland (when dynamics of CO2 emission is output variable) and Slovenia (in both instances). In these examples, the stable long-term relationship exists among the considered variables, but it is not significant to economic growth or CO2 emission, depending on what is estimated as the target variable.

A further consideration in the article is how long it will necessitate for the current imbalance to be reduced by 50 percent. The first observation covers an instance where gdp_pc is the response variable. In the Republic of Bulgaria and the Slovak Republic, a coefficient of -0,15 indicates that there was 15 percent of adjusting occurs in the previous period to the equilibrium, while 85 percent of disequilibrium remains. That means remain imbalance will be reduced by 50 percent in around four years. Slightly less time is needed to halve the imbalance in the Czech Republic (about three years). In the case of the

Republic of Croatia and Romania, a significantly longer time is required - about nine and eleven years to halve the imbalance, respectively. The shortest period of about one year is exposed in the instance of the Republic of Poland.

Table 6 The Error Correction Term

Dependent variable	gdp_pc ARDL(1 0 0 0)	CO2_emission ARDL (1 1 1 0)
Error Correction Term		
The Republic of Bulgaria	-0.1517864 (0.000)	-0.6793443 (0.000)
The Republic of Croatia	-0.0688383 (0.002)	-0.0847174 (0.255)
The Czech Republic	-0.1955955 (0.001)	-0.4842131 (0.000)
Hungary	-0.0521207 (0.275)	-0.2140877 (0.030)
The Republic of Poland	-0.4058853 (0.002)	-0.0541444 (0.252)
Romania	-0.0649143 (0.078)	-0.6584657 (0.000)
The Slovak Republic	-0.1503593 (0.000)	-0.558725 (0.000)
The Republic of Slovenia	-0.03884 (0.335)	-0.1211329 (0.385)

Figures in the parenthesis are p-values

Source: Author's calculations

The following observation incorporates a case where the dynamics of CO2 emission is the dependent variable. What can be noticed at first sight from Table 6 is that the longest time required to halve the imbalance is registered in Hungary (around three years), while in other countries that time is incomparably shorter (it is determined that is needed between a half year to one year for the imbalance to be halved).

CONCLUSIONS AND RECOMMENDATIONS

The article analyzed some of the most important patterns of economic development in the CEEC. Specific causalities among economic growth, export dynamics, innovation diffusion, and intensity of CO2 emission have been tested. More precisely, it was an attempt to determine the extent to which the concept of sustainable development in the observed economies has been developed so far.

Apart from the efforts of establishing a new socio-economic framework during the transition period, all countries from our sample have faced the catching-up process for developing economies. With this in mind, it is obvious that the development of these countries in the previous decades predominantly relied on reformed industrial capacity, without fully utilizing the potential of new technological improvements.

In addition to examining significant relationships between these variables in the short term, the key analysis relies on their interdependence over the long term, with three hypotheses tested. The article has drawn several main insights. First, raised export scope and intensified CO2 emissions have a positive impact on economic growth. Besides the slightly significant impact of export dynamics, increased gas emissions are more significantly associated with economic growth and development in the CEEC. Also, the evidence showed that innovation activity, measured by the number of patents per million population, did not significantly determine economic growth. This was explained by the fact that innovation diffusion requires a longer period for technological spillovers to become more visible factors of economic performance. Considering the positive impact of economic growth and export dynamics on CO2 emission trends, but also an exclude of the significant role of the innovation activities, the first hypothesis with the assumption that innovation capacity, export intensity, and dynamics of CO2 emission incite economic growth, can only be partially accepted.

Second, surveying the role of the underlying determinants of CO2 emissions has yielded divided conclusions. Following the theoretical arguments, a positive relationship between economic growth and CO2 emission was confirmed. The negative relationship between export and environmental pollution can be justified by the adoption of new production technology and the improvement of trade channel efficiency as mainly blueprinted solutions during the trade liberalization of the observed countries in previous years. Further, there is an identification of the negative impact of innovation activities on CO2 in the long-term. From the presented results, it is possible to evaluate the remaining two hypotheses. The second hypothesis, starting from the assumption that a positive trajectory of economic growth causes increased CO2 emission, has been proved. Similarly, recognizing the result that dynamized export activities and diffusion of innovation have a positive impact on the environmental economy, a third hypothesis can also be accepted.

Undoubtedly, an important contribution of this analysis is determined by the necessity of a better understanding of economic growth and its determinants through different perspectives. Also, discovering the role of economic trajectories on sustainable development is of particular relevance to contemporary socio-economic analysis. In this regard, exploring the dichotomy between the dynamics of economic growth and the main characteristics within which this growth is realized, this article represents a valuable essay for identifying economic weaknesses, as well as the potentials for further implementation of the sustainable development concept in the CEEC.

The paper has started with an effort to identify the development patterns in selected countries. In an aim to provide as much realistic comparative analysis, the absence of specific CEEC economies from testing is evident. The recommendation for future research could be oriented to cover the complete CEEC region. Additionally, an interesting approach can be the extent of the sample to the EU group to provide a wider perspective on this topic. Also, a variant combination of used variables can secure interesting perspectives for future surveys.

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