Economic Growth, Renewable Energy, Trade Openness and CO_2 Emissions: A Causality Analysis

Jelena Živković[1*], Nevena Veselinović[1,2], Stefan Zdravković[3,]

[1] University of Kragujevac, Institute for Information Technologies Kragujevac, Jovana Cvijića bb, 34000 Kragujevac, Republic of Serbia, e-mail: jelenazivkovic@uni.kg.ac.rs,

[2] Institute of Economic Sciences, Zmaj Jovina 12, 11000 Belgrade, Republic of Serbia, e-mail: nveselinovic@uni.kg.ac.rs

[3] University MB, Faculty of Business and Law, Teodora Drajzera br. 27, 11040 Belgrade, Republic of Serbia, e-mail: szdravkovic034@yahoo.com

DOI: 10.46793/ICCBIKG25.099Z

Abstract: The paper analyses the causal relationship between economic growth, renewable energy consumption, trade openness, and CO_2 emissions using a sample of 13 countries from 2006 to 2021. The JKS Granger non-causality test is applied. The results of the analysis show a bidirectional relationship between economic growth and CO_2 emissions. Additionally, there is a two-way causal relationship between CO_2 emissions and renewable energy consumption. Trade openness causes an increase in CO_2 emissions, but emissions do not, in turn, cause trade openness. This may be explained by the increasing role of renewable energy sources in offsetting fossil fuel dependence, while trade openness, particularly in developing economies, often leads to greater industrial activity and energy consumption, which in turn raises emission levels. The study highlights the interrelated nature of CO_2 emissions, economic growth, renewable energy use, and trade openness, emphasising the importance of coordinated policies for achieving carbon reduction and sustainable development. These findings offer valuable insights for policymakers aiming to design balanced strategies for energy transition and environmental protection.

Keywords: CO_2 emission, economic growth, renewable energy, trade openness, causality

1. Introduction

The interplay between economic activities, such as energy production, trade, and economic growth not only shapes overall human well-being and the functioning of a country's economic system, but also significantly contributes to climate change through increased carbon dioxide (CO_2) emissions and environmental degradation [1]. The paper aims to analyse the causal relationship between economic growth, renewable energy consumption, trade openness and carbon emissions because of the significant impact of climate change on economic activity. Economic growth can play a mitigating role in air pollution, thereby reducing its harmful impacts and environmental consequences [2].

Substantial evidence suggests that the increasing share of renewable energy in electricity generation serves as a key factor in reducing carbon emissions from the power sector, an effect that appears particularly pronounced during the early stages of economic development in Europe [3,4]. The role of renewable energy in the EKC hypothesis has gained attention due to its potential to reduce environmental degradation and support sustainable growth. [5,6,7,8]. Trade openness, along with the interaction between economic growth and renewable electricity consumption, has been found to negatively affect environmental quality by contributing to increased CO_2 emissions [9,10]. This study is motivated by the lack of empirical research that jointly examines the causal relationships between these variables in Europe, as existing studies often address these factors separately.

2. Data and Methodology

The study covers 13 European countries: Albania, Bosnia and Herzegovina, Serbia, Montenegro, North Macedonia, Bulgaria, Romania, Croatia, Czechia, Hungary, Poland, the Slovak Republic and Slovenia from 2006 to 2021. The variables used in research are GDP per capita (GDPpc), renewable energy consumption (REC) and trade openness ((export+import)/GDP) – TO). Data are retrieved from the World Bank database [11] and Our World in Data [12].

After applying cross-sectional dependence tests and the second-generation unit root CIPS test, the JKS Granger non-causality test is applied. It was introduced a novel approach for testing the null hypothesis of no Granger causality, applicable to models with either homogeneous or heterogeneous coefficients [13,14]. It assumes the following econometric specification for panel data:

$$y_{it} = \varphi_{0,1} + \sum_{p=1}^{p} \varphi_{p,1} y_{i,t-p} + \sum_{p=1}^{p} \beta_{p,i} x_{i,t-p} + \tau_{i,t} \tag{1}$$

with $i=1,\dots,N$ and $t=1,\dots,T$. The model assumes that $x_{i,t}$ is scalar. The constant term $\phi_{0,i}$ captures individual-specific (non-group) effects, while $\tau_{i,t}$ denotes the disturbance terms. The parameters $\phi_{p,i}$ represent non-homogeneous autoregressive components for $p=1,\dots,P$, and $\beta_{p,i}$ denote non-homogeneous feedback coefficients [14]. Moreover, the null hypothesis that $x_{i,t}$ does not Granger-cause $y_{i,t}$ can be expressed as a set of linear restrictions on the parameters of equation: H0: $\beta p,1=0$, $\forall i$ and p; H1: $\beta p,1\neq 0$ for some i and p. If the null hypothesis is not rejected, this suggests that past values of $x_{i,t}$ do not provide statistically significant information for predicting $y_{i,t}$ indicating the absence of Granger causality.

2. Results and Discussion

Three cross-sectional dependence tests are performed (Table 1).

Table 1. Cross-sectional dependence tests

Variable	Breusch-Pagan LM		Pesaran scaled LM		Pesaran CD	
	Statistic	**p-value**	**Statistic**	**p-value**	**Statistic**	**p-value**
CO2pc	545.1532	0.0000	37.40219	0,0000	9.758662	0.0000
GDPpc	1057.830	0.0000	78.44915	0,0000	32.42833	0.0000
REC	630.1951	0.0000	44.21099	0.0000	21.45932	0.0000
TO	780.2683	0.0000	56.22646	0.0000	25.06326	0.0000

Source: Authors' calculation

Table 1 presents that the null hypothesis is rejected at the significance level of 5%. Therefore, it can be concluded that all variables contain cross-sectional dependence. Based on these findings, a second-generation unit root test (CIPS test) is employed to ensure the reliability of stationarity analysis in panel data (Table 2)

Table 2. Unit root CIPS test results

Variable	t-stat	p-value	Critical level (5%)	Integration level
CO2pc	-1.11968	≥0.10	-2.32	
dCO2pc	-2.18356	≥0.10	-2.34	I(2)
ddCO2pc	-3.29040	<0.01	-2.37	
GDPpc	-2.75880	<0.01	-2.32	I(0)
REC	-1.75731	≥0.10	-2.32	I(1)
dREC	-3.57620	<0.01	-2.34	
TO	-1.96845	≥0.10	-2.32	I(1)
dTO	-3.00188	<0.01	-2.34	

Source: Authors' calculation

The results presented in Table 2 indicate that the variable GDPpc is stationary at level. In contrast, the variables REC and TO exhibit non-stationarity at level but achieve stationarity after first differencing. The variable CO_{2pc} attains stationarity only after the second differencing. In the subsequent step, the causality relationship between CO_2pc and the other variables was examined using the JKS non-causality test (Table 3).

Table 3. JKS Granger non-causality test

Null Hypothesis	HPJ Wald Test	p-value	Conclusion
ddCO2pc → GDPpc	4.3247	0.0376	Yes
GDPpc → ddCO2pc	34.5145	0.0000	Yes
ddCO2pc → dREC	7.2370	0.0071	Yes
dREC → ddCO2pc	7.7382	0.0054	Yes
ddCO2pc → dTO	0.6757	0.4111	No
dTO → ddCO2pc	16.9482	0.0000	Yes

Source: Authors' calculation

A lag length of two was selected, taking into consideration the time dimension of the panel. The results indicate that CO_2 emissions exert a statistically significant influence on GDPpc. Moreover, economic growth significantly affects CO_2 emissions, as evidenced by an HPJ Wald test statistic of 34.5145. A bidirectional causality is also observed between CO_2 emissions and renewable energy consumption. Conversely, the test results suggest that CO_2 emissions do not Granger-cause trade openness, whereas trade openness is significantly influenced by CO_2 emissions, with an HPJ Wald test statistic of 16.9482.

4. Conclusion

The results highlight a complex interdependence between CO_2 emissions, economic growth, renewable energy, and trade openness, emphasising the need for integrated policies that align environmental sustainability with economic development, particularly in the context of carbon reduction and energy transition strategies.

Acknowledgment

This research is funded by the Ministry of Education and the Ministry of Science, Technological Development and Innovation, Republic of Serbia, Grants: No. 451-03-136/2025-03/200378

References

[1] Hdom, H. A. D. & Fuinhas, J. A. (2020). Energy production and trade openness: Assessing economic growth, CO2 emissions and the applicability of the cointegration analysis. *Energy Strategy Reviews*, *30*(2020), 1-13. https://doi.org/10.1016/j.esr.2020.100488

[2] Bozkurt, C. & Akan, Y. (2014). Economic Growth, CO2 Emissions and Energy Consumption: *The Turkish Case. International Journal of Energy Economics and Policy*, *4*(3), 484-494.

[3] Moutinho, V. & Robaina M. (2016). Is the share of renewable energy sources determining the CO2 kWh and income relation in electricity generation? *Renew. Sustain. Energy Rev. 65*(2016) 902–914. https://doi.org/10.1016/j.rser.2016.07.007

[4] Nguyen, K. H. & Kakinaka, M. (2019). Renewable energy consumption, carbon emissions, and development stages: Some evidence from panel cointegration analysis. *Renewable Energy. 132*: 1049–57. https://doi.org/10.1016/j.renene.2018.08.069

[5] Sener, S. E. C., Sharp J. L, & Anctil, A. (2018). Factors impacting diverging paths of renewable energy: A review. *Renewable and Sustainable Energy Reviews 81*(2), 2335–42. https://doi.org/10.1016/j.rser.2017.06.042

[6] Omri, A., Daly, S., Rault, C. & Chaibi, A. (2015). Financial development, environmental quality, trade and economic growth: what causes what in MENA countries. *Energy Econ 48*, 242–252. https://doi.org/10.1016/j.eneco.2015.01.008

[7] Saud, S., Chen, S., Danish, & Haseeb, A. (2019). Impact of financial development and economic growth on environmental quality: an empirical analysis from Belt and Road Initiative (BRI) countries. *Environmental science and pollution research international*, *26*(3), 2253–2269. https://doi.org/10.1007/s11356-018-3688-1

[8] Raza, S. A., & Shah, N. (2018). Testing environmental Kuznets curve hypothesis in G7 countries: the role of renewable energy consumption and trade. *Environmental science and pollution research international*, *25*(27), 26965–26977. https://doi.org/10.1007/s11356-018-2673-z

[9] Balsalobre-Lorente, D., Shahbaz, M., Roubaud, D. & Farhani, S. (2018). How economic growth, renewable electricity and natural resources contribute to CO_2 emissions?. *Energy Policy*, *113*, 356-367. https://doi.org/10.1016/j.enpol.2017.10.050

[10] Al Mamun, R., Sohag, K., Mia, A. H., Uddin, G. S. & Ozturk, I. (2014). Regional differences in the dynamic linkage between CO_2 emissions, sectoral output and economic growth. *Renewable and Sustainable Energy Reviews, 38*, 1-11. https://doi.org/10.1016/j.rser.2014.05.091

[11] https://databank.worldbank.org/

[12] CO_2 and Greenhouse Gas Emissions - Our World in Data

[13] Juodis, A., Karavias, Y. & Sarafidis, V. (2021). A homogeneous approach to testing for Granger non-causality in heterogeneous panels. *Empirical Economics 60*, 93–112. https://doi.org/10.1007/s00181-020-01970-9

[14] Xiao, J., Karavias, Y., Juodis, A., Sarafidis, V., & Ditzen, J. (2023). Improved tests for Granger noncausality in panel data. *The Stata Journal*, *23*(1), 230-242. https://doi.org/10.1177/1536867X231162034