ECONOMIC DEVELOPMENT AND ENVIRONMENTAL DEGRADATION: A PANEL ARDL/PMG MODEL FOR EU-27 COUNTRIES

Ionuț Jianu*
The Bucharest University of Economic Studies, Bucharest, Romania

Abstract
This research aims to examine the relationship between economic development and environmental degradation in European Union over the period 2000-2019 using a Panel ARDL/PMG model. In this respect, I have used GDP per capita expressed in PPS to catch the economic development and greenhouse gas emission per capita as a proxy for environmental degradation. The study confirms a positive impact of greenhouse gas emissions (per capita) on GDP (per capita) on short-run, but also a negative effect on long-run - the long-run effect being present in 24 EU Member States.

Keywords
economic development, environment, GDP, greenhouse gas emissions, Panel ARDL / PMG model

JEL Classification
C33, Q53, O11, Q56

Introduction

Climate change is one of the main global challenges that we are facing in our days and is generally driven by the greenhouse gas (GHG) emissions, carbon dioxide (CO_2) accounting for approximately three quarters of GHG emissions (Huaman and Jun, 2014). In this context, the climate transition is a real need, as humanity is at risk of a sixth global extinction caused by the rapid extinction rate of animal species, and deepening climate risks may exacerbate this challenge - this also reflecting the motivation for focusing on this research area. Climate change exercises economic effects, both in the short-run, but also in the long-run taking into account the negative externalities of global warming on health, labour productivity and on the biocenosis physically affected by the pollution. Zaman and Vasile (2014) also stated that climate change generate economic vulnerabilities at macroeconomic level.

Moreover, climate change became a central objective of the European Union in the latest years, which implemented several initiatives to address this challenge. To encourage the

* Corresponding author, **Ionuț Jianu** – ionutjianu91@yahoo.com

EU Member States to address climate risks, European Commission is trying to create links to climate transition in the case of several EU financial instruments (e.g.: Recovery and Resilience Facility). Nevertheless, tackling climate change is not an easy to reach objective, since there are many factors that limit the world capacity to reverse the current trend of global warming, such as resilience to change of individuals, high acquisition costs of the new green technologies, the lack of educational knowledge on climate issues and also human passivity.

The main goal of this paper is to calculate the short-run impact of economic development on environmental degradation in EU, but also the long-run effect. In particular, I have used GDP per capita as a proxy for economic development, while greenhouse gas emissions per capita has been taken into account as a relevant factor for catching environmental degradation. To strengthen the quantitative assessment framework, I have decided to calculate the impact for each EU Member State.

1. Review of the scientific literature

The relationship between economic development and environmental degradation has been analysed in many papers and the authors findings are mixed. According to Phimphanthavong (2013), economic growth may affect the environment through many channels, such as pollution, overexploitation of natural resources, climate change, but also the degradation of wildlife habitat. Some authors supported an initial positive linkage between CO_2 emissions and economic growth which then turns negative (Shahbaz et al., 2016; Riti et al., 2017), while other authors confirmed a positive long-run relationship (Wang et al., 2011; Dong et al., 2018; Khan et al. 2019). There is also support for the hypothesis related to a general negative relationship (Roca et al., 2001; Baek and Pride, 2014; Balıbey, 2015), but also for the one indicating a positive relationship between the variables (Saidi and Mbarek, 2016; Chaabouni et al., 2016).

Other relevant study is that of Majewska and Gieraltowska (2022) who analysed the impact of GDP on CO_2 emissions in CEE countries between 2000-2019 and found a negative relationship in HR, CZ, HU, RO, SK and SI and a positive linkage in BG, EE, LV, LT and PL. Aye and Edoja (2017) found a negative effect of economic growth on CO_2 emissions if the growth rate is below 0.93% and a positive impact if growth rate exceeds this threshold, but stated that in low income countries, the relationship is negative regardless of the economic growth rate level. A similar hypothesis has been supported also by Ardakani and Seyed (2019). There are also papers confirming a negative relationship between economic growth and greenhouse gas emissions in later stages of development (Azomahou and Phu, 2001).

Furthermore, the most common theory when studying the effect of GDP growth on environmental degradation is "Environmental Kuznets Curve" (KEC - inspired from the paper of Kuznets (1955) studying the relationship between economic growth and income inequality), which has been implemented by Grossman and Krueger (1995) - this providing evidence for an inverted "U" shape relationship between economic development and environmental degradation, since in the industrial development phase, the relationship becomes stronger from lower level registered in preindustrial phase, while the relationship becomes weaker or negative following the transition to a post-industrial economy. This theory has been supported by many authors such as Lindmark (2002), Martínez-Zarzoso and Bengochea-Morancho (2004), Ang (2007), He and Richard (2010), Lopez-Menendez et al. (2014), Kasman and Duman (2015), Hatmanu et al. (2022), Majeed et al. (2022), Ugur (2022), while other authors did not find proper evidence to confirm it (Friedl and Getzner, 2002; Richmond and Kaufmann, 2006; Halicioglu, 2009; Wang, 2012; Magazzino, 2014; Zoundi, 2017).

Other authors consider that climate change has several implications on different forms of development. In this respect Tudorache (2020) found an inverse relationship between automation and ecological development, while the technological development (which includes automation, but also the digital component) is positively linked to ecological development. On the other hand, Safonov (2019) stated that climate change exercise negative effects on social dimension, respectively on health status, food security, safe drinking water, physical infrastructure and on energy supplies. As it can be observed, climate change affects several key sectors, including education, as Randell and Gray (2019) confirmed.

Finally, many authors recommended a sustainable approach of governments which should take into consideration all particularities of the sustainability process, including its focus on increasing the level of economic, social and environmental development, as Zaman and Goschin (2010) defines this process. In addition, Caporale et al. (2021) recommended enhancing the implementation of environmental policies during periods of high economic growth rates.

2. Research methodology

In this section, you can find the main methods used to analyse the relationship between economic development and environmental degradation in European Union (27 countries) over the period 2000-2019. In this respect, as a proxy for environmental degradation, I have used greenhouse gas emissions per capita data, while for catching economic development GDP per capita data have been used (Eurostat).

First, I have applied Panel approach to catch the evolution of the mentioned indicators in all EU countries and I have checked the stationarity of the data using (Levin, Lin & Chu t*; Breitung t-stat; Im, Pesaran and Shin W-stat; ADF-Fisher Chi-square; PP-Fisher Chi-square) Schwarz information criterion as a tool to decide lag length. The results show that the data is stationary at level - I(0) - and at the first difference - I(1), which is compatible with a Panel ARDL / PMG (Autoregressive Distribute Lag/Pooled Mean Group) model. ARDL / PMG model advantage consist in the fact that it allows heterogeneity on short-run, restricts it on long-run favouring homogenous results, but also solves the issues related to serial correlation and endogeneity. The ARDL/PMG model fits well with the focus of the paper, since GDP growth is harmful for the environment on short-term (but the effects are country-specific), while on long-run, when countries reach a higher level of development, it reduces the environmental degradation.

In the model selection process, I have used Akaike Information Criterion (AIC), Schwarz Criterion (SC) and Hanan-Quin criterion (HQ). AIC recommended the use of an ARDL(1, 4) model, while SC and HQ indicated that an ARDL(1, 1) model will provide better results (*Annex 1*). In this context, I decided to estimate an ARDL(1, 1) model since it is supported in a greater extent by the model selection criteria. Therefore, I have estimated the following ARDL(1,1) model:

$$\Delta lnGHGpercap_{i,t} = \phi_i\left(lnGHGpercap_{i,t-1} - \theta'_t lnGDPpercap_{i,t}\right) + + \sum_{j=1}^{p-1} \lambda^*{}_{i,j} \Delta lnGHGpercap_{i,t-j} + \sum_{j=0}^{q-1} \delta'^*_{i,j}\, \Delta lngdppercap_{i,t-j} + \mu_i + \varepsilon_{i,t} \quad (1)$$

where $lnGHGpercap$ is the natural logarithm of the greenhouse gas emissions per capita (expressed in tonnes of CO_2 equivalent), $lnGDPpercap$ represents the natural logarithm of gross domestic product at market prices per capita (expressed in purchasing power standards - PPS), ϕ_i is the speed of adjustment parameter which should be negative and significant to confirm a long-run relationship between GDP per capita and greenhouse gas emissions per capita, $\lambda\ and\ \delta$ are the short-run coefficients, i refers to the number of cross-sections (27 in our case - EU Member States), t reflects the time period used (2000-2019: 20 observations per cross-section), p and q are the lags of the dependent (p) and independent (q) variables, μ reflects the cross-section effects, while ε represents the residuals.

I have interpreted the cointegration relation according to the approach of Pesaran and Shin (1999) who stated that the error correction term coefficient should be negative (to indicate that a disequilibrium is adjusted on long-run), significant and lower than the value 1.

Further, I have examined the cross-section short-run coefficients for all EU Member States and I checked the heteroskedasticity using White and Breusch-Pagan-Godfrey tests.

3. Results and discussions

In this section, I present the correlation between GDP per capita and greenhouse gas emissions per capita, but also the main results of the estimated model. In this context, I obtained a Pearson correlation coefficient of 61.53% between the analysed variables, which creates the premises of a short-term positive relationship between these. This correlation is also reflected in *Figure 1,* which provides data for all EU Member States over the period 2000-2019.

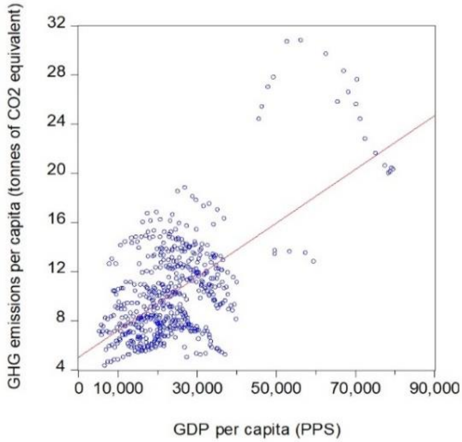


Figure 1. GDP per capita vs. GHG emissions per capita scatter plot (EU-27 data for the period 2000-2019)

Source: own processing using Eviews 9.0

Next, as I have indicated in the methodology section, I checked the stationarity of the data, the results being provided in *Table 1*. In the case of the dependent variable, 8 of 12 performed tests rejected the null hypothesis related to the presence of unit root at level (5% significance threshold) and confirmed the stationarity hypothesis. On the other hand, I have found that GDP per capita is not stationary at level (only Breitung t-stat in the case of trend and intercept rejected the unit root hypothesis), but becomes stationary after computing the first difference.

Table no. 1. Stationarity tests

Variable	Level / 1st Difference	Intercept / Trend / None	Levin, Lin & Chu t*	Breitung t-stat	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square	Stationary at:
GDP per capita (PPS)	Level	Intercept	1.934	N.A.	6.863	14.050	13.581	I(1)
		Trend and intercept	-0.348	-1.675**	-0.163	55.624	32.756	
		None	18.388	N.A.	N.A.	1.405	0.605	
		Intercept	-13.870*	N.A.	-11.659*	227.238*	242.690*	

	First difference	Trend and intercept	-12.348*	-10.533*	-8.612*	166.328*	191.194*	
		None	-8.039*	N.A.	N.A.	149.145*	169.468*	
GHG emmissions per capita	Level	Intercept	0.998	N.A.	3.915	29.784	36.942	I(0)
		Trend and intercept	-3.830*	-2.018**	-3.745*	89.981*	92.099*	
		None	-6.938*	N.A.	N.A.	124.979*	141.780*	

Note: * means significance at 1%; ** means significance at 5%; *** means significance at 10%.

Source: own calculations using Eviews 9.0

With a view to the quantitative assessment, I have estimated the impact of GDP per capita (PPS) - expressed in natural logarithm form - to catch its growth dynamic - on the natural logarithm of greenhouse gas emissions per capita, on short-run, but also on long-run. According to the results presented in *Table 2*, I have found a positive relationship on short-run, but a negative impact on long-run, this finding being also in line with the most important findings in this research area.

In particular, at European Union level, I have found that an increase in the GDP per capita (PPS) by 1% led to a growth of greenhouse gas emissions per capita in the period 2000-2019 by 0.58% on short-run, while on long-run, the dependent variable dropped by 1.027%. It is worth mentioning that all coefficients are significant at 1% level of significance - which confirms a high confidence level in the parameters. Moreover, the long-run relationship is also confirmed by the negative and significant coefficient of the cointegration (also, less than one) - which indicates that the speed of adjustment to the equilibrium is 12.64%.

Further, I have estimated the cross-section short-run coefficients for all EU-27 countries and I confirmed the positive relationship (on short-run) between the analysed variables in all EU Member States. However, the coefficients of cointegration are significant but positive in the case of three countries (LT, HU, EL), which indicates that, in these particular cases, the coefficients calculated for the speed of adjustment do not indicate the presence of a long-run relationship. In the remaining cases I confirmed that if there is a risk of disequilibrium, the dependent variable will adjust to the equilibrium on long-run, the highest speed rates of adjustment being these calculated for FI (40.01%), FR (34.30%) and MT (33.55%). Regarding the cross-section short-run coefficients, the highest positive effects of GDP per capita on greenhouse gas emissions were found in BE (1.39% increase of GHG emissions per capita when GDP per capita grows by 1%), IT (1.09%) and BG

(1.09%), while the lowest impact coefficients were obtained in the case of NL (0.18%), SK (0.19%) and LV (0.22%).

Table no. 2. Main results of the model

Dependent variable: lnGHGpercap	**EU equation**			
	Long-run equation	**Short-run equation**		
	lnGDPpercappps	dlnGDPpercappps	Coint	Constant
	-1.027026*	0.587834*	-0.126457*	1.592522*
	Cross-section short-run coefficients			
	Country	dlnGDPpercappps	Coint	Constant
	LU	0.434157*	-0.222989*	3.236419*
	IE	0.258104*	-0.009348*	0.095390
	NL	0.182045**	-0.178435*	2.350318
	DK	0.501573***	-0.288565*	3.736282
	AT	0.601839**	-0.198716*	2.558645**
	DE	0.522395*	-0.078753*	1.003218
	SE	0.733661*	-0.298424*	3.707665***
	BE	1.390985*	-0.206783*	2.659491
	FI	0.677149**	-0.400132*	5.218964
	FR	0.445296*	-0.343006*	4.288572
	MT	0.303173	-0.335572*	4.080985
Coefficients	**IT**	1.091520*	-0.050633*	0.605810
	CZ	0.498206*	-0.041873*	0.504970***
	CY	0.603216*	-0.098847*	1.246832**
	ES	0.926869*	-0.139325*	1.704143**
	SI	0.774626*	-0.088355*	1.070014***
	LT	0.838588*	0.006046*	-0.115041***
	EE	0.794431**	-0.065177*	0.769645
	PT	0.542067**	-0.226569*	2.731268
	HU	0.716779*	0.037377*	-0.481372
	PL	0.313113**	-0.016624*	0.187848***
	SK	0.191326*	-0.048742*	0.572541***
	LV	0.229879*	-0.010685*	0.126630
	RO	0.274740*	-0.025191*	0.261890
	HR	0.701315*	-0.083482*	0.950249*
	EL	0.234150*	0.011816*	-0.169832
	BG	1.090305*	-0.013343*	0.096550

Note: * - significant at 1%; ** - significant at 5%; *** - significant at 10%.

Source: own calculations using Eviews 9.0

In addition, there is a need to mention that all cross-section short-run coefficients were significant at 10%, excepting MT for which the confidence in the calculated coefficient is weak. Moreover, in the case of 19 EU Member States, I have obtained impact coefficients which are significant at 1%, while for 6 countries - the coefficients were significant at 5% and for 1 country - I obtained a coefficient significant at 10%. Furthermore, I have checked the heteroskedasticity and the results (White test - p-value: 0.3831 / Breusch-Pagan-Godrey - p-value: 0.4004) indicate that the model is homoscedastic.

Finally, I confirmed the hypothesis of a positive relationship between economic development and environmental degradation on short-run, and a negative relationship between these on long-run, which also recommends enhancing the implementation of environmental policies during periods of high economic growth rates.

Conclusions

This paper confirmed the existence of a positive short-run relationship between economic development and environmental degradation, but also a negative relationship on long-run in European Union over the period 2000-2019, which is also compatible with the hypothesis of Environmental Kuznets Curve. This may be argued by the fact that, on short-run, many economic activities are detrimental to the environment through the pollution channel, but on long-run, the negative externalities of the production on the environment are reduced to lower levels when the economy advances to a post-industrial phase.

Further, countries are advancing to a innovation based economy which is an important driver of a sustainable and resilient growth, but may also support the development of technologies which are climate friendly. However, there are also particular cases where I did not find proper evidence validating the long-run relationship between GDP growth per capita and greenhouse gas emissions per capita (Lithuania, Hungary and Greece). In addition, the highest short-term impact coefficients were found in the case of Belgium, Italy and Bulgaria. Finally, it should be noted that all impact coefficients (excepting the one calculated in the case of Malta) are significant at 10%, while in the case of 19 EU Member States, I have obtained coefficients significant at 1%. This confirms high confidence in the estimators. Finally, this paper recommends enhancing the implementation of environmental policies during periods of high economic growth rates.

References

[1] Ang, J., 2007. *CO_2 Emissions, Energy Consumption and Output in France*, Energy Policy, Vol. 35, No. 10, pp. 4772-4778.

[2] Ardakani, M. K. and Seyed, M. S., 2019. *Impact of Energy Consumption and Economic Growth on CO_2 Emission Using Multivariate Regression*, Energy Strategy Reviews, Vol. 26: 100428.

[3] Aye, G. C. and Edoja, P. E., 2017. *Effect of Economic Growth on CO_2 Emissions in Developing Countries: Evidence from a Dynamic Panel Threshold Model*, Congent Economics & Finance, Vol. 5, No. 1, pp. 1-22.
[4] Azomahou, T. and Phu, N. V., 2001. *Economic Growth and CO2 Emissions: a Nonparametric Approach*, Core Discussion Papers 2001012.
[5] Baek, J. and Pride, D., 2014. *On the Income-nuclear Energy-CO_2 Emissions Nexus Revisited*, Energy Economics, Vol. 43, No. C, pp. 6-10.
[6] Balıbey, M., 2015. *Relationships among CO_2 Emissions, Economic Growth and Foreign Direct Investment and the Environmental Kuznets Curve Hypothesis in Turkey*, International Journal of Energi Economics and Policy, Vol. 5, No. 4, pp. 1042-1049.
[7] Caporale, M. G., Claudio-Quiroga, G. and Gil-Alana, L. A., 2021. *Analysing the Relationship between CO_2 Emissions and GDP in China: a Fractional Integration and Cointegaration Approach*, Journal of Innovation and Entrepreneurship, Vol. 10, Article number: 32.
[8] Dong, K., Sun, R. and Dong, X., 2018. *CO_2 Emissions, Natural Gas and Renewables, Economic Growth: Assessing the Evidence from China*, Science of the Total Environment, Vol. 640-641, pp. 292-302.
[9] Chaabouni, S., Zghidi, N. and Mbarek, M. B., 2016. *On the Causal Dynamics between CO_2 Emissions, Health Expenditures and Economic Growth*, Sustainable Cities and Society, Vol. 22, No. C, pp. 184-219.
[10] Eurostat, 2022. Eurostat Database. [online]. available at: <http://ec.europa.eu/eurostat/data/database>.
[11] Friedl, B. and Getzner, M., 2002. *Environment and Growth in a Small Open Economy: an EKC Case-study for Austrian CO_2 Emissions*, College of Business Administration, University of Klagenfurt Discussion Paper, No. 2002/2.
[12] Grossman, G. M. and Krueger, A. B., 1995. *Economic Growth and the Environment*, The Quarterly Journal of Economics, Vol. 110, No. 2, pp. 353-377.
[13] Halicioglu, F., 2009. *An Econometric Study of CO_2 Emissions, Energy Consumption, Income and Foreign Trade in Turkey*, Energy Policy, Vol. 37, No. 3, pp. 1156-1164.
[14] Hatmanu, M., Căutișanu, C., Iacobuță, A. I., 2022. *On the Relationships Between CO_2 Emissions and their Determinants in Romania and Bulgaria. An ARDL Approach*, Applied Economics, Vol. 54, No. 22, pp. 2582-2595.
[15] He, J., and Richard, P., 2010. *Environmental Kuznets Curve for CO_2 in Canada*, Ecological Economics, Vol. 69, No. 5, pp. 1083-1093.
[16] Huaman, R. N. E. and Jun, T. X., 2014. *Energy Related CO_2 Emissions and the Progress on CCS Projects: A Review*, Renewable and Sustainable Energy Reviews, Vol. 31, pp. 368-385.
[17] Kasman, A. and 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, Vol. 44, No. C, pp. 97-103.
[18] Khan, I., Khan, N., Yaqub, A. and Sabir, M., 2019. *An Empirical Investigation of the Determinants of CO_2 Emissions: Evidence from Pakistan*, Environmental Science and Pollution Research, Vol. 26, pp. 9099-9112.
[19] Kuznets, S., 1955. *Economic Growth and Income Inequality*, American Economic Review, Vol. 45, No. 1, pp. 1-28.

[20] Lindmark, M., 2002. An EKC-*Pattern in Historical Perspective: Carbon Dioxide Emissions, Technology, Fuel Prices and Growth in Sweden 1870–1997*, Ecological Economics, Vol. 42, No. 1-2, pp. 333-347.
[21] Lopez-Menendez, A. J., Pérez, R. and R. and Moreno, B., 2014. *Environmental Costs and Renewable Energy: Revisiting the Environmental Kuznets Curve*, Journal of Environmental Management, Vol. 145, No. 1, pp. 368-373.
[22] Magazzino, C., 2014. *The Relationship between CO_2 Emissions, Energy Consumption and Economic Growth in Italy*, International Journal of Sustainable Energy, Vol. 35, No. 9, pp. 844-857.
[23] Majeed, A., Ye, C., Chenyun, Y., Wei, X., Muniba, 2022. *Roles of Natural Resources, Globalization, and Technological Innovations in Mitigation of Environmental Degradation in BRI Economies*, *PLOS ONE,* Vol. 17, No. 6.
[24] Majewska, A. and Gieraltowska, U., 2022. *Impact of Economic Affluence on CO_2 Emissions in CEE Countries*, Energies, Vol. 15, No. 1, article number 322.
[25] Martínez-Zarzoso, I. and Bengochea-Morancho, A., 2004. *Pooled Mean Group Estimation of an Environmental Kuznets Curve for CO_2*, Economics Letters, Vol. 82, No. 1, pp. 121-126.
[26] Pesaran, M. H. and Shin, Y., 1999. *An Autoregressive Distributed-Lag Modelling Approach to Cointegration Analysis*, in Strøm, S. (ed.) Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium, Cambridge: Cambridge University Press (Econometric Society Monographs), pp. 371-413.
[27] Phimphanthavong, H., 2013. *The Impacts of Economic Growth on Environmental Conditions in Laos*, International Journal of Business Management and Economic Research, Vol. 4, No. 5, pp. 766-774.
[28] Randell, H. and Gray, C., 2019. *Climate Change and Educational Attainment in the Global Tropics*, Proceedings of the National Academy of Sciences of the United States of America, Vol. 116, No. 18, pp. 8840-8845.
[29] Richmond, A. K. and Kaufmann, R. K., 2006. *Is There a Turning Point in the Relationship between Income and Energy Use and/or Carbon Emissions?*, Ecological Economics, Vol. 56, No. 2, pp. 176-189.
[30] Riti, J. S., Song, D., Shu, Y. and Kamah, M., 2017. *Decoupling CO_2 Emission and Economic Growth in China: Is there Consistency in Estimation Results in Analyzing Environmental Kuznets Curve?*, Journal of Cleaner Production, Vol. 166, No. 1, pp. 1448-1461.
[31] Roca, J., Padilla, E., Farre, M. and Galletto, V., 2001. *Economic Growth and Atmospheric Pollution in Spain: Discussing the Environmental Kuznets Curve Hypothesis*, Ecological Economics, Vol. 39, No. 1, pp. 85-99.
[32] Saidi, K. and Mbarek, M. B., 2016. *Nuclear Energy, Renewable Energy, CO_2 Emissions, and Economic Growth for Nine Developed Countries: Evidence from Panel Granger Causality Tests*, Progress in Nuclear Energy, Vol. 88, No. C, pp. 364-374.
[33] Shahbaz, M., Mahalik, M. K., Shah, S. H. and Sato, J. R., 2016. *Time-varying Analysis of CO_2 Emissions, Energy Consumption, and Economic Growth Nexus: Statistical Experience in Next 11 Countries*, Energy Policy, Vol. 98, No. C, pp. 33-48.

[34] Safonov, G., 2019. *Social Consequences of Climate Change - Building Climate Friendly and Resilient Communities via Transition from Planned to Market Economies*, Friedrich-Ebert-Stiftung Working Paper.

[35] Tudorache, M. D., 2020. *Sustainable Development in European Union as Expression of Social, Human, Economic, Technological and Environmental Progress*, Theoretical and Applied Economics, Vol. XXVII, Special Issue - Economic Convergence in European Union 17th Conference, pp. 191-204.

[36] Ugur, M. S., 2022. *The Relationship Between Foreign Direct Investment, Economic Growth, Energy Consumption and CO_2 Emissions: Evidence from ARDL Model with a Structural Break for Turkey, EGE* Academic Review, Vol. 22, No. 3, pp. 337-352.

[37] Wang, K. M., 2012. *Modelling the Nonlinear Relationship Between CO_2 Emissions from Oil and Economic Growth*, Economic Modelling, Vol. 29, No. 5, pp. 1537-1547.

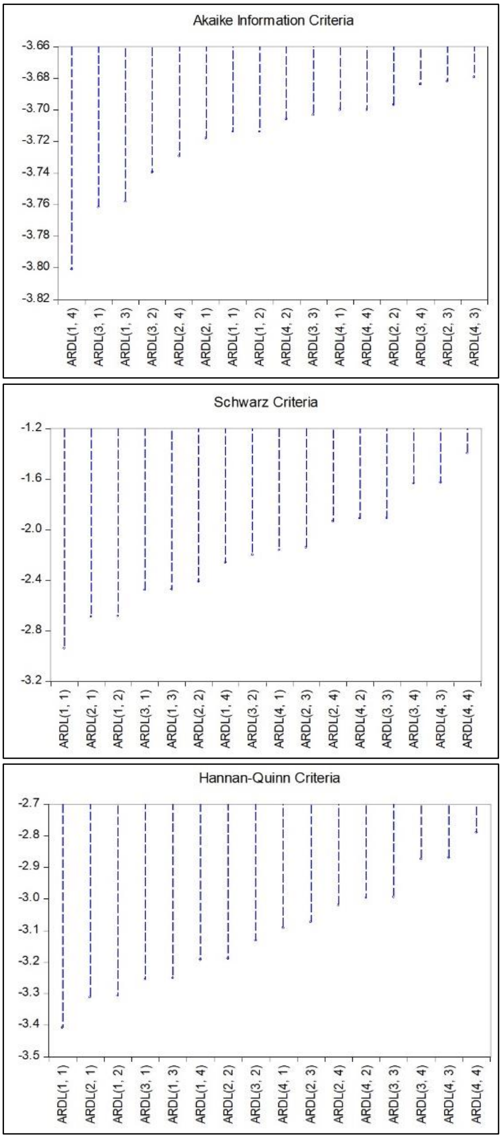
[38] Wang, S. S., Zhou, D. Q., Zhou, P. and Wang, Q. W., 2011. CO_2 *Emissions, Energy Consumption and Economic Growth in China: A Panel Data Analysis*, Energy Policy, Vol. 39, pp. 4870-4875.

[39] Zaman, G. and Goschin, Z., 2010. *Multidisciplinarity, Interdisciplinarity and Transdisciplinarity: Theoretical Approaches and Implications for the Strategy of Post-Crisis Sustainable Development*, Theoretical and Applied Economics, Vol. 17, No. 12, pp. 5-20.

[40] Zaman, G. and Vasile, V., 2014. *Conceptual framework of economic resilience and vulnerability at national and regional levels*, Romanian Journal of Economics, Vol. 39, No. 2(48), pp. 5-18.

[41] Zoundi, Z., 2017. CO_2 *Emissions, Eenewable Energy and the Environmental Kuznets Curve, a Panel Cointegration Approach*, Renewable and Sustainable Energy Reviews, Vol. 72, No. C, pp. 1067-1075.

Annex 1. Model selection process – the results of Akaike Information Criterion (AIC), Schwarz Criterion (SC) and Hanan-Quin criterion (HQ)



Source: own processing using Eviews 9.0