

The Relationship between CO₂ Emissions, Industry, Services and Gross Fixed Capital Formation in the Balkan Countries

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The examination of the economy-environment nexus is one of the focal issues in the field of environmental economics. This study examines the causal relationships between carbon dioxide (CO₂) emissions, industry, services, and gross fixed capital formation for a panel of Balkan countries over the period 1996-2017. A three-step methodological approach is used, including panel unit root tests, panel cointegration tests, and panel causality tests. The results suggest a strong cointegration between the variables, meaning that all variables have a long-run relationship with CO₂ emissions. The results of the panel causality show that there is a short-run bidirectional panel causality running between industry and services, and gross fixed capital formation and services. Moreover, there is a unidirectional causality running from industry and gross fixed capital formation to CO₂ emissions, and from industry to gross fixed capital formation. The results of the long-run causal relationships show that estimated coefficients of the error correction terms (ECT) in the case of CO₂ emissions, industry and gross fixed capital formation are statistically significant, indicating that these three variables are an important part in the adjustment process as the model diverges from the long-run equilibrium. Balkan countries need to further invest in the modernisation of their technological process, as well as to act following the global policy incentives. Environmental taxes, carbon capture and storage, taking part in emission trading schemes and orientation towards renewable energy sources, should further strengthen Balkan countries in achieving environmentally sound economic growth.

Keywords: CO₂ Emissions; Industry; Services; Environment; Panel Cointegration; Panel Causality.

Introduction

Climate change, in general, is one of the key areas the international community has dealt with in the past. Climate change and global warming will almost certainly appear as a topic of interest when considering the contemporary problems that our planet is facing. According to Munitlak Ivanovic, Mitic, and Raspopovic (2015), these issues require an interdisciplinary approach, and experts in different fields are researching the causes, consequences, adaptation, and mitigation of the effects of climate change. “Environmental degradation and the decline of environmental quality has become a global concern and has attracted significant attention from development cooperation” (Sarkodie & Strezov, 2019, p. 129). According to Khan, Teng, Khan, & Khan (2019), environmental degradation is an international problem and the whole world is experiencing the effects of deteriorating environmental quality, which is a major concern of all countries that release GHGs. “High emissions of greenhouse gases (GHGs) are impacting the industrialized and unindustrialized countries across the globe” (Khan, Teng, & Khan, 2019, p. 23480).

Moreover, it is necessary to constantly work to stimulate economic growth and development that causes a minimal adverse impact on the environment and depletion of natural resources. When analysing and discussing the quality of the environment, it is almost certain that the economy will emerge at some point. The economy and the environment are phenomena that have a significant number of interdependent points. It can be said that the economy has a significant impact on everything that happens in the environment, either positive or negative.

Therefore, with a certain amount of restraint, it can be argued that the economy has become the cause of poor and mediocre environmental management since most harmful substances arise as a direct consequence of production and other human activities. Economies increase production and utilize production processes and technologies that pollute the environment to achieve prosperity. Thus, it can be concluded that the environmental problems we have today are largely initiated, facilitated and/or encouraged by human activities.

The research objective of this paper is to determine both short-run and long-run relationships between CO₂ emissions,

industry (value-added), services (value-added), and gross fixed capital formation for nine Balkan countries.

This study contributes to the existing literature in several ways. Firstly, we did not use the gross domestic product (GDP) per capita as a proxy for economic growth, which is one of the most commonly used indicators in this type of research. Instead, industry (value-added) and services (value-added) were used to provide a more in-depth understanding of the variables that influence carbon dioxide (CO₂) emissions, rather than the GDP as a more aggregated measure. Furthermore, the literature review focuses for the most part on European countries. The European Union (EU) has always been the initiator and a major actor in the fight against global climate change, always acting uniquely, decisively, and effectively in working on sound international policies that will address this issue (European Commission, 2019). "The increasing effort is being made seeking for sustainable development including regional integration in the European Union." (Dumciuviene, Stundziene, & Startiene, 2015, p. 507).

Moreover, examining Balkan countries has not presumably been the subject of this type of research using these variables. The Balkans as a region is specific in several ways. The Balkan countries are undergoing diverse transformation processes, which are related not only to economic, political, but also, in the broadest sense, social and cultural reforms resulting from the transition from the centrally planned to the open market economy. Also, a number of these countries are recovering from the conflicts that have characterized this region in the past as well as from the aftermath of the global economic crisis, which has left significant consequences on the financial systems and economies of the Balkan countries.

The Balkan countries had stable economic growth before the economic crisis of 2008 due to the expansion of credit and a notable inflow of foreign direct investments. The similar remark that Hlavacek and Bal-Domanska (2016) stated for CEE countries also holds for the Balkans, as these countries are also economically underdeveloped when compared to the developed Western European countries. "... they did not have adequate resources and technological levels, and their growth was therefore conditioned by major foreign investment." (Hlavacek & Bal-Domanska, 2016, p. 294). "It is necessary to improve productivity and adapt the production structure to high levels of finalization" (Kalas, Mirovic, & Pjanic, 2017), permanent inclusion of new technical and technological innovations, and modern management.

Another problem that all Balkan countries face is that a great part of the shadow economy is in their GDP. The analysis of the structure of the economies of the Balkan countries shows that significant segments involve mining, industry, agriculture, and forestry, which are significant environmental pollutants. Furthermore, tourism is a significant segment in the economic structure of some of the Balkan countries, such as Albania, Croatia, and Greece.

The remainder of this study is organized in the following way: Literature review offers a brief insight into previous economy-environment nexus research mainly from the European perspective; Data and Methodology section contains data analysis and the methodological framework, while Results presents the obtained empirical results. This study ends with a Conclusion section, which provides the

most important remarks about the study, interpretations of the results and associated policy implications as well as limitations and prospects for future research.

Literature Review

There is a vast number of empirical studies investigating the interdependence between environmental and economic indicators using the most diverse econometric tools. Grossman and Krueger (1991) and Shafik and Bandyopadhyay (1992) are among the first authors to conduct this type of research. Grossman and Krueger (1991) found evidence in support of the fact that the ratio of SO₂ and smoke, on the one hand, and income per capita, on the other, increase in the initial stages of economic growth, and start to decrease after a certain level of growth. Shafik and Bandyopadhyay (1992) found a significant correlation between income and environmental quality. They found evidence of possible nonlinearity, showing that most environmental indicators deteriorate at first, while the inclination for improvement occurs as countries come close to the middle-income levels. The ensuing papers subsequently increased methodological complexity by following theoretical progress in econometric time series, and in particular, panel data analysis.

As previously mentioned, this section only briefly presents literature that investigated different groups of European countries. For example, Atici (2009) examined the impact of GDP, energy use, and trade openness on CO₂ emissions in the CEE countries (Bulgaria, Hungary, Romania, and Turkey) over the period 1980-2002. The results indicate that CO₂ emissions decrease over time as the GDP per capita increases. Furthermore, energy use is a significant factor that causes higher levels of pollution in the region. Mitic and Cvetanovic (2018) analysed the interdependence between CO₂ emissions and economic growth in SEE countries over the period 1992-2016. The results of cointegration analysis and causality testing show positive bidirectional causality between CO₂ emissions and GDP per capita in the short-run. A unidirectional long-run causality is running just from GDP per capita to CO₂ emissions.

Population growth was also an interesting variable for this type of research. Martínez-Zarzoso, Bengochea-Morancho, and Morales-Lage (2007) analysed the impact of population growth on CO₂ emissions in EU countries over the period 1975-1999. The results indicate that for recent accession countries, population growth impacts CO₂ emissions more than proportional. On the other hand, this does not hold for old EU members.

Later research introduced more variables in the models. Kasman and Duman (2015) analysed the causalities between CO₂ emissions, economic growth, energy consumption, trade openness, and urbanization for a group of candidate and new EU member countries from 1992 to 2010. By using panel cointegration and Granger causality analysis, the obtained results show that there is short-run unidirectional causality from energy consumption, trade openness and urbanization to CO₂ emissions, from economic growth to energy consumption, from economic growth, energy consumption and urbanization to trade openness, and from urbanization towards economic growth. Additionally, the results of the long-run causal relationship indicate that "estimated

coefficients of lagged error correction term in the carbon dioxide emissions, energy consumption, GDP, and trade openness equations are statistically significant, implying that these four variables could play an important role in adjustment process as the system departs from the long-run equilibrium” (Kasman & Duman, 2015, p. 97).

Several studies on the topic of economy-environment nexus for European countries were done with the indicators of different types of energy. Boluk and Mert (2014) investigated the relationship between CO₂ emissions, renewable and fossil fuel energy consumption, and income in 16 EU countries for the period 1990-2008. Renewable energy consumption contributes about 1/2 less greenhouse gas (GHG) emissions per unit of energy consumed than fossil fuel energy consumption. A similar study was the one conducted by Ucan, Aricioglu, and Yucel (2014). They analysed the relationship between real GDP, non-renewable and renewable energy consumption, real gross fixed capital formation, energy technology R&D and GHG emissions for a panel of 15 EU countries from 1990-2011. A long-run equilibrium exists between real GDP, renewable and non-renewable energy consumption, GHG emissions and energy technology R&D. The results of Granger causality indicate unidirectional causality between non-renewable energy consumption and economic growth.

Similar indicators, renewable and non-renewable energy, real income, trade openness, and CO₂ emissions were tested by Dogan and Seker (2016) for the EU from 1980 to 2012. Renewable energy and trade openness alleviate CO₂ emissions, while non-renewable energy increases CO₂ emissions, according to the DOLS estimator. The Dumitrescu-Hurlin non-causality approach proves that there is a bidirectional causality between CO₂ emissions and renewable energy. Furthermore, unidirectional causalities are running from real income to CO₂ emissions, from CO₂ emissions to non-renewable energy, and from trade openness to CO₂ emissions. In addition, Armeanu, Vintila, and Gherghina (2017) investigated the impact and causal links between renewable energy sources and the economic growth of EU-28 from 2003 to 2014. The results of panel data fixed-effects regression models indicate a positive impact of total renewable energy, as well as all its types (biomass, hydropower, geothermal energy, wind energy, and solar energy) on economic growth. The results also indicate that biomass energy has the highest impact on economic growth. Granger causality results based on a vector error correction model show both short and long-run unidirectional causalities running from sustainable economic growth to primary renewable energy production. One of the latest panel studies was conducted by Simionescu, Bilan, and Streimikiene (2019). The effects of biodiesel consumption by transport on economic growth were analysed for the EU countries over the period 2010–2016. The results indicate a very low positive impact of biodiesel energy consumption on economic growth. Furthermore, the results indicate a unidirectional Granger causality relationship between these two variables.

Analysis beyond the purely European context takes a significant part of the economy-environment literature. For example, Alvarado et al. (2018) used panel data from 151

countries classified by income levels for the period 1980-2016. The results indicate that there is a strong U-shaped relationship between CO₂ emissions and income in middle-high and low income countries. On the other hand, in the high-income and middle-high income countries, the Environmental Kuznets curve hypothesis is valid. Furthermore, the results indicate that energy consumption and manufacturing have a positive and statistically significant relationship with CO₂ emissions in all groups of countries, while urbanization has a positive and significant relationship with carbon dioxide emissions in middle-high and middle-low income countries. Ahmad et al. (2019) investigated the relationships between CO₂ emissions, FDI, exports, renewable energy consumption, and GDP per capita for twenty-six OECD countries over the period 1990 to 2014. The results from multiple empirical analyses indicated that positive shocks to innovation improve, but the negative shocks disrupt environmental quality. “From the negative coefficient of income per capita (squared) and the existence of a negative nexus between FDI and CO₂e, both the EKC and the Pollution Halo Hypothesis (PHH) were confirmed in sampled economies, respectively” (Ahmad et al. 2019, p. 1).

One part of the literature investigates the relationship between the economy and the environment from the standpoint of individual countries. From the aspect of observing the European countries, a more in-depth look should be made at the studies, such as Akbostancı, Turut-Asık, and Tunc (2009); Ozturk and Acaravci, (2010); Vlahinic-Dizdarevic and Zikovic, (2010); Tsani (2010); Shahbaz, Mutascu, and Tiwari (2012); Polemis and Dagoumas (2013); Shahbaz, Mutascu, and Azim (2013); Ocal and Aslan (2013); Ahmad et al. (2017); and Cetin, Ecevit, and Yucel, (2018). Beyond the European perspective, a further look should be made at the studies, such as Khan, Khan, and Rehan (2020); Rahman and Ahmad (2019); Gong, Zheng, Guo, and Ordieres-Mere (2019); Ahmad, Khan, Ur Rahman, and Khan (2018); Ahmad and Khattak (2020); and Xie, Gao, and Sun, (2019).

Data and Methodology

Data

This study aims to examine the relationships between four variables: CO₂ emissions, industry (value-added), services (value-added), and gross fixed capital formation. CO₂ emissions are used as a proxy for the environmental degradation, while industry (value-added) and services (value-added) are used as a proxy of economic outputs of these sectors. Gross fixed capital formation is used as a proxy for capital, as it consists of all land improvements, starting from fences, ditches, and drains, through the procurement of plants, machinery, and equipment.

A balanced panel data for nine Balkan countries from 1996 to 2017 is used. Each variable included 198 observations of time series data. Sampled countries are Albania, Bulgaria, Croatia, Greece, North Macedonia, Romania, Serbia, Slovenia, and Turkey. Bosnia and Herzegovina, Kosovo¹, and Montenegro are also Balkan countries, but data availability was

¹ Kosovo under United Nations resolution 1244/99 is the subject of a territorial dispute between Kosovo and Serbia.

a limiting factor in terms of the observation period length and consequently, the balance of the panel data, so these countries are omitted from the study.

The data for CO₂ emissions in tonnes per capita is collected from Our World in Data (with sources: OWID based on the Global Carbon Project, Carbon Dioxide Information Analysis Centre (CDIAC), and Gapminder and UN population estimates) (Our World in Data, 2019). Data for services, value-added in constant 2010 USD, industry (including construction), value-added in constant 2010 USD, and gross fixed capital formation in constant 2010 USD was collected from the World Development Indicators (WDI) of the World Bank (World development indicators, 2019). All variables in the research are transformed into natural logarithms.

We first present descriptive statistics of the four variables. A statistical summary with the actual values for each country and the panel are presented in Table 1.

Among Balkan countries, the highest mean of CO₂ emissions per capita is found in Greece, whereas Albania has the lowest mean of CO₂ emissions per capita. On the other hand, the highest mean of services (value-added), industry (value-added), and gross fixed capital formation are all found

in Turkey. The lowest mean of services (value-added) is found in Albania, whilst North Macedonia has the lowest means of industry (value-added) and gross fixed capital formation. Additionally, Greece displays the greatest standard deviation (variation) in CO₂ emissions per capita, whereas Bulgaria has the lowest mean of CO₂ emissions per capita. The highest variation of services (value-added), industry (value-added), and gross fixed capital formation are all found in Turkey, while the lowest variation of these three variables is all found in North Macedonia.

The lowest minimal value of all four variables in the model is recorded in Albania. On the other hand, the highest minimal value of CO₂ emissions per capita is recorded in Greece, while the highest minimal value for the other three variables is recorded in Turkey. Furthermore, the lowest maximum value of CO₂ emissions per capita is recorded in Albania, but for services (value-added), industry (value-added), and gross fixed capital formation, the lowest maximum value is recorded in North Macedonia. The highest maximum value of CO₂ emissions per capita is recorded in Greece, but for services (value-added), industry (value-added), and gross fixed capital formation, the highest maximum value is recorded in Turkey.

Table 1

Summary Statistics

		CO ₂	SER	IND	GFCF
Albania	Mean	1.389187422	4,380,798,541	2,230,015,161	2,618,913,257
	Stdev	0.48314382	1,353,302,504	802,038,758	1,049,291,528
	Min	0.498714372	2,383,626,781	774,632,879	578,429,369
	Max	2.177064808	6,675,964,584	3,041,635,173	3,704,379,794
Bulgaria	Mean	6.493000025	25,894,959,796	10,745,172,194	9,155,531,216
	Stdev	0.479232886	5,193,211,012	2,551,485,013	3,923,357,497
	Min	5.653304645	17,941,965,489	6,682,088,841	1,673,818,871
	Max	7.352637659	33,781,830,586	14,416,454,406	16,582,983,620
Croatia	Mean	4.734705966	31,677,672,531	13,020,626,740	11,912,826,726
	Stdev	0.535733453	4,598,472,413	1,639,502,683	2,742,777,572
	Min	3.85347423	23,446,084,813	9,995,785,104	6,918,344,434
	Max	5.743855384	37,473,942,015	16,167,588,123	17,475,776,191
Greece	Mean	8.625902377	188,681,087,815	42,221,075,131	50,144,496,160
	Stdev	1.172081812	23,883,536,453	8,994,834,922	16,597,886,256
	Min	6.381875336	148,839,364,999	29,810,433,724	27,928,375,714
	Max	10.08079423	234,243,289,136	58,412,615,810	81,610,574,361
North Macedonia	Mean	4.82872928	4,665,338,488	1,876,651,721	2,110,321,272
	Stdev	0.921741252	776,759,029	533,324,964	676,978,852
	Min	3.432634631	3,654,667,018	1,226,180,211	1,472,430,087
	Max	6.269778639	6,174,078,721	2,814,757,443	3,531,729,622
Romania	Mean	4.483156561	74,240,020,380	51,658,387,031	36,493,230,101
	Stdev	0.512358001	19,361,826,883	12,055,426,120	15,109,497,674
	Min	3.794688164	49,840,886,722	33,762,553,541	17,711,642,551
	Max	5.625184331	110,701,476,758	69,842,120,806	67,496,837,038
Serbia	Mean	4.999204934	18,265,416,115	9,854,903,915	6,402,896,299
	Stdev	0.551270808	4,104,602,733	1,686,789,599	2,354,916,850
	Min	3.699649923	12,240,051,726	7,153,436,306	2,738,495,758
	Max	5.86044822	23,987,204,385	12,237,887,471	10,204,555,345
Slovenia	Mean	7.877783936	25,193,258,530	11,863,748,201	10,159,176,511
	Stdev	0.650425304	4,162,338,656	1,877,039,775	1,948,928,956
	Min	6.52515083	17,633,764,672	8,311,631,491	6,893,419,241
	Max	8.988416775	31,476,839,541	14,871,859,577	15,134,926,033
Turkey	Mean	4.116341147	401,340,264,595	184,004,680,545	183,919,765,571
	Stdev	0.683821719	119,813,751,052	71,885,763,210	88,195,660,616
	Min	3.264127333	249,388,880,864	101,663,788,673	75,036,054,161
	Max	5.547056348	648,473,840,157	330,227,254,335	351,906,313,694
Panel	Mean	5.283112405	86,037,646,310	36,386,140,071	34,768,573,012
	Stdev	2.148933153	130,686,008,853	59,862,798,318	62,619,301,774
	Min	0.498714372	2,383,626,781	774,632,879	578,429,369
	Max	10.08079423	648,473,840,157	330,227,254,335	351,906,313,694

Source: Author's calculation.

Methodology

The methodology used in this study is aimed at investigating the existence of long-term relationships between CO₂ emissions and selected model variables. A generic specification of the model is:

$$Y_{i,t} = \alpha + \beta'X_{i,t} + u_{i,t}, t = 1, \dots, T; i = 1, \dots, N. \quad (1)$$

where $Y_{i,t}$ is a dependent variable, α is a scalar, β' is the m -dimensional vector of coefficients (slope coefficients of the model), $X_{i,t}$ is an m -dimensional vector of the explanatory variables, $u_{i,t}$ is a stochastic error (disturbance term), t is time, and i is the cross-section unit (i^{th} country).

According to (Al-mulali, 2011, p. 6165), the majority of the panel data models use a one-way error factor model for the stochastic error, with

$$u_{i,t} = \mu_i + v_{i,t}, \quad (2)$$

where $u_{i,t}$ is the residual, μ_i is the unobservable individual-specific effect, and $v_{i,t}$ is the remaining disturbance.

Following equation (1), for this study, we investigate the factors affecting CO₂ emissions in nine Balkan countries for the period 1996-2017. The model's dependent variable is CO₂ emissions, whilst the independent variables are services (value-added), industry (value-added), and gross fixed capital formation. Therefore, the CO₂ emission model is specified as follows:

$$CO_{2i,t} = \alpha + \beta_1SER_{i,t} + \beta_2IND_{i,t} + \beta_3GFCF_{i,t} + u_{i,t}, \quad (3)$$

where CO₂ is carbon dioxide emissions in tonnes per capita, SER is services, value-added in constant 2010 USD, IND is industry (including construction), value-added in constant 2010 USD, and GFCF is gross fixed capital formation in constant 2010 USD.

As systematized by Baltagi (2005), based on Klevmarcken (1989) and Hsiao (2003), the use of panel data instead of individual time series brings several advantages to econometric modelling, such as:

- “Panel data helps in controlling for individual heterogeneity.
- Panel data give more informative data, more variability, less collinearity among the variables, more degrees of freedom, and more efficiency.
- Panel data are better able to study the dynamics of adjustment.
- Panel data are better able to identify and measure effects that are not detectable in pure cross-section or pure time-series data.
- Panel data models allow us to construct and test more complicated behavioural models than purely cross-section or time-series data.” (pp. 4-6).

The model estimation procedure follows a common approach to panel cointegration analysis, following the works of (Wang, Li, & Fang, 2018; Shahbaz, Hye, Tiwari, & Leitão, 2013; Al-mulali & Sab, 2012; Al-mulali, 2012; Hossain, 2011; Al-mulali, 2011). A three-step approach implies unit root testing, cointegration testing, and causality assessment.

Panel Unit Root Testing

Panel unit root tests are of great interest among economists and econometricians because they are more powerful compared to the normal unit root tests for individual time series. (Al-mulali, 2011, p. 6167).

The scientific literature offers a significant number of unit root tests for panel data, which are an extension of tests for individual time series that should capture the dimensions of comparative data. For the purpose of this study, we consider four tests which are most commonly used in panel cointegration analysis: LLC test (Levin, Lin, & Chu, 2002), IPS test (Im, Pesaran, & Shin, 2003), Fisher-ADF test (Maddala & Wu, 1999) and Fisher-PP test (Choi, 2001).

These tests utilise the panel specification of the AR(1) data generating process, provided by Augmented Dickey-Fuller (ADF) regression (deterministic terms are omitted for simplicity):

$$\Delta y_{i,t} = \rho_i y_{i,t-1} + \sum_{p=1}^{P_i} \phi_{ip} \Delta y_{i,t-p} + X'_{i,t} \delta + u_{it}, \quad (4)$$

where $y_{i,t}$ is the dependent variable, ρ and δ are individual effects of entity and time, ϕ_{ip} are coefficients, $X'_{i,t}$ are independent variables, u_{it} is a stochastic error, t is time, and i is the cross-section unit (i^{th} country).

All four tests have the null hypothesis that each individual process has a unit root versus the alternative hypothesis that there is at least one single process that does not have a unit root. The null hypothesis can be written as follows:

$$H_0: \rho_i = 0 \quad \forall i, \quad (5)$$

while the alternative can be written as follows:

$$H_1: \begin{cases} \rho_i = 0, & \forall i = 1, 2, 3, \dots, N_1 \\ \rho_i < 0, & \forall i = N_1 + 1, \dots, N \end{cases} \quad (6)$$

These tests are dissimilar in statistical inference and starting assumptions. For example, the LLC test assumes the same autoregressive process for each i ($\forall \rho_i = \rho$), while the other tests allow for variations in ρ_i coefficients. IPS test uses t -stat mean from subjects (countries):

$$\bar{t}_{NT} = N^{-1} \sum_{i=1}^N t_{iT}(P_i, \phi_{i1}, \dots, \phi_{iP_i}), \quad (7)$$

where $t_{iT}(P_i, \phi_{i1}, \dots, \phi_{iP_i})$ denotes individual t -statistics.

“On the other hand, the statistical inference of the Fisher-ADF test and its non-parametric correction - the Fisher-PP (Phillip-Peron) test is based on the Fisher method (Fisher, 1932) combining p -values from N individual tests into one test.” (Petrovic-Randelovic et al., 2019):

$$-2 \sum_{i=1}^N \ln(p_i) \sim \chi^2_{2N}. \quad (8)$$

Panel Cointegration Tests

Coinciding to unit root testing in panel data, panel cointegration tests provide more reliable results than applying single cointegration tests to individual time series. They represent a method that allows estimation of long-term parameters or equilibrium in systems that have a unit root (Rao, 2007). Cointegration analysis in the case of a single time series aims to examine the long-term relationships between two or more variables for the same country, while the panel data emphasizes the examination of long-term relationships between two or more variables for multiple countries (Greene, 2008).

For this study, two frequently used panel cointegration tests will be performed: Pedroni test (Pedroni, 2004) and Johansen-Fisher test (Maddala & Wu, 1999).

The Pedroni panel cointegration test utilizes different statistics to test the null hypothesis of no cointegration.

Based on the auxiliary regressions (9) and (10) from the OLS-estimated residuals from equation (1),

$$\hat{\varepsilon}_{i,t} = \rho \hat{\varepsilon}_{i,t-1} + \mu_{i,t}; \quad (9)$$

$$\hat{\varepsilon}_{i,t} = \rho \hat{\varepsilon}_{i,t-1} + \sum_{p=1}^{P_i} \phi_{ip} \Delta \hat{\varepsilon}_{i,t-p} + \mu_{i,t}^*, \quad (10)$$

the assumption when performing the Pedroni cointegration test is that the vector $z_{i,t} = [y_{i,t}, x_{i,t}]$ describes the actual process $z_{i,t} = z_{i,t-1} + \xi_{i,t}$, where $\xi_{i,t} = [\varepsilon_{i,t}, \epsilon_{i,t}]$ is a stationary process with $(m+1) \times (m+1)$ asymptotic covariance matrix Ω_i . The covariance matrix can be decomposed as follows:

$$\Omega_i = \begin{bmatrix} \Omega_{11i} & \Omega_{12i} \\ \Omega_{21i} & \Omega_{22i} \end{bmatrix}, \quad (11)$$

where Ω_{11i} is the long-term error variance $\varepsilon_{i,t}$, Ω_{22i} is the long-term matrix variance of $\epsilon_{i,t}$, and $\Omega_{21i} = \Omega'_{12i}$ is the long-term covariance vector between $\varepsilon_{i,t}$ and $\epsilon_{i,t}$.

Pedroni performed a triangulation of the matrix Ω_i , resulting in the lower tridiagonal matrix L_i :

$$L_i = \begin{bmatrix} L_{11i} & L_{12i} \\ L_{21i} & L_{22i} \end{bmatrix}, \quad (12)$$

where $L_{11i} = (\Omega_{11i} - \Omega'_{21i} \Omega_{21i}^{-1} \Omega_{21i})$, $L_{12i} = 0$, $L_{21i} = \Omega_{21i} \Omega_{21i}^{-\frac{1}{2}}$, $L_{22i} = \Omega_{22i}^{\frac{1}{2}}$.

“Pedroni performs two groups of panel cointegration test statistics. The first group consists of four statistics that are derived under the assumption of a common AR process: semi-parametric v -, ρ - and t - statistics (corresponding to the variance ratio, Phillip-Peron ρ - and t - statistics univariate analogues, respectively), and parametric panel ADF t -statistics. The second group consists of three statistics that are derived by varying individual processes: Phillip-Peron ρ - and t -statistics and ADF t -statistics computed on the group-mean principle” (Petrovic-Randelovic et al., 2019).

Although the Pedroni test offers more test statistics, the Johansen-Fisher test has the advantage of indicating not only the presence of cointegration but also the number of cointegration vectors.

Johansen Fisher Panel Cointegration Test (Johansen, 1988) is based on the Vector-Error Correction representation of VAR(p) process:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{p=1}^{P-1} \Gamma_p \Delta Y_{t-p} + u_{i,t}, \quad (13)$$

where Y_t is a k -dimensional vector of possible cointegrating variables. Two tests are proposed to determine the presence of cointegration in non-stationary time series, the likelihood ratio trace statistics and the maximum eigenvalue statistics:

$$LR_{trace}(r_0, k) = -T \sum_{j=r_0}^k \ln(1 - \lambda_j); \quad (14)$$

$$LR_{max}(r_0, r_0 + 1) = -T \sum_{j=r_0}^k \ln(1 - \lambda_{r_0}), \quad (15)$$

where $r_0 = rank(\Pi)$ is a number of assumed cointegrating relations, and λ_j is the j^{th} largest eigenvalue of the matrix Π from equation (13). The same $H_0: rank(\Pi) = r_0$ is tested by both tests, against the alternative $H_1: rank(\Pi) = k$ in case of LR_{trace} , and $H_1: rank(\Pi) = r_0 + 1$, in case of LR_{max} . Based on Fisher’s method described in (8), Maddala and Wu (1999) propose a panel alternative of Johansen (1988) univariate case.

Panel Granger Causality Tests

At least one directional causal link exists between the variables if they are cointegrated. The Granger causality can be used to identify the direction of the causality in the panel models.

The Granger causality test can identify the short-run causality by conducting a joint test of the coefficients, based on F-statistics and χ^2 test. On the other hand, long-run causal relationships can be examined based on the lagged error correction term in the Vector error correction model based on the t-test.

The following equations express the panel Granger causality with ect(-1):

$$\begin{aligned} \Delta CO_{2i,t} = & \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^l \xi_{i,t} \Delta CO_{2i,t-1} \\ & + \sum_{i=1}^l \varphi_{i,t} \Delta SER_{i,t-1} \\ & + \sum_{i=1}^l \theta_{i,t} \Delta IND_{i,t-1} \\ & + \sum_{i=1}^l \tau_{i,t} \Delta GFCE_{i,t-1} + u_{i,t}; \end{aligned} \quad (16)$$

$$\begin{aligned} \Delta SER_{i,t} = & \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^l \xi_{i,t} \Delta SER_{i,t-1} \\ & + \sum_{i=1}^l \varphi_{i,t} \Delta CO_{2i,t-1} \\ & + \sum_{i=1}^l \theta_{i,t} \Delta IND_{i,t-1} \\ & + \sum_{i=1}^l \tau_{i,t} \Delta GFCE_{i,t-1} + u_{i,t}; \end{aligned} \quad (17)$$

$$\begin{aligned} \Delta IND_{i,t} = & \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^l \xi_{i,t} \Delta IND_{i,t-1} \\ & + \sum_{i=1}^l \varphi_{i,t} \Delta CO_{2i,t-1} \\ & + \sum_{i=1}^l \theta_{i,t} \Delta SER_{i,t-1} \\ & + \sum_{i=1}^l \tau_{i,t} \Delta GFCE_{i,t-1} + u_{i,t}; \end{aligned} \quad (18)$$

$$\begin{aligned} \Delta GFCE_{i,t} = & \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^l \xi_{i,t} \Delta GFCE_{i,t-1} \\ & + \sum_{i=1}^l \varphi_{i,t} \Delta CO_{2i,t-1} \\ & + \sum_{i=1}^l \theta_{i,t} \Delta SER_{i,t-1} \\ & + \sum_{i=1}^l \tau_{i,t} \Delta IND_{i,t-1} + u_{i,t}, \end{aligned} \quad (19)$$

where Δ is the first difference operator, α_{it} is a constant term, $\beta_{i,t}$, ξ_{it} , $\varphi_{i,t}$, $\theta_{i,t}$, and $\tau_{i,t}$ are the parameters, $ect_{i,t-1}$ is the lagged error correction term, and $u_{i,t}$ is the white noise.

Results

Panel Unit Root Test Results

As a prerequisite to testing cointegration, it is important to determine the order of cointegration through four types of panel unit root tests: Levin, Lin & Chu (LLC), Im, Pesaran, and Shin (IPS), ADF-Fisher (ADF), and PP-Fisher (PP) tests. According to (Al-mulali, U., & Tang, C. F. 2013) Pedroni

cointegration test can only handle $I(1)$ variables. LLC test assumes a common unit root process across the cross-sections, while the other three tests assume an individual unit root process across the cross-sections. The null hypothesis for

all four tests is that there is a unit root against the alternative hypothesis of no unit root. The results of the four unit root tests are reported in Table 2.

Table 2

Panel Unit Root Test Results

Variable	Levin, Lin & Chu t^*			
	Level		First Difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
CO ₂	-0.75419	-1.51466	-9.45699***	-8.81623***
SER	-1.27234	-1.80787*	-6.45708***	-5.52992***
IND	-1.33343	-0.57079	-6.27020***	-7.39387***
GFCF	-1.03255	-1.28739	-5.78573***	-6.51120***
Im, Pesaran and Shin W-stat				
	Level		First Difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
CO ₂	-0.21255	0.04471	-8.77072***	-7.63038***
SER	2.13490	-1.45470	-6.96053***	-5.41997***
IND	0.63721	-0.48002	-6.85224***	-5.37678***
GFCF	0.71441	-0.20513	-5.48522***	-5.16995***
ADF - Fisher Chi-square				
	Level		First Difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
CO ₂	24.1634	13.5963	100.665***	81.4482***
SER	10.5075	26.0256	79.8637***	60.7501***
IND	16.3643	23.2279	78.5727***	67.1367***
GFCF	14.6839	19.7764	62.3470***	57.5299***
PP - Fisher Chi-square				
	Level		First Difference	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
CO ₂	16.6270	15.4669	113.281***	95.0561***
SER	9.91794	10.6000	92.3043***	69.9926***
IND	9.45691	9.49800	88.1524***	82.3238***
GFCF	27.8300	10.2019	66.1948***	57.1333***

Source: Author's calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 to 0.01; * denotes statistical significance between 0.01 to 0.05; For the unit root tests, the lag length was determined using Schwarz automatic selection; An asymptotic Chi-square distribution was used for computing probabilities for Fisher tests. All other tests assume asymptotic normality.

All four test results show that all the variables are non-stationary at level, but stationary when converted to the first difference. At level, we cannot reject the null hypothesis of a unit root, while at first difference, we reject the null hypothesis of a unit root at the 0.05% significance level. All of the above indicates that CO₂ emissions, services (value-added), industry (value-added), and gross fixed capital formation belong to the $I(1)$ process. Only the variable services (value-added) shows one deviation at level, under intercept and trend assumption. But as all other tests under all assumptions provide proof of non-stationarity at level and

stationarity at first difference, we proceed to test cointegration.

Panel Cointegration Results

The panel cointegration between CO₂ emissions and its determinants is checked using Pedroni Residual Cointegration Test and Johansen Fisher Panel Cointegration Test. Results for Pedroni Residual Cointegration Test are reported in Table 3, while the results for Johansen Fisher Panel Cointegration Test are reported in Table 4.

Table 3

Pedroni Residual Cointegration Test Results

Null hypothesis: No cointegration		
Test	Deterministic intercept with no deterministic trend	
	Alternative hypothesis: common AR coefs. (within-dimension)	
	Statistics	Weighted Statistics
Panel v -Statistic	1.082637	1.011372
Panel rho-Statistic	-0.192809	0.010231
Panel PP-Statistic	-2.383099**	-1.901937*
Panel ADF-Statistic	-2.618027**	-2.620953**
Alternative hypothesis: individual AR coefs. (between-dimension)		
	Statistics	Weighted Statistics
Panel v -Statistic	1.257963	-
Panel rho-Statistic	-2.438785**	-
Panel PP-Statistic	-3.056874**	-
Deterministic intercept and deterministic trend		

Null hypothesis: No cointegration		
Alternative hypothesis: common AR coeffs. (within-dimension)		
	Statistics	Weighted Statistics
Panel v-Statistic	0.947164	1.081986
Panel rho-Statistic	0.067791	0.712471
Panel PP-Statistic	-4.385760***	-3.559538***
Panel ADF-Statistic	-4.809075***	-4.444422***
Alternative hypothesis: individual AR coeffs. (between-dimension)		
	Statistics	Weighted Statistics
Panel v-Statistic	1.973296	-
Panel rho-Statistic	-7.576495***	-
Panel PP-Statistic	-5.275966***	-

Source: Author's calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 to 0.01; * denotes statistical significance between 0.01 to 0.05; Automatic lag length selection based on SIC with a max lag of 3 has been used for both Deterministic intercept with and without deterministic trend; Newey-West automatic bandwidth selection and Bartlett kernel have been used.

Pedroni test was done under two trend assumptions: deterministic intercept with no deterministic trend, and deterministic intercept and deterministic trend. Results from weighted statistics have also been included. Under both trend assumptions, six statistics out of eleven reject the null hypothesis of no-cointegration. The Pedroni cointegration test shows that all variables are cointegrated, as both trend assumptions prove cointegration. Above mentioned indicates

that services (value-added), industry (value-added), and gross fixed capital formation have a long-run relationship with CO₂ emissions.

Johansen Fisher Panel Cointegration Test results indicate the existence of at least three cointegrated equations, meaning that there is cointegration among all four variables (Table 4).

Table 4

Johansen Fisher Panel Cointegration Test Results

Linear deterministic trend (restricted)		
Null hypothesis: Variables are not cointegrated		
Hypothesized No. of CE(s)	Trace	Maximum eigenvalue
r = 0	177.1***	110.5***
r ≤ 1	89.63***	72.06***
r ≤ 2	34.71*	25.92
r ≤ 3	22.35	22.35

Source: Author's calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 to 0.01; * denotes statistical significance between 0.01 to 0.05; r denotes the number of cointegrating equations; Intercept and trend in CE – no trend in VAR has been used; Lags interval (in first differences): 1 1; Probabilities are computed using asymptotic Chi-square distribution.

The possibility that the estimated relationships are “spurious” can be ruled out by the evidence of cointegration among variables (Pao, H. T., & Tsai, C. M. 2011). The existence of a panel long-run cointegration relationship among four variables has been proven. These results suggest that there must be Granger causality, at least in one direction.

Panel Granger causality results

The results of the panel causality analysis are presented in Table 5.

Table 5

Panel Causality Analysis Results

Short-run Granger causality					Error correction	
	ΔCO ₂	ΔSER	ΔIND	ΔGFCF	ECT (-1)	Coeff.
ΔCO ₂	-	5.405047	6.226845*	7.537215*	-3.561956***	-0.028429
ΔSER	1.567388	-	9.299033**	18.35191***	-1.068547	-0.004468
ΔIND	1.973124	7.088969*	-	4.166366	-2.588165**	-0.017700
ΔGFCF	0.802267	9.830114**	10.86979**	-	-6.345485***	-0.067636

Source: Author's calculation. Note: values of the t-statistic are reported, with the accompanying p-values where *** denotes statistical significance at 1% level; ** denotes statistical significance at 5% level; * denotes statistical significance at 10% level; Δ is the first difference operator; ECT (-1) represents the error correction term lagged one year.

The results indicate that there is a short-run bidirectional panel causality running between industry (value-added) and services (value-added), and gross fixed capital formation and services (value-added). According to the results, it can also be seen that there is a unidirectional causality running from industry (value-added) and gross fixed capital formation to CO₂ emissions, and from industry (value-added) to gross fixed capital formation.

For the long-run causal relationships, the statistical significance of ECT coefficients provides evidence of an error correction mechanism that drives the variables back to their long-run relationship. The results show that estimated coefficients of ECT in the CO₂ emissions, industry (value-added) and gross fixed capital formation are statistically significant, indicating that these three variables could take a significant part in the adjustment process as the system

diverges from the long-run equilibrium. Therefore, the existence of bidirectional Granger causality relationships between these three variables becomes evident. In the case of services, on the other hand, the coefficient of lagged ECT is statistically insignificant.

Conclusion

This study examined the relationship between CO₂ emissions and industry (value-added), services (value-added), and gross fixed capital formation. The results show the existence of a short-run bidirectional causality running between industry (value-added) and services (value-added), and gross fixed capital formation and services (value-added). Furthermore, there is a unidirectional causality running from industry (value-added) and gross fixed capital formation to CO₂ emissions, and from industry (value-added) to gross fixed capital formation. In the long-run, according to the obtained results, it is evident that estimated coefficients of ECT in the CO₂ emissions, industry (value-added) and gross fixed capital formation are statistically significant, indicating that these three variables could take a significant part in the adjustment process as the system departs from the long-run equilibrium. The above mentioned indicates the existence of bidirectional Granger causality between these three variables. In addition, the coefficient of lagged ECT is statistically insignificant for services (value-added).

Services as a less carbon-intensive sector do not cause CO₂ emissions, both in short and in the long-run. Additionally, industry and gross fixed capital formation do not cause CO₂ emissions in the short-run. On the other hand, in the long-run, industry and capital formation both take a significant part in the process of adjustment as the system diverges from the long-run equilibrium in the case of Balkan countries.

Insufficient use of modern technological solutions in the Balkan countries is a significant source of environmental pollution. Results of this study, that industry causes pollution in the long-run, can be interpreted by the use of outdated technology. Lack of understanding from the organisational structure about the importance of investing in the modernization of production processes, as well as the high cost of modernization, is certainly a challenge that the whole region faces. Therefore, both policymakers and management should support the significance of investing in new technological solutions. Furthermore, state-owned enterprises may use their political or monopoly power to their advantage and may, to some extent, ignore environmental and other types of legislation.

Gross fixed capital formation, which causes CO₂ emissions, includes all public investments, land improvements, equipment purchases and machinery. Research and Development expenditures need to be increased in the Balkan countries regarding primarily ecologically

sound technologies. Supervision of the capital formation, especially in the sense of adopting advanced technologies that mitigate CO₂ emissions should be incorporated in all the Balkan countries.

Additionally, the population of developing countries does not have enough perception of environmental problems as the population of developed countries. Environmental protection actions should be a continuous effort, above all by the state, as well as by all other actors. In general, countries in the Balkans should follow global political incentives, such as COP 21. These countries should do more to achieve the goals set out in this and other international agreements. In addition, these countries should review and update existing policies and laws, as well as create new environmental policies and laws aimed at reducing pollutant emissions.

One of the ways for Balkan countries to reduce CO₂ emissions is to work on carbon capture and storage, as it is considered an effective instrument for reducing CO₂ emissions. Furthermore, environmental taxes can significantly contribute to efforts to reduce pollutant emissions, especially if tax revenues are directed at addressing environmental issues.

Attempts to reduce CO₂ emissions and ensure a satisfactory rate of economic growth in Balkan countries can be partially achieved through the emissions trading systems. The EU ETS is the first major trading platform for CO₂ emissions in the world and is one of the cornerstones of EU policy to combat climate change and reduce greenhouse gas emissions. Balkan countries that are EU members already participate in trading on the EU ETS. Finally, increasing the use of renewables in the coming years can bring significant benefits in terms of achieving green growth. All this could be a decisive factor in the Balkan countries' aspirations for sustainable economic growth.

The results of this study should be viewed considering certain limitations. One of the limitations is that econometric analysis was conducted at the aggregate level. Furthermore, this research uses CO₂ emissions as a proxy for environmental degradation. Future studies may use other indicators for environmental degradation, which may give better perception into the links between environmental degradation and economic growth. There are several factors to consider if we are to try to understand the nature of the relationship between environmental pollution and economic growth. Therefore, directions for future research should go towards looking at new variables that can be used in the model of interdependence research on economic growth and environmental pollution, such as foreign trade, renewable energy, financial development, wealth, prosperity, agricultural development, and the whole a set of industrial, social, economic, environmental and sustainability indicators. Also, variables such as the level of technological development and environmental awareness can be further examined.

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