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THE RELATIONSHIP BETWEEN CO_2 EMISSIONS AND GDP PER CAPITA, ENERGY CONSUMPTION, INDUSTRIAL PRODUCTION IN THE CASE OF WESTERN BALKAN COUNTRIES

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Abstract

Purpose: This research investigates the relationship among CO_2 emission, GDP per capita, energy consumption and industrial production for the Western Balkan countries during the period 2011 – 2022. Design/methodology/approach: The model consists of CO_2 emission as a dependent variable, and GDP per capita, energy consumption and industrial production as independent variables. The analysis includes Ordinary Least Square (OLS), Fixed Effects (FE), Random Effects (RE), and Hausman–Taylor IV model. Findings: Results reveal a negative relationship between CO_2 emissions and GDP per capita, and a positive relationship with energy consumption, while industrial production is not significant at all. Practical implications: Knowing the relationship between CO_2 emissions and GDP per capita, energy consumption, and industrial production could help in projecting the policies that help protect the environment.

Keywords: CO_2 emission, Western Balkan countries, Panel data, Hausman–Taylor IV model.

1. INTRODUCTION

There are many research papers that have studied the interaction between CO_2 emissions and various macroeconomic variables, exploring their complex interplay within diverse socioeconomic contexts. Scholars have examined the impacts of CO_2 emissions on economic expansion and environmental sustainability. Numerous studies conclude the negative link among CO_2 emissions and economic growth (Badunenko et al., 2023, Alkhars et al., 2022, Zhang et al., 2020, Saba, 2023, Zubair et al., 2020, Handoyo et al., 2022). However, there are other studies that conclude a positive relationship between CO_2 and economic growth (Shang et al., 2022, Rahman et al., 2022, Patino et al., 2020). Amid this extensive scholarly discourse, a notable gap exists in the literature concerning the relationship between CO_2 emissions and macroeconomic indicators, such as GDP per capita, energy consumption, and industrial production, within the context of the Western Balkan countries. The lack in literature about the intricate interplay between economic indicators and environmental outcomes is a significant gap in current research despite the growing urgency to understand and mitigate climate change. Through rigorous analysis and empirical investigation, the research question guiding this study will be how GDP per capita, energy consumption, and industrial production affect CO_2 emissions.

To summarize, the analysis encompasses various econometric statistical tools including Ordinary Least Squares (OLS), Fixed Effects (FE), Random Effects (RE), and the Hausman–Taylor IV model. The synthesized findings show a negative relationship between emissions of CO_2 and GDP per capita, alongside a positive relationship with energy consumption. However, industrial production fails to demonstrate statistical significance in this context.

The contribution of this study lies in its significance to advance existing research by examining the interrelation between emissions of CO_2 and economic indicators encompassing GDP per capita, energy consumption, and industrial production, with a specific focus on the Western Balkan countries. This region has been underexplored in the extant literature concerning this relationship. Moreover, the study contributes methodologically by employing econometric techniques, notably the Hausman Taylor IV approach, to address inherent econometric problems in the analysis.

While in some other works, environmental issues are examined in the general context and interaction with the economics of tourism (Koncul, 2007), or in the economic perspectives of dealing with climate change in global context (Redek, 2010), or the impact of environmental taxes in the EU and Croatia (Hodzic & Bratic, 2015), this paper is focused on regional economics as it investigates the economic dynamics and environmental concerns within a specific regional context. By analyzing the interplay between CO_2 emissions and the specified variables in the Western Balkan countries, the study contributes to understanding regional economic trends and their impact on environmental sustainability. The research sheds light on the complex relationship between economic development and environmental factors, addressing relevant concerns for both regional policymakers and economists.

The next chapters of this research are organized as follows: The second chapter closely examines existing research in the field. The third chapter explains the research methods and data used. The fourth chapter shares the findings from the study and their implications. Finally, the fifth chapter summarizes the main results of the research.

2. LITERATURE OVERVIEW

In this section, a systematic review of the written papers on the relationship between CO_2 emissions, GDP per capita, energy usage, and industrial production has been compiled.

Scholars come to varying conclusions concerning the link between CO_2 emissions and economic expansion. Through a rigorous literature examination for the GCC member nations during the period 2010 – 2020, it was found that the relationship between environmental decline and economic advancement is evidenced by the environmental Kuznets curve (EKC) theory (Alkhars et al, 2022). According to this hypothesis, CO_2 emissions could be reduced by expanding economically (Badunenko et al., 2023). Furthermore, long term data (1990 – 2013) of 15 emerging economies were analyzed by using the Autoregressive – Distributed Lag (ARDL), and it was concluded that prosperity positively affects CO_2 emissions, while its square affects it negatively (Zhang et al., 2020). The data for South Africa in the interval 1960 – 2019, through dynamic ARDL estimation, show that in the short-term, economic development increases releases of CO_2. During an extended duration, economic advancement displays an adverse effect on CO_2 discharges (Saba, 2023). In the case of Greenland, some authors have found over the entire period from 1970 to 2018, the presence of the ecological Kuznets curve through ARDL approach (Arnaut & Lidman, 2021). Empirical evidence from Nigeria, with application of Autoregressive Distributed Lag (ARDL), the enhanced Vector Autoregressive (VAR) methods, covering the interval from 1980 to 2018, also supports the validity of EKC assumption (Zubair et al., 2020). The economic growth and energy usage in the long term affect the reduction of CO_2 emissions, as shown in another study for the case of Vietnam, during the period 1980 – 2024, analyzed with vector error correction model (Do & Dinh, 2020). Furthermore, the link between environmental damage and other variables was studied in the case of Turkey for the period 1971 – 2015, through the autoregressive distributed lag (ARDL) method. Evidence indicates that hypothesis of the environmental Kuznets curve is true since international trade increases the CO_2 emissions in the environment, but also reduces the ecological footprint in the long term. The authors suggest switching to environmentally friendly energy sources to combat degradation (Acaroglu et al., 2023). Moreover, according to another research for Asian countries for the period 2010 – 2019, through Poisson Pseudo-Maximum Likelihood method, it resulted that for developed countries the environmental

Kuznets curve hypothesis is true (Handoyo et al., 2022). The existence of the hypothesis is also proven by other authors who have analyzed the link between income and the releasing of the amount of CO_2 for 86 countries, by using PMG – ARDL model (Htike et al., 2022). Another study, which investigates the link between CO_2 release, energy usage, and GDP for the United States, in the period 1997 – 2016, through static and dynamic models, comes to similar conclusion (Salari et al., 2021). Using time-series econometrics approaches and Granger causality for the 1971 – 2014 period, the hypothesis is true in the case of Myanmar, but not true in the case of Indonesia and Malaysia (Vo et al., 2019). Additionally, analyzed through the ARDL bounds test, the increase in GDP above a certain level begins to mitigate environmental harm in the case of Russia during the study period 1991 – 2016 (Ketenci, 2018). Other authors have found that this hypothesis is true only for the most developed countries, which belong to the EU, OECD, and G7 (Maneejuk et al., 2020). Since 1990, the rate of CO_2 has increased in developing economies, while it has started to decrease in developed countries (Hannesson, 2022). In the case of Peru for 1980 – 2019 period, through performing unit root evaluations using Dickey-Fuller and Phillips-Perron methods, Granger Causality, and VAR model, it is concluded that GDP and environmental degradation are both increasing, which means that the country is at the beginning of the EKC (Mougenot et al., 2021). In the case of Mexico, in the short term, causality was established between GDP and CO_2 releases, with application of ARDL bounds test approach for the yearly data from 1993 to 2017 (Odugbesan & Rjoub, 2020). Lastly, for the Western Balkans during the study interval spanning 2008 to 2018, through panel VAR model, it has been concluded that continuous economic prosperity in the long term reduces the release of CO_2 (Pejovic et al., 2021).

Other scholarly works robustly conclude the supportive connection between the release of CO_2 and economic prosperity. According to a study, through regression equations for the case of Columbia for the period 1971 – 2017, the EKC hypothesis was rejected because the increase in GDP affects the increase in environmental degradation and the relationship is linear (Patino et al., 2020). The EKC hypothesis does not have a strong statistical basis (Stern, 2004). The hypothesis was also not supported when ARDL models applied for China's data from 1970 – 2019, and it was found that a higher economic development does not reduce the increase in the CO_2 emission level (Shang et al., 2022). Moreover, with ARDL approach for the period 1982 – 2018, it was concluded that at the onset of the Malaysian economic progress, expansion had a negative relationship with CO_2 emissions, while at the peak of economic development, higher economic growth had a positive relationship with CO_2 emission (Rahman et al., 2022). Other authors conclude that GDP levels and CO_2 emissions are positively related in the prolonged timeframe. The work focusing on China covered 1978 – 2015 data with fractional integration and cointegration technique (Caporale et al., 2021). Similar conclusions apply to the countries of Latin America and Southeast Asia (Zeeshan, 2022), and Japan (Mendoza et al., 2021). A two-sided causality is found between economic expansion and releases of CO_2 in the case of the USA, Germany, and Canada, for the period 1975 – 2017, with ARDL model performed (Wang et al., 2019).

Industrial development affects the increase in CO_2 emissions, as in a study for Pakistan, covering 1970 – 2019 period, and performing ADRL model (Ali et al., 2022). The findings from another paper, in the case of West African countries during the period 2007 – 2014 through causality analysis, suggest one-way causality linking overall incomes to release of CO_2 (Ameyaw & Yao, 2018). Furthermore, by applying ARDL, DOLS and FMOLS techniques in the case of South Korea for the period 1965 – 2019, authors found an association between CO_2 and economic growth. The findings show that there is a one-sided causality from CO_2 emissions and energy usage to development of economy (Adebayo et al., 2021). According to another study, in the context of 12 western European countries during the period 1861 – 2015, the bond amidst GDP and CO_2 results positive through time shifting coefficients cointegration technique (Mikayilov et al., 2018). According to another paper, which studied data of 17 transitional countries from 1997 – 2014 with DOLS and FMOLS estimators, the findings show a cointegrating association between economic growth and the release of CO_2 in the extended period (Mitic et al., 2017). In the context of Brazil for the period 1995 – 2018, with application of ARDL model, it results that CO_2 emissions show an upward tendency as the GDP increases, since increased production requires more energy consumption (Ullah et al., 2022), therefore the relationship of GDP and industrial production with CO_2 percentage appears positive (Sane et al., 2022), as in the case of Nigeria for the study period 1981 – 2014 through ARDL model.

While there are different opinions on the relationship between energy utilization and CO_2 discharges, recent research conducted by Ayad et al (2023) provides compelling proof to bolster the concept that energy usage contributes to increased CO_2 percentage. Specifically, their analysis of MENA countries using ARDL models spanning from 1970 to 2020 indicates a favorable relationship between energy usage and CO_2 discharges. Furthermore, the connection involving energy usage and CO_2 releases was analyzed in the context of Indonesia with Dickey Fuller test and ARDL model, for the period 1980 – 2014. It was found that the consumption of energy has a positive effect on CO_2 emissions in the short and long term (Alanazi et al., 2020). A study showing the correlation between energy prices and income has shown that income is not a determining factor in environmental protection or energy demand, and the authors have not found significant proof on the existence of the environmental Kuznets curve (Agras & Chapman, 1999). Results from another study, covering 1980 – 2019, suggest that the Kuznets energy curve for South Asian countries is valid (Adeleye et al., 2022). In addition, in the case of Saudi Arabia in the period 1980 – 2018, through performing Granger causality and cointegration models, it was shown that the rise in energy consumption and economic expansion affects the rise in CO_2 level (Alsaedi et al., 2022).

A study for the seven countries that are the most significant contributiors to worldwide CO_2 emissions per individual (United States of America, Turkey, Mexico, Korea, Japan, Germany, and Canada), spanning from 1990 to 2019 period and performing panel regression and PHTT, reveals a favorable relation between energy consumption and CO_2 level, and a weak positive relation among GDP and industrial production (Puntoon et al., 2022). Data-driven results from the GMM estimation of 58 countries for the period 1990 – 2012 show that the prosperity of economics and CO_2 emissions have a significant supportive effect on energy use (Saidi & Hammami, 2015).

A negative correlation between CO_2 dioxide and energy usage was found in the case of China for the study period 1971 – 2015 by using ARDL, indicating that environmental Kuznets curve hypothesis exists (Gessesse & He, 2020). In another study for Pakistan, through FMOLS and DOLS approaches, covering 1990 – 2014, it was found that energy consumption was among the primary contributors to the emission of CO_2 (Muhammad et al., 2020).

The study deviates from the existing literature in both methodology and empirical techniques in the field of empirical studies that analyze the relationship between CO_2 emissions and aggregate benchmarks such as Gross Domestic Product per capita, energy consumption and industrial production. Beyond traditional econometric methods, the study includes the Hausman-Taylor (IV) instrumental factor estimation approach to tackle endogeneity concern, and the data are specified for Western Balkan countries, where literature is lacking both in the elaboration of the topic and the use of advanced econometric models.

3. DATA AND METHODOLOGY

3.1. Data

The research employs panel data for the Western Balkan region (Kosova, Albania, North Macedonia, Croatia, Bosnia and Herzegovina, Montenegro, and Serbia), during the timeframe 2011 – 2022. This region is relevant for observation because the Western Balkan countries are undergoing significant economic transitions, moving from a centrally planned to a market economy. Their unique energy consumption patterns, which include a mix of coal, natural gas, and renewables, provide valuable insights into the impact of different energy sources on CO_2 emissions. The varied levels of industrial development in the region highlight how industrial activity affects emissions in different stages of economic growth. Additionally, these countries are aligning their environmental policies with the European Union standards, offering a relevant context for studying the effects of policy changes.

The sources from which the dataset for this investigation has been obtained are the World Bank and Our World in Data. The time span was selected given the accessibility of data for all variables included in the model. Statistical analysis through Stata software was performed on the data to identify the characteristics and significance of the factors introduced in the model.

3.2. Methodology

We utilized the Hausman–Taylor model to assess the relationship between CO_2 level, GDP per capita, energy consumption and industrial production in Western Balkan region during 2011 – 2022, due to its improved reliability and efficiency compared to fixed and random effects models. Its instrumental IV approach provides a robust solution for endogeneity problems, thereby improving the reliability of empirical findings. Additionally, we performed Ordinary Least Square (OLS), Fixed Effects (FE), Random Effects (RE) as comparative estimators. Following our comprehensive analysis, the Hausman–Taylor estimator emerges as the optimal choice for robust interpretation and reliable estimation within our research framework.

To mitigate endogeneity, we adopt a singular-equation methodology employing instrumental variables (IVs). The Hausman-Taylor parameter estimator is specified as follows:

$$CO_{2it} = c + \beta_1 (CO_{2it-1}) + \beta_2 (GDPC_{it}) + \beta_3 (EC_{it}) + \beta_4 (IP_{it}) + \varepsilon_{it}$$

The model incorporates CO_2 (carbon dioxide emissions) as the dependent variable and GDPC (GDP per capita), EC (energy consumption), and IP (industrial production) as independent variables. It also includes CO_{2it-1} as the first lagged of CO_2 emissions. Including CO_{2it-1}, the previous period's CO_2 emissions, is relevant because it helps capture the persistence and potential inertia in CO_2 emissions over time. This means that current CO_2 emissions are likely influenced by past emissions due to factors such as existing infrastructure, technology, and ongoing industrial activities. By including this lagged variable, the model accounts for these persistent effects, leading to more accurate and reliable estimates. It helps the study by providing a more comprehensive understanding of how past emissions impact current emissions, improving the model's explanatory power and the accuracy of predictions. The model also consists of the constant term denoted as 'c', exogenous disturbance represented by 'ε', and panel data where 'i' presents countries, while 't' represents years.

4. EMPIRICAL RESULTS

The ensuing section presents the results obtained from regression techniques including Ordinary Least Squares (OLS), Fixed Effects (FE), Random Effects (RE), and the Hausman–Taylor IV method.

The OLS, FE, and RE models are used for comparison to validate the robustness of the results under different assumptions. OLS does not account for unobserved heterogeneity or endogeneity, FE controls for unobserved heterogeneity but not time-invariant variables, and RE assumes no correlation between unobserved effects and independent variables.

The Hausman-Taylor IV model is used because it addresses both unobserved heterogeneity and potential endogeneity, providing more reliable and unbiased estimates compared to OLS, FE, and RE models.

First, to avoid biases of OLS, which does not account for individual-specific characteristics that are unobservable, fixed effects and random effects estimators were calculated, as detailed in the following table. The Hausman test was used to compare these two models (as shown in Appendix II). The test result was 0.27, indicating that the null hypothesis cannot be rejected, thus supporting the random effects estimator.

However, to mitigate the problem of endogeneity, we opt to employ the Hausman–Taylor IV estimator. The Hausman–Taylor estimator mitigates the correlations among the effects of factors unique to each individual, which cannot be directly observed, and the independent factor.

Using the Hausman–Taylor IV estimator, we determine the first lag of CO_2 emissions, deemed endogenous and instrumented through individual mean deviations, while all other model variables retain their exogenous status. The first lag of CO_2 serves as the baseline of CO_2 emission level, instrumented through variations in individual averages, thereby enabling the control of conditional convergence across the seven Western Balkan countries. The negative coefficient and the statistically significant first lagged CO_2 emission variable (CO_{2it-1}), which is equal to -.0635175 (s.e. – standard error: 0220275), in the Hausman–Taylor IV model suggests a reverse effect, indicating a potential decrease in current emissions associated with past levels.

As indicated by the outcomes presented in the table, the econometric analysis demonstrates that the GDP per capita exhibits a significant negative coefficient of -245.4674 (s.e.: 102.731), indicating a statistically significant inverse relationship with CO_2 levels. Furthermore, the outcome implies that an expansion in GDP per capita is linked with a decrease in CO_2 levels. The outcomes of this research align with most prior studies, as exemplified by Saba (2023), Do & Dinh (2020), Pejovic et al. (2021), which found a negative relation between CO_2 emission and gross domestic product per person. Prior investigations have concluded a positive relationship between CO_2 emission and gross domestic product per person, such as Patino et al. (2020), Shang et al. (2022), Rahman et al. (2022).

The ensuing evidence in the following table demonstrates that energy consumption is positive 213818.1 (s.e. 19755.92) and significant, thus presenting a positive implication on CO_2 emission. This outcome is in accordance with the outcomes of many prior workings, as illustrated by Ayad et al. (2023), Alanazi et al. (2020), Alsaedi et al. (2022), Puntoon et al. (2022), Muhammad et al. (2020), which found positive relationship among CO_2 level and energy usage. There are other investigations that observed a negative relationship between the energy consumption and CO_2 emission such as Gessesse & He (2020).

The findings shown in the table demonstrate that the parameter of industrial production is positive 178220.6 (s.e. 127332.8) but statistically not significant, therefore it will not be interpreted.

Table 1

Results of econometric models

Variables	Ordinary Least Squares	Fixed Effects	Random Effects	Hausman Taylor IV
CO_2_lag				-.0635175**
s.e.				(.0220275)
GDPC	-381.7372**	-249.0335**	-262.4562**	-245.4674**
s.e.	(95.59341)	(112.2801)	(105.5788)	(102.731)
EC	230755.3**	209990.8**	221361.7**	213818.1**
s.e.	(5803.426)	(29050.66)	(17114.74)	(19755.92)
IP	142896.8	195857.6	206148.2	178220.6
s.e.	(94988.06)	(130959.7)	(120169.3)	(127332.8)
Nr.Obs.	79	79	79	78
R-squared	0.9700	0.9694	0.9694	
F	0.0000	0.0000		
Chi^2			173.89	148.76

Note: * $p<0.1$, ** $p<0.05$, *** $p<0.01$

Source: Authors' calculation

5. CONCLUSION

Using the Hausman-Taylor IV estimator, the relationship between CO_2 emission and GDP per capita, energy consumption and industrial production in Western Balkan countries, through 2011 – 2022 period was examined. The Hausman-Taylor IV estimator was selected due to its ability to address the endogeneity concerns.

According to the results, the increase of GDP per capita decreases the CO_2 level. This idea motivates countries to invest in clean technologies, implement regulatory frameworks, cooperate internationally, and raise public awareness for sustainable development.

Moreover, our findings highlight a robust positive causality between energy consumption and CO_2 levels, implying that increased energy consumption levels are linked with higher CO_2 levels. This emphasizes the importance of addressing measures of optimization of energy and switching towards cleaner alternative energy sources to alleviate ecological harm.

Furthermore, our analysis reveals that industrial production does not exhibit statistical significance across all estimators employed in the study.

Given the relatively low levels of economic growth in the Western Balkans and their aspirations for improving the well-being, understanding these dynamics is crucial for developing policies that balance economic development with environmental conservation. These countries have been experiencing moderate economic growth, often hindered by political instability, underdeveloped infrastructure, and limited industrial diversification. The Western Balkan countries have the potential to pursue green aspirations despite their economic challenges. By focusing on renewable energy, energy efficiency, robust policy frameworks, and international cooperation, they can achieve sustainable economic growth while reducing CO2 emissions. Overcoming economic and political barriers will be critical to realizing these aspirations and improving national wellbeing in an environmentally sustainable manner.

The study highlights the need for continued research and data collection efforts to monitor trends in CO2 emissions and evaluate the effectiveness of mitigation measures, thereby supporting evidence-based policymaking for sustainable development in the Western Balkans.

A limitation of this study may be that it uses CO_2 emissions as the sole dependent variable, which might oversimplify the complex dynamics of environmental impact. The chosen independent variables (GDP per capita, energy consumption, and industrial production) may not fully capture all factors influencing CO_2 emissions, such as technological advancements, regulatory changes, and energy mix variations.

Future studies in this area may aim to expand the case study by including other Balkan countries and examining the impact of emissions of different harmful gases, to emphasize the importance of sustainable economic growth without compromising the environment.

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APPENDIX

Table AI.

Variables description

Variable name	Formal definition	Variable Code	Unit	Source
CO_2 emission	Carbon dioxide (CO_2) emissions from fossil fuels and industry. Land-use change is not included.	CO_2	t	Our world in data
GDP per capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.	GDPC	US $	WB
Energy consumption	Primary energy consumption is measured in terawatt-hours, using the substitution method.	EC	TWh	Our world in data
Industrial production	Industry (including construction) comprises value added in mining, manufacturing (also reported as a separate subgroup), construction, electricity, water, and gas.	IP	% of GDP	WB

Source: WB & Our world in data

Table AII.

Hausman specification test

Chi^2	Prob>Chi^2	Outcome
0.27	0.9649	Doesn’t refuse null hypothesis

Source: Authors’ calculation

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ODNOS IZMEĐU EMISIJE CO_2 I BDP-a PO GLAVI STANOVNIKA, POTROŠNJE ENERGIJE I INDUSTRIJSKE PROIZVODNJE U SLUČAJU ZEMALJA ZAPADNOG BALKANA

Sažetak

Svrha: Ovo se istraživanje bavi odnosom između emisije CO_2 i BDP-a po glavi stanovnika, potrošnje energije i industrijske proizvodnje za zemlje Zapadnog Balkana u razdoblju 2011. – 2022. Izrada/metodologija/pristup: Model se sastoji od emisije CO_2 kao zavisne varijable te BDP-a po glavi stanovnika, potrošnje energije i industrijske proizvodnje kao nezavisnih varijabli. Analiza uključuje obični najmanji kvadrat (OLS), fiksne učinke (FE), slučajne učinke (RE) i Hausman–Taylor IV model. Nalazi: Rezultati pokazuju negativan odnos između emisija CO_2 i BDP-a po glavi stanovnika te pozitivan odnos s potrošnjom energije, dok industrijska proizvodnja uopće nije značajna. Praktične implikacije: Poznavanje odnosa između emisija CO_2 i BDP-a po glavi stanovnika, potrošnje energije i industrijske proizvodnje moglo bi pomoći u planiranju politika koje pomažu zaštiti okoliša.

Ključne riječi: emisija CO_2, zemlje Zapadnog Balkana, panel podaci, Hausman–Taylor IV model.

JEL klasifikacija: C33, Q53.