RESEARCH ARTICLE

The relationship between CO$_2$ emissions, economic growth, available energy, and employment in SEE countries

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Abstract

As a result of a greater worldwide aspiration for wealth and economic progress, increased use of natural resources for diverse industries resulted in increased pollution emissions, mainly carbon dioxide. Energy security, economic stability, job security, biodiversity loss, climate change, and global warming all require reconciliation and resolution now, more than ever before. This paper explores the causal relationship between CO$_2$ emissions, economic growth, available energy, and employment for a panel of eight South-Eastern European countries from 1995 to 2019. We investigate the relationship using panel unit root tests, panel cointegration methods, and panel causality tests. The results show a short-run bidirectional panel causality between CO$_2$ emissions and employment and between available energy and employment. The results further indicate a unidirectional causality from available energy and employment to GDP. The long-run causal relationship results show that the estimated coefficients of the lagged ECT in the CO$_2$ emissions, GDP, and employment equations are statistically significant, implying that these variables could play a significant role in the system's adjustment process as it departs from long-run equilibrium. We also conducted a variance decomposition analysis, which allowed us to compare the extent of the individual factors' contributions to each other over the next 5 years.

Keywords CO$_2$ emissions · Energy · Economic growth · Employment · SEE countries · Panel causality · Variance decomposition

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Introduction

The Industrial Revolution brought a new period of fast economic expansion among countries, giving rise to today's well-known phenomena: global warming and climate change. Compared to industrialized countries, CO$_2$ emissions from energy use have grown dramatically in newly industrialized economies since the 1990s. The decline of environmental quality has reached worrisome levels, raising global warming and climate change concerns. As a result, understanding the causes of environmental deterioration and its relationship to economic growth has become increasingly important in recent years (Kasman & Duman, 2015). According to Hamakawa (2004), the "3E trilemma"—integrating economic growth, energy consumption, and environmental preservation—represents a principal challenge for policymakers in various countries, compelling scientists to devote increasing attention to investigating complex linkages among sustainable development goals.

The global health crisis caused by the COVID-19 pandemic resulted in substantial societal repercussions, growing

inequality and poverty rates, and Europe's sharpest recession since World War II. However, the pandemic could catalyze more efficient transitioning toward developmental and environmental improvement policies. Governments should boost this transition with economies at a crossroads. European countries will need to ensure a green, sustainable, and inclusive recovery in the future (World Bank, 2021a) since they are dealing with a twofold crisis. On the one hand, long before the pandemic, most European countries crossed ecological limits in terms of pollution, climate change, and biodiversity extinction rate (Rockström et al. 2009). On the other hand, poverty and inequality are pervasive. They have been worsened by events such as the 2008 financial crisis, the 2010 sovereign debt crisis, and the 2015 migration crisis. Before the pandemic, the so-called greening of the economy was one of the top priorities in the EU (Ritzen & Zimmermann, 2014). However, currently, there is little room for further greening initiatives in countries with high unemployment and inert economic development. As a result, environmental degradation and socio-economic concerns are two main challenges of this century and the primary source of uncertainty for policymakers worldwide (Monasterolo et al. 2019).

The economic downturn in 2020 caused by the pandemic is more severe than the global financial crisis of 2008 and, according to authors like Dosi et al. (2020), Alrefai (2020), Hwang and Höllerer (2020), and Kaushik and Guleria (2020), even the Great Depression (1929–1933). Although the short-term decline in economic activity caused by the enforced confinement has drastically reduced energy use and hence CO_2 emissions, the long-term consequences on energy consumption and CO_2 emissions are not fully understood. It is critical to investigate such consequences since relevant findings will obtain critical information for policymakers to formulate post-pandemic economic recovery packages (Smith et al. 2021). It became evident that unique policies and stimulus packages would be required to manage the COVID-19 pandemic ramifications, with policymakers generally feeling more ready for green stimulus than in 2008. However, for economic and environmental reasons, it may be argued that the economic effects of the pandemic at the sectoral level are more relevant than the macro-level outcomes (Pollitt et al. 2021).

The shift to a low-carbon economy has become a fundamental goal for governments worldwide to combat climate change, ensure energy security, and decrease pollution (de Miguel et al. 2019). Without considering other strategic goals, CO_2 emissions may be efficiently lowered by restricting high-emission industries while expanding low-emission ones. Although there is an urgent need to minimize CO_2 emissions from energy usage, this should be achieved by preserving economic growth and prosperity (Paramati et al. 2021). Therefore, an intelligently designed industrial

strategy may impact a country's growth, generating more and better domestic employment, emitting less CO_2 and other greenhouse gasses, and increasing productivity and competitiveness at the national economy level. Such a strategy would have to emphasize linkages and effect assessments (Bai et al. 2021). Furthermore, Zhao et al. (2022) state that new patents and utility models for low-carbon, energy-saving, and alternative energy technologies are the main indicators of green innovation effects, especially among large and nonstate companies.

Energy is crucial for all economic sectors in many nations (Stavytskyy et al. 2018). Therefore, determining the role of energy in ensuring sustainable development is crucial. The role of fossil fuel-based energy resources is diminishing, and the world is progressively shifting to alternative sources (Stavytskyy, 2018), but the world is still engaged in an active struggle over diverse energy resources. So, whether examined in the context of exporting or importing energy resources, energy security today is one of the most critical components of a country's national security (Mara et al. 2022).

This study focuses on SEE countries because developing economies contribute a growing percentage of CO_2 emissions (Liu et al. 2019) and strive to maintain sufficient economic growth and energy security under (post)pandemic circumstances and the intense Russia-Ukraine conflict. The SEE region's top sources of air pollution are coal power plants, followed by air pollution from cities and urban areas. Most electricity is produced using domestic lignite and coal as well as hydropower. Given that coal is one of the primary sources of CO_2 emissions, pressure on coal-based energy production may grow. The production of hydropower is risky when there is less water available, which can result in a disruption in the supply of electricity and increased costs (Rüttinger et al. 2021). We can observe how much the CO_2 emissions have increased over the past seven decades in the SEE region by looking at Fig. 1. The last 15 years have been relatively stable with some rises and falls. At 740.5 million tonnes of CO_2, the emissions peaked in 2017. However, given the aforementioned (post)pandemic conditions and the effect of the Russian-Ukrainian crisis on energy markets, the future of CO_2 emissions remains uncertain for the SEE region.

Despite certain similarities, the observed countries had different development paths, especially after the 1990s. When analyzing the economic structure of all SEE countries by sector, a significant share of GDP creation belongs to the mining, manufacturing, agriculture, and forestry sectors. All these sectors are considered significant polluters of the environment. Another reason for choosing SEE countries is their considerable unexploited renewable energy potential. Most of them heavily rely on Russian gas supplies and have limited internal energy production (Armeanu et al. 2019).

Fig. 1 Territorial CO_2 emissions in million tonnes in South-Eastern Europe from 1951 to 2020. Source: Authors created the figure based on data from Ritchie et al. (2020). Note: This graph represents the sum of territorial CO_2 emissions from eleven SEE countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Montenegro, North Macedonia, Romania, Serbia, Slovenia, and Turkey)
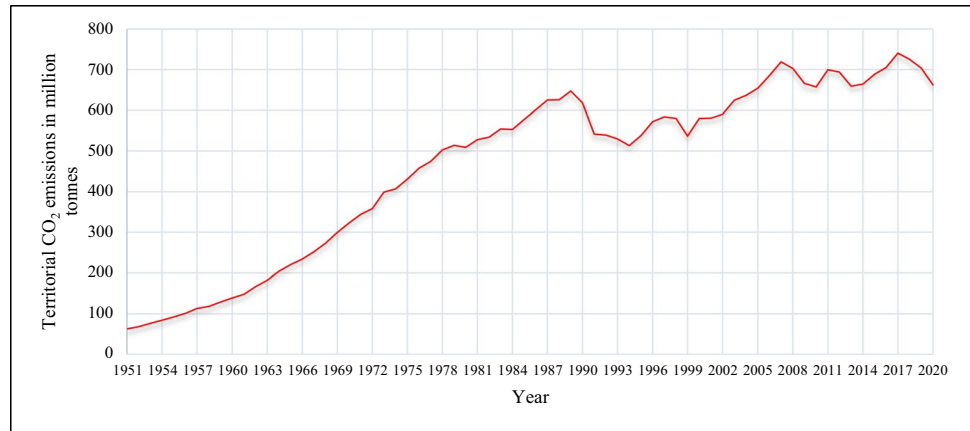
Significant disparities in energy mixes, which are still predominantly driven by fossil-fuel usage, make integrating national energy systems challenging. The SEE countries have been dealing with various similar energy-related issues. Their economies are energy-intensive, their energy markets are small, and energy prices are below economic levels (Dominković et al. 2016). It is worth noting that these countries are geographically in a region that contains some of the world's most important energy corridors. Thus, this region is of major importance because most countries have gone through a transition period during which their development policies were re-oriented (Bellos, 2019).

All the SEE countries are the signatures to the Paris Agreement—the world's most important international treaty on climate change. The United Nations Conference of the Parties on Climate Change (COP21) in Paris saw its adoption by 196 parties, and on November 4th, 2016, it came into effect. Its objective is to keep global warming far below 2 °C, ideally below 1.5, compared to pre-industrial levels. Countries strive to reach the worldwide peaking of greenhouse gas emissions as quickly as possible to create a climate-neutral planet by the middle of the century (UNFCCC, 2022). It is necessary to mention COP26 in Glasgow, where the parties agreed to keep global warming to 1.5 °C. There are many important outcomes of COP 26; for instance, countries merely committed to "phase down" coal, not "phase it out." However, the accord does call for, among other things, the gradual elimination of inefficient subsidies for fossil fuels, a 30% reduction in methane emissions by 2030, and forest regeneration. Unavoidable to mention—the Paris Rulebook has been adopted (COP26 Goals).

This research examines the complex links between CO_2 emissions, economic growth, available energy, and employment in eight SEE countries (Albania, Bulgaria, Croatia, Greece, North Macedonia, Romania, Serbia, and Slovenia) using panel unit root tests, panel cointegration methods, and panel causality tests employing data from 1995 to 2019. One of the most important contributions of the study was how using this combination of indicators provided additional policy insights that were not included in other studies. Although SEE economies are on their way to environmental and economic sustainability, their path is still rocky. Poverty, unsolved political problems, unclear environmental protection legislation, brain drain, and other challenges are only some of the issues these countries are dealing with (Pavlović et al. 2021). These issues are solvable by effectively implementing a suitable sustainable development strategy. As a result, the findings of this study should point to the most appropriate policy measures for this region, especially in recommending a baseline energy strategy for the SEE region.

The remainder of this paper is divided into four sections: "Literature review" section describes previous research on this topic and evaluates the literature review connected to this research. The data and methodology are introduced in the "Data and methodology" section. "Results" section illustrates the results, while "Discussion and policy implications" section provides discussion and policy implications. "Conclusion" section concludes this paper based on the research results and content.

Literature review

Over recent years, policymakers, environmental scientists, and national and international organizations have paid close attention to the issue of CO_2 emissions. CO_2 emissions have been rising due to energy-related human activities influenced by economic development (Sadorsky, 2010). Many studies have found that energy consumption and economic growth positively affect pollution caused by CO_2 emissions (Wang et al. 2013; Gao & Zhang 2014; Mikayilov et al. 2018; Nosheen et al. 2021; Genç et al. 2022). One of the most important empirical linkages examined in environmental economics is the relationship between CO_2 emissions and economic growth (Narayan & Narayan, 2010). The most

prominent theoretical hypothesis for examining this relationship is the environmental Kuznets curve (EKC)—an inverted U-shaped curve that describes the link between environmental deterioration and income. So, the EKC is a hypothesized link between environmental degradation indicators and economic growth that suggests that the intensity of environmental degradation tends to rise as economic growth occurs until average income reaches a specific point over the development course (Seker et al. 2015). Although the EKC hypothesis was validated in most studies, there are some exceptions, like the Baltic States are countries with significant differences regarding the dependence on fossil fuels (Kar, 2022) and Kazakhstan as an energy-rich economy (Hasanov et al. 2019).

Energy is a crucial driver for social and economic development, and its role in growth and development is pivotal in environmental economics research. Although most of them considered energy consumption (Zaman & Abd-el Moemen, 2017; Cai et al. 2018; Dong et al., 2018; Ardakani & Seyedaliakbar, 2019; Gardiner & Hajek, 2020; Addo et al. 2021; Acheampong et al. 2021; Shahzad et al. 2022), an increasing number of authors have emphasized the importance of energy security as critical in the context of frequent and sudden disturbances (Ang et al. 2015; Azzuni & Breyer, 2018; Huang et al. 2021). Due to the current complexities associated with global energy resources, energy security definitions have morphed to include a variety of dimensions, such as energy supply and demand security, pollution prevention, socio-economic aspects, security apparatus, information security, and cultural and health aspects (Ang et al. 2015; Azzuni & Breyer, 2018; Rafique et al. 2022). Taking all these aspects into account, Oryani et al. (2022) analyzed the concept of energy poverty, and their findings highlighted the importance of improving access to clean energy and energy poverty reduction by implementing efficient economic, environmental, and energy policies.

Traditional fossil-fuel-based energy sources are potent drivers of economic development (Ellabban et al. 2014). However, their use is the primary source of GHG emissions (Armeanu et al. 2019). Furthermore, concerns about oil price volatility and dependency on foreign energy sources are significant drivers in transitioning to renewable energy sources (Apergis & Payne, 2010). Using renewable energy resources should improve public health, reduce pollution, promote sustainable (economic) development, create job opportunities, and positively affect overall well-being. Authors like Bhattacharya et al. (2016) and Radmehr et al. (2021) include just renewable energy in their research on the economic growth-environment relationship, while others additionally include variables like public health (Chaabouni & Saidi, 2017), globalization (Liu et al. 2020), population growth (Dong et al. 2018), and employment (Lehr et al. 2012; Bhattacharya et al. 2016).

Renewable energy offers jobs and is a core part of the transition to a low-carbon economy. Due to environmental regulation, many current occupations would be redefined as green, while some jobs in carbon-intensive sectors would be replaced or eliminated without replacement (OECD, 2012). The measurement of these employment benefits has sparked much interest. Most researchers have concentrated on assessing gross employment impacts while ignoring cross-sector effects. Fragkos and Paroussos (2018) combine the employment factor method and general equilibrium analysis to analyze the net employment effects of the expected transformation of the EU energy industry toward renewable energy sources (RES). Compared to fossil fuels, RES technologies will be more labor demanding and have a more significant domestic job potential as far as the expectations go. Most new employment will be in solar photovoltaics construction, advanced biofuels supply and production, and wind turbine manufacture and installation. On the other hand, employment in traditional energy supply industries would be eliminated, particularly in the coal mines, refineries, and refueling stations. Pollin et al. (2009) found that investing in energy efficiency creates 2.5–4 times as many jobs as investing in oil and gas, whereas Wei et al. (2010) found that both RES and energy efficiency are more labor-intensive per unit of energy than fossil fuel supply sectors. Behrens et al. (2014) examined the employment implications of the EC Energy Roadmap 2050, concluding that decarburization resulted in significant job growth.

The relevance of labor unions is growing under the above-mentioned circumstances. There is evidence that, in some situations, unions have been sluggish in recognizing climate change as a priority in their mission due to their desire to save jobs. The capitalist system promotes profit growth through technical progress and environmental degradation from a theoretical standpoint. All this results in job losses, necessitating more production, the development of new jobs, and, eventually, the provision of additional finances to clean up the environment (Gould et al. 2008; Alvarez et al. 2019). The term "production treadmill" is used when labor plays a critical role in speeding the production and accumulation (Gentry, 2009). Effective labor market regulations may assist in a successful low-carbon transition by supporting structural labor market transformation toward clean energy industries, preventing adverse effects in the labor market.

Recognizing that these adverse effects of low-carbon transition are more severe in transition countries, authors such as Pavlović et al. (2021), Mitić et al. (2017), and Becker et al. (2018) analyzed the interconnection among economic performances, energy indicators, and environmental effects. Additionally, Li et al. (2020) used the example of post-capitalist countries to demonstrate that progress in energy efficiency decreases CO_2 emissions per capita. In that case, the GDP increase is followed by a decrease in CO_2 emissions.

If energy efficiency progress is not realized, GDP per capita increases CO_2 emissions, so the wealthier the economy becomes, the more CO_2 emissions per capita it produces. Hatzigeorgiou et al. (2011) discovered that Greece's GDP growth causes CO_2 emissions. Petrović et al. (2018) found that population, GDP per capita, and energy intensity positively influence CO_2 emissions in EU countries, implying that economic expansion enhanced pollution in the short run. Nepal et al. (2017) investigated the effects of market-based economic reforms on per capita CO_2 emissions in transition economies in Europe and Central Asia, where environmental degradation was widespread prior to reforms. A dynamic panel data model is used for 28 countries over 22 years from 1990 to 2012. Their findings imply that competition policy and corporate governance reforms are the primary drivers of regional emissions reductions. According to their findings, the Kyoto Protocol had no substantial impact on reducing emissions levels, and the relationship between economic growth and emissions appears weak. For a sample of 11 CEE countries from 2000 to 2016, Armeanu et al. (2019) explored the influence of energy consumption and pollution on economic growth and the causal relationships. The panel data regressions show that renewable energy and GDP per capita growth have a non-linear association. Non-linear correlations exist in alternative and nuclear energy and fossil fuel energy consumption. On the other side, the impact of non-renewable energy on growth was not statistically significant, while GHG emissions had a significant positive influence on economic growth. The Granger causality results backed up the conservation hypothesis for renewable energy in the short run.

Some studies investigated the state and prospects of the SEE region. Mitić and Cvetanović (2018) examined the relationships between CO_2 emissions and GDP per capita in nine SEE countries from 1992 to 2016. Granger causality testing showed a positive bidirectional causal relationship between CO_2 emissions and GDP per capita in the short run, but only from GDP per capita to CO_2 emissions in the long run. Mitić et al. (2017) used annual data from 1997 to 2014 to examine the link between real GDP and CO_2 emissions in 17 transitional economies. The findings indicate that CO_2 emissions and real GDP have a statistically significant long-run cointegrating relationship. Obradović and Lojanica (2017) used the cases of Greece and Bulgaria to investigate the causal relationships between energy use, CO_2 emissions, and economic growth. In order to identify probable causation between the variables, a vector error correction model was applied with annual data from 1980 to 2010. The empirical data show a long-term causal relationship between energy and CO_2 emissions and economic growth in both countries. There is no connection between energy and economic growth in the short run, neither in Greece nor Bulgaria.

This paper contributes to the existing literature as the topic of examining economy-environment-energy links in the SEE region is underrepresented in the literature, aside from just a few studies (Pejović et al. 2021; Bellos, 2019; Obradović & Lojanica, 2017; Dominković et al. 2016; and Mitić & Cvetanović, 2018). Hence, it is an intriguing topic, especially since many developing and developed countries see cutting CO_2 emissions as a foremost economic strategy (Lau et al. 2018). Furthermore, to the best of our knowledge, none of the existing literature on SEE has focused on our chosen variables, namely, gross available energy and employment, so this paper will fill this research gap.

Data and methodology

The main objective of this study is to examine the links between carbon dioxide emissions, gross domestic product, gross available energy, and employment. The econometric techniques utilized in this research are as follows. We investigate the stationarity of the variables using panel unit root tests. If the variables are non-stationary at level but stationary at the first difference, we check if the variables' time series have a cointegrating relationship. If the variables are cointegrated, we explore the interactions between the short-run and long-run dynamics of the time series using a panel vector error correction model. Finally, we use variance decomposition analysis to determine the significance of one variable's causal effect on another and estimate how each variable responds to changes in others. This section describes the data before proceeding to the econometric method.

Data

This study includes eight South-Eastern European countries, namely, Albania, Bulgaria, Croatia, Greece, Northern Macedonia, Romania, Serbia, and Slovenia. Although Turkey, Montenegro, Kosovo, and Bosnia and Herzegovina are frequently referenced in discussions of South-Eastern Europe, they are not included in this study. Turkey was excluded from the study due to its vastness and the fact that East Thrace is the only region actually in South-Eastern Europe. On the other hand, data availability is a major limiting factor for including Montenegro and Kosovo. Furthermore, under the United Nations Resolution 1244/99, Kosovo is the subject of a territorial dispute between Kosovo and Serbia. The same data availability limitation, but in this case, only for available energy data, applies to Bosnia and Herzegovina. Consequently, this resulted in balanced panel data for eight South-Eastern European countries from 1995 to 2019. Each variable included 200 observations of time series data.

The model applied in this research includes four variables. Carbon dioxide emissions and gross available energy are used as environmental proxies, whereas gross domestic product per capita and employment are used as proxies of economic development and well-being. Table 1 lists all of the variables used in this study.

We selected CO_2 emissions as the primary indicator of environmental quality because it serves as a baseline for measuring other greenhouse gas emissions. CO_2 emissions are a by-product of fossil fuel and biomass combustion, land use, and other industrial processes. Carbon-based fuel combustion raises CO_2 levels in the atmosphere, resulting in anthropogenic climate change, global warming, and rising sea levels. The data for CO_2 territorial emissions in million tons was collected from Friedlingstein et al. (2020). Furthermore, we chose the gross available energy variable as all energy sources affect the environment. Fossil fuels, such as coal, oil, and natural gas, substantially damage the environment, causing air and water pollution, public health impairment, biodiversity and habitat degradation, and global warming emissions. Gross available energy is the total energy supply for all activities on the country's territory, including energy transformations such as electricity generation from combustible fuels, distribution losses, and non-energy uses of fossil fuel outputs (Eurostat, 2021b). The data for gross available energy in thousand tons of oil equivalent were collected from Eurostat (2021a).

Gross domestic product divided by population equals GDP per capita. The GDP is a quantitative measure of the market worth of all final goods and services produced over a given period. Because GDP incorporates price changes, it gives an accurate measurement of economic growth, which is why we chose it as an indicator of economic growth in our paper. From a research perspective, it is important because economic growth is measured by the change in the volume of production or real incomes of the residents of a country. The data for GDP per capita in constant 2010 US dollars were collected from the World Bank Open Data (World Bank, 2021b). The employment to population ratio measures how much of a country's population is employed. Persons of working age (15 and older) who were engaged in any activity to generate goods or provide services for pay or profit during

a particular reference period, whether at work or not at work owing to temporary absence from a job, are considered to be employed. Employment is a metric that shows how far the economy has progressed. Data for employment to population ratio were collected from the World Bank Open Data (World Bank, 2021c).

Notably, GDP per capita and employment are economic indicators at the forefront of the sustainable development goals under SDG 8 "Decent Work and Economic Growth." This goal aims to promote long-term, inclusive, and sustainable economic growth and full and productive employment, and decent work for all. Additionally, CO_2 emissions are a predominant greenhouse gas that needs to be mitigated and decreased under the SDG 13 "Climate Action," stating that immediate action to address climate change and its consequences is needed. Energy is also a topic addressed under the SDGs, as SDG 7 "Affordable and Clean Energy" aims to guarantee that everyone can access affordable, reliable, sustainable, and modern energy (United Nations, 2021).

For research purposes, we transformed all variables into natural logarithms. However, before transforming variables to logarithmic forms, we present descriptive statistics for each variable and the panel. Table 2 shows a statistical summary of the actual values for each country and the panel.

Romania has the highest descriptive statistics values for CO_2 emissions, while Albania has the lowest. The mean and standard deviation of CO_2 emissions vary by country, from 3.97 and 0.24 in Albania to 95.58 and 3.28 in Romania. While Albania has the lowest minimum and maximum CO_2 emissions, Romania has the highest minimum and maximum. The GDP mean is found between 3409.76 in Albania and 24,224.42 in Greece. Greece has the highest minimum and maximum GDP, while Albania has the lowest. On the other hand, North Macedonia has the lowest GDP standard deviation while Slovenia has the highest. Furthermore, except for standard deviation, all of the highest descriptive statistics for gross available energy values are reported in Romania, while the lowest values are noted in Albania. The gross available energy standard deviation is highest in Romania and lowest in North Macedonia. Of the eight nations, Slovenia has the highest mean and the lowest standard deviation for employment. North

Table 1 Description of variables

Variable	Abbreviations	Measurement	Source
Carbon dioxide emissions	CO_2	Territorial emissions in million tons of CO_2	Friedlingstein et al. (2020)
Gross domestic product	GDP	GDP per capita (constant 2010 US$)	World Bank (2021b)
Gross available energy	EN	Total gross available energy in thousand tons of oil equivalent	Eurostat (2021a)
Employment	EMP	Employment to population ratio, 15+, total (%) (modeled ILO estimate)	World Bank (2021c)

Table 2 Summary statistics

		CO$_2$	GDP	EN	EMP
Albania	Mean	3.97	3409.76	2036.97	49.72
	St. dev	0.24	229.03	71.50	0.62
	Min	1.53	1676.13	1211.80	43.68
	Max	5.62	5207.31	2408.00	54.49
Bulgaria	Mean	49.36	6093.29	19,477.26	47.27
	St. dev	0.93	330.71	308.90	0.69
	Min	42.01	3784.08	17,172.81	41.36
	Max	58.11	9058.74	23,643.47	54.35
Croatia	Mean	20.22	12,974.10	9006.16	46.27
	St. dev	0.47	442.08	122.92	0.44
	Min	16.93	8619.10	7927.79	41.93
	Max	24.84	16,519.04	10,182.34	50.01
Greece	Mean	94.36	24,224.42	29,934.44	45.15
	St. dev	2.98	592.54	650.22	0.76
	Min	67.18	19,741.52	25,374.15	38.01
	Max	114.59	29,801.26	34,508.86	49.09
North Macedonia	Mean	9.67	4156.52	2800.39	37.60
	St. dev	0.36	167.51	32.98	0.67
	Min	6.98	3058.65	2536.49	33.84
	Max	12.57	5625.74	3122.37	45.90
Romania	Mean	95.58	7601.72	37,410.49	53.91
	St. dev	3.28	459.23	910.29	0.94
	Min	75.08	4775.31	31,665.43	49.63
	Max	130.10	12,079.55	47,950.57	62.87
Serbia	Mean	48.36	5065.51	15,589.64	45.93
	St. dev	1.32	255.59	272.25	0.76
	Min	35.79	3064.03	12,530.75	38.93
	Max	60.86	7229.94	18,098.55	51.14
Slovenia	Mean	15.75	21,757.18	6972.24	54.28
	St. dev	0.24	699.11	91.80	0.30
	Min	13.53	15,141.93	6091.96	51.66
	Max	18.22	27,421.03	8083.85	56.89
Panel	Mean	42.16	10,660.31	15,403.45	47.52
	St. dev	2.49	563.16	866.90	0.42
	Min	1.53	1676.13	1211.80	33.84
	Max	130.10	29,801.26	47,950.57	62.87

Source: Authors' calculation.

Macedonia has the lowest minimum and maximum values, as well as the employment mean, whereas Slovenia has the highest minimum employment value. It should be emphasized that North Macedonia has an enormous problem of informal employment, which significantly impacts the low values of the employment rate (World Bank, 2020). The employment mean and maximum values are the highest in Romania.

Additionally, Table 3 demonstrates a strong positive correlation between CO$_2$ emissions and available energy, while all other variables have a weak positive correlation. The

Table 3 Correlation matrix

Variable	CO$_2$	GDP	EN	EMP
CO$_2$	1			
GDP	0.2769***	1		
EN	0.9812***	0.2340***	1	
EMP	0.2211***	0.2102***	0.2953***	1

model's pairwise correlations are all statistically significant at the 1% level.

The econometric methodology

This study uses a methodological approach to examine if there are any long-term correlations between CO$_2$ emissions and model variables. The following is a generic model description:

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

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

As the preceding section states, this study investigates factors influencing CO$_2$ emissions in eight Balkan countries from 1995 to 2019. CO$_2$ emissions are the model's dependent variable, whereas GDP per capita, available energy, and employment are independent variables. As a result, the following is the study's specific model:

$$CO_{2i,t} = \alpha + \beta_1 GDP_{i,t} + \beta_2 EN_{i,t} + \beta_3 EMP_{i,t} + u_{i,t} \qquad (2)$$

Unit root tests for panel data are an extension of tests for individual time series that should capture the dimensions of comparative data. Selecting the unit root tests is influenced mainly by cross-sectional dependence in the data. Pervasive cross-sectional dependence, where all units in the same cross-section are correlated, can be found in panel data. This dependence is frequently ascribed to the activity of some unobserved common factors shared by all units and affect them all, albeit in different ways (Henningsen & Henningsen, 2019). Therefore, if there is evidence of cross-sectional dependence, methodology suggests second-generation panel unit root tests, such as Panel Analysis of Nonstationarity in Idiosyncratic and Common Components—PANIC (Bai & Ng, 2004) and cross-sectionally augmented IPS—CIPS (Pesaran, 2007). For the cases where there is no evidence of cross-sectional dependence, it implies considering first-generation panel unit root tests, such as the LLC test (Levin et al. 2002), IPS test (Im et al. 2003), Fisher-ADF test (Maddala & Wu, 1999), and Fisher-PP test (Choi, 2001).

After conducting panel unit root testing, we proceed to panel cointegration testing. In the case of a single time series, cointegration analysis focuses on examining long-term correlations between two or more variables for the same country. In contrast, panel data examines long-term relationships between two or more variables for numerous countries (Greene, 2008).

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

Johansen Fisher panel cointegration test (Johansen, 1988) is founded on the vector error correction representation of the VAR(p) process:

$$\Delta Y_t = \Pi Y_{t-1} + \sum_{p=1}^{P-1} \Gamma_p \Delta Y_{t-p} + u_{i,t} \tag{3}$$

where Y_t is a k-dimensional vector of possible cointegrating variables. The likelihood ratio trace statistics and the maximum eigenvalue statistics are two methods proposed to evaluate the presence of cointegration in non-stationary time series. Based on Fisher's method described in (3), Maddala and Wu (1999) offer a panel alternative to Johansen's (1988) univariate case.

Another test commonly used for testing cointegration is Kao residual panel cointegration test. According to Barbieri (2008), in the case where cointegration vectors are homogeneous between individuals, Kao (1999) presents Dickey-Fuller (DF) and augmented Dickey-Fuller (ADF) (Dickey & Fuller, 1981) type tests for the null hypothesis of no cointegration in panel data. Furthermore, the long-run covariance matrix is expected to be the same across individuals. Under the alternative hypothesis, these tests do not allow for heterogeneity and thus cannot be used on a bivariate system (Barbieri, 2008).

If the variables are cointegrated, at least one directional causal link exists. In panel models, the Granger causality can be utilized to determine the direction of causality. The Granger causality test can identify short-run causation by doing a joint test of the coefficients based on F-statistics and the χ^2 test. On the other hand, long-run causal relations can be investigated using the lagged error correction term in the vector error correction model based on the t-test. The following equations express the panel Granger causality:

$$\Delta CO_{2i,t} = \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^{l} \xi_{i,t} \Delta CO_{2i,t-1}$$
$$+ \sum_{i=1}^{l} \varphi_{i,t} \Delta GDP_{i,t-1} + \sum_{i=1}^{l} \theta_{i,t} \Delta EN_{i,t-1} \tag{4}$$
$$+ \sum_{i=1}^{l} \tau_{i,t} \Delta EMP_{i,t-1} + u_{i,t}$$

$$\Delta GDP_{i,t} = \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^{l} \xi_{i,t} \Delta GDP_{i,t-1}$$
$$+ \sum_{i=1}^{l} \varphi_{it} \Delta CO_{2i,t-1} + \sum_{i=1}^{l} \theta_{i,t} \Delta EN_{i,t-1} \tag{5}$$
$$+ \sum_{i=1}^{l} \tau_{i,t} \Delta EMP_{i,t-1} + u_{i,t}$$

$$\Delta EN_{i,t} = \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^{l} \xi_{i,t} \Delta EN_{i,t-1}$$
$$+ \sum_{i=1}^{l} \varphi_{i,t} \Delta CO_{2i,t-1} + \sum_{i=1}^{l} \theta_{i,t} \Delta GDP_{i,t-1} \tag{6}$$
$$+ \sum_{i=1}^{l} \tau_{i,t} \Delta EMP_{i,t-1} + u_{i,t}$$

$$\Delta EMP_{i,t} = \alpha_{i,t} + \beta_{i,t} ect_{i,t-1} + \sum_{i=1}^{l} \xi_{i,t} \Delta EMP_{i,t-1}$$
$$+ \sum_{i=1}^{l} \varphi_{i,t} \Delta CO_{2i,t-1} + \sum_{i=1}^{l} \theta_{i,t} \Delta GDP_{i,t-1} \tag{7}$$
$$+ \sum_{i=1}^{l} \tau_{i,t} \Delta EN_{i,t-1} + u_{i,t}$$

where Δ is the first difference operator; $\alpha_{i,t}$ is a constant term; $\beta_{i,t}$, $\xi_{i,t}$, $\varphi_{i,t}$, $\theta_{i,t}$, 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.

Granger causality tests can only determine the direction of causal relationships between variables. Therefore, a variance decomposition analysis can assess the importance of one variable's causal effect on the other and estimate how each variable reacts to changes in the other variables (Wang et al. 2018). In other words, by decomposing the variance of forecast errors of each variable and identifying the amount of information in the variable explained by other variables, we can assess how much one variable contributes to the explanation of another variable. When a variable is mainly explained by itself, it is considered mostly exogenous. On the other hand, when other variables mostly explain a variable, it is mostly endogenous.

Results

As initial tests, the Pesaran CD, Pesaran scaled LM, and Breusch-Pagan LM tests are used to check for any cross-sectional dependence between the time series. Table 4 shows that the null hypothesis of no cross-section dependence (correlation) in weighted residuals is accepted, implying no cross-sectional dependency or correlation between time series.

It is necessary to establish the order of cointegration before testing for it. Four panel unit root tests are used to identify cointegration order: Levin, Lin, and Chu; Im,

Table 4 Residual cross-section dependence test

Test	Statistics
Breusch-Pagan LM	18.95348
Pesaran scaled LM	− 1.208892
Pesaran CD	− 0.604863

Source: Authors' calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 and 0.01; * denotes statistical significance between 0.01 and 0.05. There was non-zero cross-section means in the data. During the computation of correlations, cross-section means were removed.

panel long-run cointegration

Table 5 Panel unit root test results

Variable	Level	First difference
Levin, Lin, and Chu *t**		
CO_2	−1.62118	−10.4800***
GDP	−1.03303	−3.80679***
EN	−1.23806	−8.67717***
EMP	−0.30275	−3.36732***
Im, Pesaran, and Shin *W*-stat		
CO_2	−0.40149	−8.69562***
GDP	−0.63826	−3.38203***
EN	−0.80337	−8.83510***
EMP	0.01908	−3.85181***
ADF-Fisher chi-square		
CO_2	15.9862	88.5423***
GDP	18.7166	38.6897***
EN	18.2736	89.1221***
EMP	20.7717	42.9290***
PP-Fisher chi-square		
CO_2	15.4270	117.178***
GDP	7.98030	49.0872***
EN	17.8235	129.814***
EMP	3.66858	39.1004**

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

Pesaran, and Shin; ADF-Fisher; and PP-Fisher. The Levin, Lin, and Chu test assumes a common unit root process across all cross-sections, whereas the other three tests assume an individual unit root process across the cross-sections (Mitić et al. 2020). For all four tests, the null hypothesis is that there is a unit root, as opposed to the alternative hypothesis that there is not. Table 5 summarizes the findings of the unit root tests.

The findings of all four tests reveal that all of the variables are non-stationary at level but become stationary when converted to the first difference. We cannot reject the null hypothesis of a unit root at the 0.01% significance at level, but we can reject the null hypothesis of a unit root at the first difference. So, the variables (CO_2 emissions, GDP per capita, available energy, and employment) are integrated of order $1 - I(1)$. We proceed to test cointegration because all tests, under all assumptions, provide proof of non-stationarity at level and stationarity at the first difference.

Therefore, Table 6 displays the Johansen Fisher panel cointegration test results, which reveal that at least three cointegrated equations exist, indicating that all four variables are cointegrated. In other words, the Johansen Fisher panel

Table 6 Johansen Fisher panel cointegration test results

Null hypothesis: variables are not cointegrated

Hypothesized no. of CE(s)	Trace	Maximum eigenvalue
$r = 0$	204.0***	126.9***
$r \leq 1$	104.9***	83.51***
$r \leq 2$	40.74***	41.38***
$r \leq 3$	15.58	15.58

Source: Authors' calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 and 0.01; * denotes statistical significance between 0.01 and 0.05. *r* denotes the number of cointegrating equations. Lags interval (in first differences): 12. Probabilities are computed using asymptotic chi-square distribution.

cointegration test indicates a panel long-run cointegration relationship among the four variables. According to Pao and Tsai (2011), the possibility that the estimated relationships are spurious can be eliminated by confirming cointegration. These findings show that Granger causality exists, at least in one direction.

An additional test was performed to confirm the existence of cointegration further. We can strongly reject the null hypothesis of no cointegration based on the *p* value of the Kao cointegration test (Table 7).

A long-run link between CO_2 emissions, economic growth, available energy, and employment exists among the selected eight SEE countries. The vector error correction approach can be used to estimate the cointegrating coefficients of the variables since the Johansen Fisher and Kao cointegration tests show the long-run relationship between series in our model. Our results align with a study by Mitić et al. (2017) that examined the link between real GDP and CO_2 emissions in 17 transitional economies from 1997 to 2014. The findings indicate that CO_2 emissions and real

Table 7 Kao residual panel cointegration test results

Null hypothesis: no cointegration

	t-Statistic
ADF	−2.785527**

Source: Authors' calculation. Note: *** denotes statistical significance < 0.001; ** denotes statistical significance between 0.001 and 0.01; * denotes statistical significance between 0.01 and 0.05; automatic lag length selection based on SIC with a max lag of 5; Newey-West automatic bandwidth selection and Bartlett kernel.

Table 8 Panel causality analysis results

	Short-run Granger causality				Error correction	
	ΔCO_2	ΔGDP	ΔEN	ΔEMP	ECT (-1)	Coeff
ΔCO_2	–	2.990260	0.608424	7.267291**	-2.617641***	-0.008242
ΔGDP	3.398666	–	5.461007*	9.830709***	-3.466061***	-0.004075
ΔEN	0.172841	1.575736	–	4.695900*	-0.858443	-0.001867
ΔEMP	4.935031*	2.483439	6.975934**	–	3.319899***	0.003108

Source: Authors' calculation. Note: The *t*-statistic values 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 1 year.

Table 9 Variance decomposition results

Response variable	Period	Impulse variable			
		CO_2	GDP	EN	EMP
CO_2	5	97.06585	1.305831	0.068159	1.560155
GDP	5	21.70319	77.63355	0.070907	0.592360
EN	5	65.03794	10.39619	23.52452	1.041350
EMP	5	2.823273	20.13945	2.081321	74.95596

Source: Authors' calculation.

GDP have a statistically significant long-run cointegrating relationship.

The results of the vector error correction model are presented in Table 8. The results indicate a short-run bidirectional panel causality between CO_2 emissions and employment and between available energy and employment. Furthermore, a unidirectional causality from available energy and employment to GDP is also evident.

Furthermore, we examined the statistical significance of the coefficient on the lagged error correction term (ECT) in each equation to see if there was a long-term causal relationship between the variables. The statistically significant ECT coefficient confirms an error correction mechanism that drives the variables back to their long-run equilibrium. The findings demonstrate that the estimated coefficients of ECT in the CO_2 emissions, GDP, and employment equations are statistically significant, indicating that these three variables could play a vital role in the system's adjustment as it departs from long-run equilibrium. As a result, these three variables have bidirectional Granger causality links. In addition, the coefficient of lagged ECT is statistically insignificant in the case of available energy.

Finally, we used the variance decomposition method to compare the extent of the individual variables' contributions to each other. Results from the variance decomposition analysis are reported in Table 9.

Due to the number of observed years, we opted for a 5-year forecasting horizon. The results of this analysis revealed that 97.07% of the variation in CO_2 emissions could

be explained by shocks within the variable itself, whereas the respective contributions made by GDP (1.31%), available energy (0.07%), and employment (1.56%) to CO_2 emissions were low. The findings further suggest that 77.63% of the variation in economic growth, 23.52% of the variation in available energy, and 74.96% of the variation in employment can be explained by innovative shocks in these variables themselves.

We provide Fig. 2 to compare the extent of the contributions generated by the various variables to each other from year to year till year 5. In other words, it is a graphical representation of the variance decomposition, presenting year by year forecasting horizon of all four variables.

Overall, our results align with Chaabouni and Saidi (2017) and Dogan and Aslan (2017), who demonstrated a bidirectional relationship between CO_2 emissions and GDP growth for a panel of 51 countries and EU and candidate countries, respectively. Furthermore, Radmehr et al. (2021) proved a bidirectional causality between economic growth and CO_2 emissions for EU countries based on a spatial modeling analysis from 1995 to 2014. Radmehr et al. (2021) also demonstrated a positive association of labor force with GDP growth for many European countries but a negative association in Romania. Menegaki (2011) demonstrated the same bidirectional causality between GDP growth and CO_2 emissions for a panel of 27 EU countries and unidirectional causality from energy to GDP growth, while Dong et al. (2018) found the same bidirectional causality for European countries. Pejović et al. (2021) also align with our results, as they demonstrated a two-way causality between GDP growth and CO_2 emissions in the EU and Western Balkans countries.

Other authors investigating SEE or Balkans countries have reached similar results about causality between the variables. Mitić and Cvetanović (2018) demonstrated a positive bidirectional causal relationship between CO_2 emissions and GDP per capita in the short run, but only a unidirectional causality running from GDP per capita to CO_2 emissions in the long run. Obradović and Lojanica (2017) indicated a long-term causal relationship between CO_2 emissions and economic growth. However, they found no connection

Fig. 2 Variance decomposition year by year results. Source: Authors' calculation
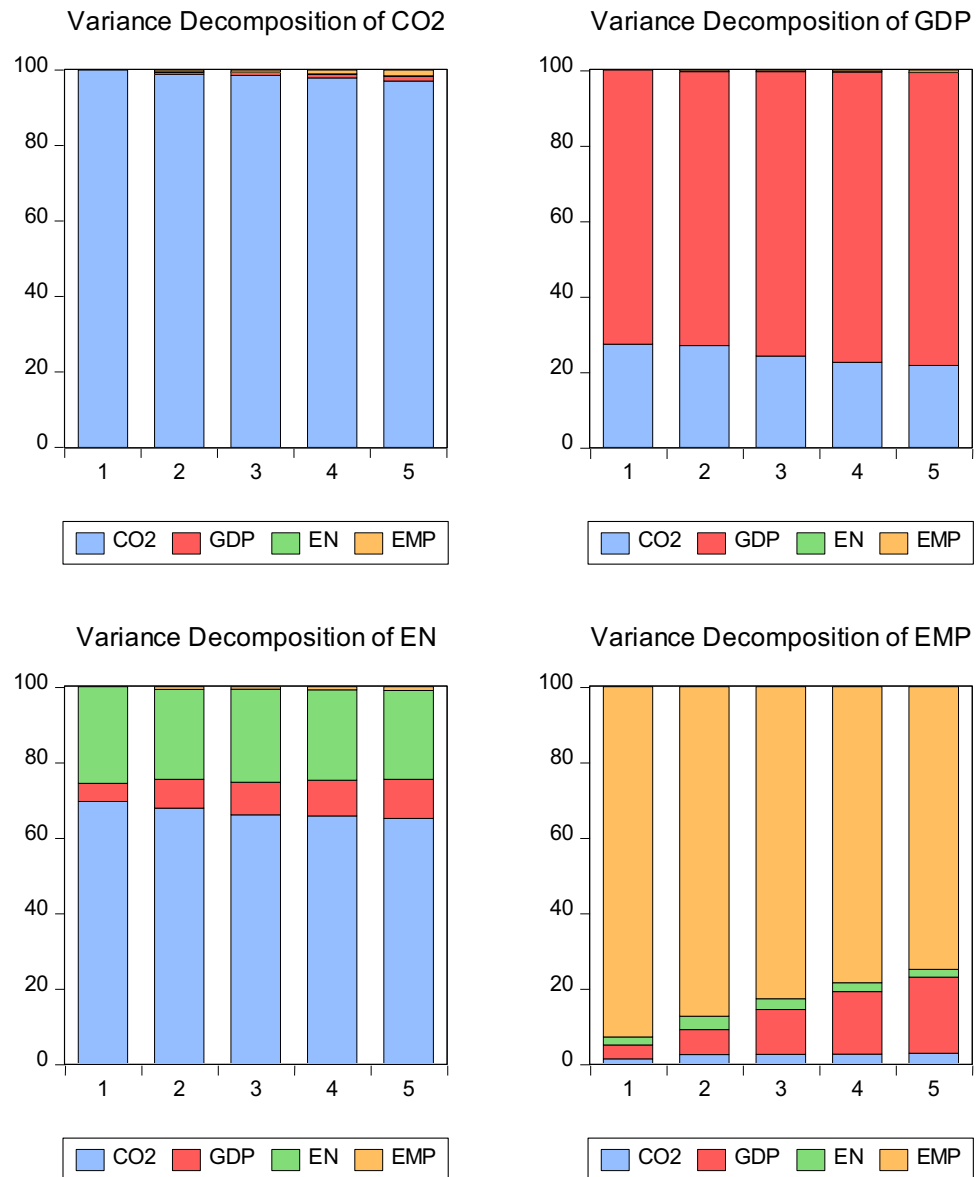
between energy and economic growth in the short run, neither in Greece nor Bulgaria. Armeanu et al. (2019) proved the short-run causality for CEE countries' energy consumption, CO_2 emissions, and GDP growth.

The obtained results suggesting no long-run causality between total gross available energy and the remaining variables can be explained by the findings of Fragkos and Paroussos (2018). They suggested that intensive usage of RES can positively impact the GDP and employment growth while reducing CO_2 emissions. SEE countries have yet to fully realize their potential in energy production from renewable energy sources, and reliance on fossil fuels does not contribute to increased energy availability or employment but increases CO_2 emissions. These results can also be explained by low energy efficiency, as Li et al. (2020) suggested. The energy efficiency in

SEE economies is still relatively low, leading to increased CO_2 emissions due to GDP growth.

Discussion and policy implications

The research on the relationships between CO_2 emissions, economic growth, available energy, and employment variables has resulted in different policy implications since it can guide regional policymakers in advancing sustainable development strategies. When developing policies to reduce CO_2 emissions, more attention should be made to the indirect employment repercussions across the entire industry chain, the induced impacts from changes in consumer consumption and income, and the direct employment impacts on the industry itself. Industrial strategies should be compatible

with employment policy to avoid potential labor market shocks resulting from industrial restructuring. Strengthening industrial chain cooperation and achieving interconnected industrial development would be critical for employment creation. Furthermore, the service sector makes a considerable contribution to job generation. Effective service sector growth promotes low-carbon industrial development while simultaneously resolving the problem of rural excess labor transfer. Significant efforts should also be made to support the development of new strategic low-carbon sectors, such as new and renewable energy, as well as to adapt and improve the energy mix while simultaneously speeding up the reorganization and upgrading of traditional industries.

Because SEE infrastructure is obsolete, significant investments in the growth of the renewable energy sector, which will also create jobs, are required. Energy policies aimed at increasing renewable energy generation and use will reduce these economies' reliance on energy-supplying countries while lowering CO_2 emissions. Because long-term success cannot be achieved by pursuing economic growth at the expense of the environment, SEE countries should employ subsidies and other measures to encourage "green" FDI into technology-intensive industries. Also, supporting research and development activity through public–private partnerships could be a good solution to decrease the cost of renewable energy sources. They should also impose or raise carbon taxes, enact new, sturdier rules, properly implement existing regulations, embrace the EU environmental standards for countries seeking to join, and shift to renewable energy sources. Policies to boost carbon efficiency and create green jobs must be supplemented with taxation policies. Developing economies can advance toward a sustainable green growth path with more employment by harmonizing climate change mitigation measures with a more rational tax structure on labor markets and macroeconomic policies to boost employment in green production activities.

Energy trade in the region is complicated and low due to still immature tariff structures, inadequate infrastructure, and a history of conflicts. As a result, SEE countries must cooperate regionally, integrate their energy systems, and harmonize their legislation. In order to improve supply security, economic efficiency, and the increased use of renewable energy sources, a single energy system might be a good solution to consider. In addition to participating in supranational energy distribution networks that are either existing or planned for the region, SEE economies should also enhance their natural resource exploitation potential.

Public policies aiming at reforming national economies and increasing energy efficiency will help boost the economic productivity of the energy utilized in the economy while reducing the environmental impact. These policies will require a mix of energy policy instruments (such as tax measures, financial and investment preferences, and appropriate training of new and retrained personnel) that will make energy consumption more efficient, productive, and environmentally friendly in all sectors of the economy. If the outcome of such policies will be a reduction in energy consumption, the ensuing energy savings should be redirected toward solving social concerns.

Given that the economy's structural transformation is environmentally damaging, it is reasonable to assume that economic activities will shift from heavy manufacturing to service-oriented activities. This shift will benefit the economy by providing more jobs while allowing companies to benefit from increased energy efficiency brought on by technology developments. Therefore, these countries will be able to produce green jobs in this situation, and service-oriented businesses will be able to advance in spreading renewable energy solutions as time goes on. Policymakers might use the financialization channels to promote this dispersion by offering low-cost loans or interest rate holidays to these businesses, ensuring that the high cost of implementation does not stifle their growth. As a result, countries will increase demand for renewable energy solutions and more jobs.

The lack of understanding among the management structure of the necessity to invest in the modernization of industrial processes and the high cost of modernization is a difficulty that the entire region faces. Nonetheless, governments and managers should agree that investing in new technical solutions is essential. Furthermore, state-owned enterprises may take advantage of their political or monopoly status and, to an extent, ignore environmental and other forms of legislation. The role of labor unions should also be reconsidered. In order to structurally restructure the workplace, long-term policies will require a joint effort from both companies and unions. Given the current climate crisis, there is no better moment than now to implement a comprehensive set of policies to ensure a sustainable future.

Conclusion

The world was in economic crisis again, nearly 15 years after the global financial crisis. This time, the cause of the crisis was the global COVID-19 pandemic, which had a different impact on the economy than the global financial crisis. Aside from economic concerns, many social and environmental problems arise, confronting policymakers with many challenging issues. Furthermore, as the Russian-Ukrainian conflict escalates, more challenges will emerge.

Research on the interdependence of environmental degradation, economic growth, employment, and energy availability in SEE countries is necessary because it raises awareness about how these countries can achieve sustainable development in the face of the frequent economic, political,

and social crises that have emerged in the new millennium. These countries also have specific features that make them more interesting for research. Specifically, the transition process brought to light the widespread environmental pollution in these countries throughout the central planning period. Before their economic reforms, a legacy of industrial inefficiencies, obsolete and polluting technology, and poor environmental management and legislation aggravated the region's environmental problems.

This research establishes the link between CO_2 emissions, GDP per capita, total gross available energy, and employment rate in South-Eastern European countries. We opted for these countries as they are underrepresented in the literature. We applied the panel unit root test and then checked for cointegration using the Johansen and Kao panel cointegration test. Then we applied a panel VECM to investigate the interactions between these variables' short-run and long-run dynamics, finishing with the variance decomposition. This research pointed to a short-run unidirectional causality from available energy and employment to GDP and a short-run bidirectional panel causality between CO_2 emissions and employment and available energy and employment. The findings further demonstrate bidirectional Granger causality relationships between CO_2 emissions, GDP, and employment, indicating that these three variables may play a key role in the system's adjustment as it drifts from long-run equilibrium. We have found no causality between those three variables and total gross available energy. The variance decomposition analysis revealed that 97.07% of the variation in CO_2 emissions could be justified by shocks within the variable itself, whereas the contributions made by GDP, available energy, and employment to CO_2 emissions were low.

Numerous theoretical and practical implications of this study can be derived from the specifics of the research and the results. In terms of theoretical implications, it will contribute to the literature in this important research area, especially to other researchers who may find it valuable for further research of the situation in the SEE region, which is underrepresented in the existing literature. Moreover, it can motivate other researchers to focus on this region, which is increasingly important in determining the EU energy policy in light of current geopolitical circumstances. Generally observed, understanding the relationship between economic growth, employment, energy availability, and the environmental impacts of economic activities is critical for developing policies that would lift people and countries out of poverty while avoiding irreparable environmental damage and depletion of energy resources. Regarding practical implications, this study suggests that industrial policies should be coherent with employment policies to avoid potential labor market

shocks resulting from industrial restructuring. Strengthening industrial chain cooperation and achieving interconnected industrial development would be critical for employment creation. Efforts should be made to promote the development of new low-carbon strategic sectors, such as new and renewable energy, and adapt and improve the energy mix. Because SEE infrastructure is outdated, significant investments in the growth of the renewable energy sector are required, creating jobs. CO_2 emissions will be reduced by energy policies that increase renewable energy generation and use. By coordinating climate change mitigation efforts, SEE countries may progress toward a sustainable green path with more jobs.

Energy efficiency measures will necessitate a combination of energy policy instruments to make energy consumption more efficient, productive, and ecologically benign. It is realistic to expect a transition from heavy manufacturing to service-oriented industries. This transition will help the economy by creating more jobs while also helping businesses to save money on energy. As a result, countries' desire for renewable energy solutions will rise, creating more jobs.

This study's primary limitation is the non-availability of data with long enough time horizons for some indicators influencing CO_2 emissions and economic growth. Be that as it may, including more explanatory variables in this type of analysis could guide further research. Among the exogenous variables, we can include FDI, globalization index, and urbanization because many previous researchers demonstrated the significant impact of these variables on carbon emissions and economic activity. One of the limitations is also neglecting the differences in development levels of the observed countries and differentiating the energy from renewable and non-renewable sources. Another direction for further research could be represented by testing the EKC curve for this panel of countries to see how different economic development stages could impact pollution in South-Eastern Europe, as some of these countries were less investigated in previous studies. It would also be interesting to study the impact of both non-renewable and renewable energy on carbon emissions for this group of countries separately.

Availability of data and materials Not applicable.

Declarations

Ethics approval and consent to participate. Not applicable.

Consent for publication. Not applicable.

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