

Potential of renewable energy and natural resources for sustainable economic growth and carbon neutrality

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Abstract: *The need for carbon neutrality is one of the main challenges of climate policies. This concept aims to reduce carbon emissions to zero, using clean energy and other measures that reduce humanity's impact on climate change. The study aims to examine the relationships between renewable energy consumption, broad money, urbanization and natural resources and their effects on carbon dioxide emissions for sustainable economic growth in Southeast European countries. The study uses secondary data covering 15 years, 2008-2022. The data is a panel that was taken from the World Bank database. Data processing and analysis were performed using STATA software, using econometric models such as OLS, fixed effects, random effects and the Hausman-Taylor method as the most appropriate approach for analyzing panel data. According to the study results, renewable energy consumption negatively impacts carbon dioxide emissions at a significant level equal to 10%. Therefore, this indicates that the environment becomes cleaner relative to the rate at which the consumption of renewable energy increases. At the same time, one of the possible implications that emerges from the study is the positive relationship of natural resources with the emission of carbon dioxide for the study countries.*

Keywords: *Renewable energy, natural resources, carbon neutrality, panel data*

JEL Classification: *Q50, Q57, C23*

ARTICLE HISTORY

Submitted: 30.10.2024.

Resubmitted: 08.01.2025.

Resubmitted: 04.03.2025.

Accepted: 05.03.2025

Introduction

Even the countries of Southeast Europe, like any other country in the world, are facing environmental pollution, pollution that, according to many studies, comes mainly from high industrialization. These countries are mainly characterized by positive economic growth and have different development histories, including transitional phases that many of these countries go through. The economic growth of countries is focused on economic development, but without emphasizing growth while maintaining the quality of the environment. The need for carbon neutrality is one of the main challenges of climate policies all over the world, including in Southeast Europe. This concept aims to reduce carbon emissions to zero, using clean energy and other measures that reduce humanity's impact on climate change. The countries of the Southeast European region have a lot of potential to benefit from the transition towards carbon neutrality. These countries are included in the European Union's strategies to achieve the climate goals set out in the Paris Agreement and other international agreements on climate change.

Strategies to achieve carbon neutrality in these countries include investing in REN, more efficient use of energy resources, reducing dependence on fossil fuels, and improving EE in various sectors of the economy. Ren can be a very important factor in reducing CO₂ emissions and air/ environment pollution (Gollopeni, 2020). Different world reports show different values for the use of primary energy. In 2050, energy use in the world is projected to rise to 800 EJ or more, and a projection for the year 2100 predicts levels as high as 1,740 EJ could occur according to (Moriarty and Honnery, 2012). As for the relationship between energy and EG, various studies show that energy and EG have different ratios to each other. Jain et al. (2023) Point out that European high-income economies support the lack of link between energy consumption and growth. While Chen et al. (2022) show that EG increases the level of energy use, indicating a positive relationship between energy and growth. "High-income countries" produce more pollution and "low- and middle-income countries" produce less pollution (Al Mamun et al., 2014). Even broad money shows an important indicator towards the increase in carbon emissions, Broad money is an important indicator of the increase in CE and reflects the monetary supply in the economy and catalyzes growth and economic development; nevertheless, it does not account for environmental factors, leading to potential adverse effects on pollution levels in the living environment. ES is mainly related to the use of various natural resources for economic activity (Abbasi et al., 2021). The importance of NS to offset energy demands for sustainable development is widely accepted (Sharif et al., 2023).

The research questions are:

1. How does the use of REN compare to traditional energy sources in terms of its effects?
2. What are the economic benefits of using REN?
3. Does the use of REN affect carbon neutralization?

The study continues with the literature review chapter in which the hypotheses of the study are also included, and then the methodology of the study is included after the methodology comes the empirical results of the study, and then the discussions and conclusions of the study.

Literature review

The process of reducing or eliminating carbon dioxide emissions helps us to reduce the negative impact on the environment and achieve carbon neutrality. After the conclusion of the "Paris

Climate Conference (COP21)", many countries are starting to progress towards carbon neutrality goals (Shan et al., 2021). On the other hand, renewable energy creates very few greenhouse gases during energy production and helps to neutralize carbon. Numerous studies have measured how the REC helps to reduce CO₂. The study by Kong et al. (2022) for the period 1996 to 2018 found that government effectiveness and REN bring carbon neutrality closer but EC slows it down. If RES are used effectively on the path to energy use, reductions in greenhouse gas emissions are possible (Zhou et al., 2023). EG is also accompanied by an increase in CO₂-emissions, while the use of REN significantly reduces CE, according to a study by (Raihan, 2023) for the period 1990 to 2021. Yuan et al. (2022) in their study showed the role of REN in reducing GE-emissions and found that the negative impact of REN on CO indicates that the substitute role of renewable energy has become increasingly important to contribute successfully towards the reduction of CO₂ emissions.

The study conducted for 27 OECD countries for the period 2001-2020 by (Işık, et al., 2024) shows a negative link with the REC and the emission of CO₂. Using regression analysis with panel data for South Asian countries, the study by Khan et al. (2024) shows that the REC hurts CO₂ emissions while the rental of NR has a positive impact on EG and emission of carbon dioxide. The study conducted for five countries of the EU by (Balsalobre-Lorente et al., 2018) shows that the consumption of electricity from renewable sources, natural resources and energy innovation improves environmental quality. Study by Alvarez-Herranz et al. (2017) confirms that in OECD countries for the period 1990-2012, renewable energy sources help improve air quality. The connection between renewable energy, EG and ED has also been investigated by authors such as (Aydoğan et al., 2020) show that there is a positive relationship between CO₂ emissions and REC in the long-term, but a negative relationship between CO₂ emissions and REC in the short term, Yao et al. (2019) found that the negative impact of RE on CO₂ shows that the replacement role of RE has become increasingly important in contributing to the realization of the reduction of carbon emissions.

Also, many researchers have shown the impact of REC and CO₂ emissions on EG towards SG. The study by Dilanchiev et al. (2024) investigated the link between REN use, EG and CO₂ in South Caucasus countries, shows that the results of the causality analysis disclose a two-way causality relationship between growth and REC. Analyzing the impact of REC and environmental quality on EG for 30 developing countries, the study by Satrianto et al. (2024) shows that REN and environmental quality significantly affect economic growth. The study by Hidayat et al. (2024) for ASEAN countries shows that the emission of CO₂ does not have a statistically significant impact on EG, while REN and NR show a significant positive impact. The study by Wang et al., (2023) investigated the relationship between resource rents and environmental sustainability and found that oil and gas rents have long-term positive effects on CO₂- emissions.

Prior studies have focused on the significance of REN and NR in alleviating or exacerbating CO₂-emissions. Nevertheless, there are limited studies that investigate the sensitivity of these characteristics in Southeastern European nations. This creates a void in the literature. The study seeks to enhance the current literature by delivering empirical analysis of these correlations and elucidating the influence of these factors on carbon dioxide emissions. Consequently, we formulated hypotheses.

The research hypotheses include the following:

H1: REN has a positive effect on CO neutralization for the countries of Southeast Europe.

H2: REN has a positive effect on EG for the countries of Southeast Europe.

Hypotheses are tested through econometric methods such as the "method of least squares", "the method of FE", "and the method of RE "and" the Hausman Taylor method".

Methodology

The study was analyzed with secondary data which were taken from the WB database and are considered the most accurate data. The countries included in the study are the eight countries of Southeast Europe, which are: Albania, North Macedonia, Greece, Bulgaria, Croatia, Bosnia and Herzegovina, Montenegro and Serbia. Due to the lack of data, Kosovo was not included in the study. The study period is 15 years, from 2008 to 2022. The period is determined based on the data for the study variables. The study analyzes the relationship between the REC, BM, NR and their effects on CE and economic development in Southeast European countries. So, to explain this relationship, the analysis is based on 5 variables. Carbon dioxide emissions will be used as the DV, while the other four dependent variables are: REC, BM, total NR rents, and EG. The interpretation of econometric results and the verification of hypotheses is done through econometric models starting with descriptive analysis of variables, correlation analysis, and linear regression, methods with RE, methods with FE, and the Hausman Taylor method as the most advanced method to solve the problem of endogeneity. The Hausman test determined the Hausman-Taylor model as the most appropriate to proceed with the interpretation of the results.

Data Analysis

In the part of models and data analysis procedure, we will start with the presentation of the econometric model. The Hausman Taylor Method. In the first model, we analyzed the impact of REC on CO₂ emissions.

So the econometric model shows us that the dependent variable Y (carbon dioxide emission) is expressed as a function of the independent variables:

$$Y=f(X_1, X_2\dots X_n) + \varepsilon \quad (1)$$

Where ε denotes the normal distribution.

$$CO_2=f(REC, NR, BM, GDP)$$

The form of the econometric model:

$$CO_{2it} = B_0 + B_1 REC_{it} + B_2 NR_{it} + B_3 BM_{it} + B_4 GDP + Y_{it}$$

Y is the dependent variable, B_0 is the intercept term (the value of Y when X = 0). The coefficients (B_1, B_2, B_3, B_4) show the relationship between each independent variable and CO₂ emissions. Y_{it} : This is the error term that accounts for unobserved factors that affect CO₂ emissions for individual i at time t . Typically, this includes factors not covered by explanatory variables (REC, NR, BM, GDP).

In the second model, the Random Effect Method, the impact of CO₂ emissions and REC on EG will be analyzed. In the second econometric model, the dependent variable Y (EG) is expressed as a function of the independent variables and the form of the model:

$$GDP = \beta_0 + \beta(CO_2) + \beta(REC) + \beta(NR) + \beta(BM) + \mu_i$$

Table no 1 -Definition of variables

| -Definition- | -Variable- | -The measure- | -Source- |
|-------------------------------|-------------------|---|-----------------|
| Carbon dioxide emissions | (CO2) | CO2 emissions (kt) | WB |
| Renewable energy consumption. | (REC) | Renewable energy consumption (% of total final energy consumption). | WB |
| Natural resources | (NR) | Total natural resources rents (% of GDP). | WB |
| Broad money | (BM) | Broad money (% of GDP) | WB |
| Economic growth | (GDP) | GDP growth (annual %) | WB |

Source: World Bank

CO2-emissions are those that flow from the burning of fossil fuels and the production of cement. They include CO2 produced during the consumption of solid, liquid and gaseous fuels and the flaring of gas. REC is the share of REN in total final energy consumption. Natural Resources (NR) - Total rent from NR is the sum of rents from oil, natural gas, coal (hard and soft), minerals and forests. Broad money (BM) is the amount of currency outside banks, long-term deposits other than those of the central government, time deposits, savings deposits and foreign currency deposits of resident sectors other than the central government, bank and traveler's checks, as well as other securities such as certificates of deposit and commercial letters of credit. Economic growth (GDP) shows the annual percentage growth rate of GDP at market prices, based on unchanged local currency.

Table 2. Descriptive statistics

| Variable | Obs | Mean | Std. Dev. | Min | Max |
|-----------------|------------|-------------|------------------|------------|------------|
| CO2 | 104 | 27255.29 | 24293.354 | 1747.5 | 100405.6 |
| REC | 104 | 25.92 | 10.674 | 8.32 | 49.34 |
| NR | 126 | 1.147 | .846 | .039 | 3.638 |
| BM | 119 | 118.074 | 157.697 | 34.113 | 647.638 |
| GDP | 134 | 2.007 | 4.234 | -15.307 | 13.785 |

Source: STATA author's calculation (WB)

Based on the descriptive statistics presented in the table above, the emission of carbon dioxide for the countries of Southeast Europe has an average of 27255.29 kt. Analyzing the CO2 emission data for the countries of the study, we see that in recent years there has been a decrease in emissions in all these countries, and from this we can see an effort by the countries of Southeast Europe to neutralize the emission of carbon dioxide. Economic growth has an average value of 2.00 for this period, considering the inclusion of two major crises that were included during the years of the study, i.e. the crisis of 2008 and the crisis of 2020 caused by the Covid 19 Pandemic and we see that all the study countries suffered high economic losses. Natural resources include an average of 1.14, REN reaches an average of 25.92 and this shows that these countries are on the right track of using renewable energy. Broad money averages 118.07.

Results

Table 3. Matrix of correlation

| Variables | CO2_Log_lag | REC | NR | BM | GDP |
|-------------|-------------|--------|--------|--------|-------|
| CO2_Log_lag | 1.000 | | | | |
| REC | -0.773 | 1.000 | | | |
| NR | 0.104 | -0.100 | 1.000 | | |
| BM | 0.117 | 0.130 | -0.241 | 1.000 | |
| GDP | -0.052 | -0.022 | 0.114 | -0.194 | 1.000 |

Source: STATA author's calculation (WB)

Correlation analysis shows a positive relationship between NR and CO2 emissions, broad money, and CO2 emissions, while there is a negative impact between REN and CO2 emissions and EGh and CO2 emissions. The following table presents the results of four econometric models.

Table 4. Econometric models of the impact of REN on CO2 emissions (First model)

| Variables | OLS "Coef./ t-stat." | FE "Coef./ t-stat." | RE "Coef./ t-stat." | THT "Coef./ t-stat." |
|-------------|-------------------------|------------------------|------------------------|-------------------------|
| REC | -0.0801*** -12.50 | -0.00649** -2.66 | 0.00810** -2.95 | -0.00600** -2.64 |
| NR | 0.122 1.42 | 0.0240 1.57 | 0.0214 1.24 | 0.0231 1.60 |
| BM | 0.00145*** 3.53 | -0.000416 -0.74 | -0.0000900 -0.16 | 0.000245 0.48 |
| GDP | -0.0105 -0.54 | 0.00347 1.34 | 0.00366 1.25 | 0.00775** 2.96 |
| CO2_Log_lag | | | | 0.412*** 4.28 |
| ID | | | | -0.00690 -0.08 |
| _cons | 11.35*** 47.25 | 9.677*** 95.31 | 9.681*** 42.53 | 5.693*** 5.34 |
| N | 91 | 91 | 91 | 84 |

"Notes: ***Statistically significant at 1% level, **statistically significant at 5% level, *statistically significant at 10% level"

The four econometric-models were executed for the interpretation of the results, which are: “OLS”, “FE”, “RE” and the Hausman-Taylor method. Naturally, the Hausman test was used to determine the most adequate method. The result of the Hausman test between the model with FE and the model with regular effects is $P=0.000$, which means that the H_0 should be rejected and therefore the method with fixed effects is chosen for interpretation, while the Hausman test between the method with FE and the Hausman Taylor method gives the result $P=0.000$, which means that the H_0 is accepted and the Hausman Taylor method is chosen for interpretation, also as more adequate considering its advantages to handle the endogeneity of the variables. The results show that EG positively impacts CO2 emissions with a coefficient $B=0.007$ and shows a level of statistical significance of 10%. So 1% EG affects the increase in CO2 emissions by 0.007 kt on average, showing us that EG is positively affecting environmental degradation. A positive impact is also shown by NR with the emission of carbon dioxide, but they do not show a statistically significant level. Also, there is a positive but statistically insignificant effect between BM and CO2-emissions.

Table 5. Econometric models of the impact of REN on EG (Second model)

| GDP_lag | -Coef.- | -St.Err- | t-v | p-v | -[95% Conf | Interval]- | -Sig- |
|-----------------------------|---------|----------|------------------------|------|---------------|------------|-------|
| CO2_Log | -3.597 | 3.37 | -1.07 | .289 | -10.305 | 3.111 | |
| REC | .208 | .077 | -2.71 | .008 | -.361 | -.055 | *** |
| NR | -1.617 | .462 | -3.50 | .001 | -2.537 | -.698 | *** |
| BM | -.008 | .017 | -0.51 | .611 | -.042 | .025 | |
| Constant | 45.329 | 32.946 | 1.38 | .173 | -20.249 | 110.908 | |
| Mean D var | 2.238 | | “SD dependent var” | | 2.591 | | |
| R² | 0.167 | | “Number of obs” | | 90 | | |
| “F-test” | 3.971 | | “Prob > F” | | 0.000 | | |
| “Akaike crit. (AIC)” | 411.951 | | “Bayesian crit. (BIC)” | | 424.451 | | |

Notes: “***Statistically significant at 1% level, **statistically significant at 5% level, *statistically significant at 10% level”.

The second econometric model will be interpreted with the RE model based on the results of the Haus-test. REN has a positive impact on EG with a coefficient of 0.208 and a significance level of 1%. NR have a negative impact on EG with a coefficient (0.167) and also show a significance level of 1%, the study by (Golopeni, K. S., & Alili, H. A., 2023) also shows a significant impact at the 5% level. Carbon dioxide and broad money show a negative impact on EG, but without showing a level of significance. To verify the reliability of the variables, the VIF method was used, which in our study turns out to be $VIF=1.08$, which means that there is no multicollinearity in the study variables.

Discussion

The study aimed to evaluate the importance of REC in carbon neutralization and economic growth for the countries of South-Eastern Europe. Some studies showed that the REC is the most acceptable method to decrease CO2-emissions and in this way influence economic growth

without damaging the environment. From the empirical analysis, we understood that the REC has a negative effect on CO₂-emissions. And also the econometric results showed us that the REC has a positive effect on EG for the countries of Southeast Europe. The first hypothesis raised is that REN has a positive effect on carbon neutralization for the countries of Southeast Europe. From the econometric results, we accept H1. The results also show in line with the results of other authors such as Baloch et al. (2023), for the period 2000-2019 shows that REN has influenced sustainable development. Kostakis et al. (2023) conducted a study for OECD-countries for the period 2014 to 2019, showing that REN contributes positively to sustainable socioeconomic development. The study by Bilalli et al. (2024) for nine developed EU countries for the period 2002-2019 verifies that the REC affects the reduction of CO₂-emissions. The negative impact of REN on CO₂-emissions is also shown by the study by (Amin, 2023). Qing et al. (2024) states that to achieve sustainable growth it is important for countries to invest in REN and green financing. Green finance is part of a larger effort to address environmental challenges and build a more sustainable future (Gollopeni et al., 2024). Beka et al. (2024) in their study show that investments in SE sources increase EG and demonstrate the importance of REN in sustainable development. These investments reduce dependence on fossil fuels, reduce GHG-emissions, and contribute to long-term economic stability and environmental health. Results show that REN has a positive and statistically significant impact on EG, while in addition, a negative impact of carbon dioxide emissions on EG is shown. The second hypothesis raised: REN has a positive effect on EG for the countries of Southeast Europe. From the econometric results, we accept H2. Our results are also consistent with the results of other authors, such as (Inglese-Lotz, 2016) who in his study showed that the consumption of REN positively affects EG and in this way shows that the promotion of renewable energy brings benefits not only for the environmental, as well as economic conditions. The study conducted for 28 countries of the EU for the year from 1995-2015 by Soava et al. (2018) shows the same, which shows a positive and significant impact of the consumption of REN on EG. While the study by Khan et al. (2022) shows that economic growth increases CO₂-emissions, and in this way they recommend the consumption of REN to improve environmental quality by reducing CO₂-emissions and achieving carbon neutrality.

Conclusion

The study analyzes and verifies that the REC has a positive effect on the EG of the countries of Southeast Europe for the period 2008-2022 using panel data and analyzed through statistical methods and at the same time has a negative effect on the CO₂ emission. The results show that EG contributes to increasing CO₂ emissions, while REN helps to reduce them. Natural resources and broad money have positive, but not statistically significant, impacts on CO₂ emissions. Also, the results show that REN has a positive and significant impact on EG, while natural resources have a negative and significant impact on EG. The effects of carbon dioxide and broad money are negative but not statistically significant for EG. And as a conclusion, countries should focus on increasing the REC for a cleaner environment and sustainable EG.

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