INVESTIGATING THE RELATIONSHIP BETWEEN RENEWABLE ENERGY, CARBON EMISSIONS AND GREEN GDP (CASE OF NORTH MACEDONIA)

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ABSTRACT

Energy production, distribution, and consumption, while necessary for economies to keep running, unfortunately, put pressure on the environment. The pressures differ, depending on how energy is produced and consumed, but this poses a big challenge in achieving sustainable development goals and sustainable economic development since most of the patterns of energy supply and use are unsustainable. Energy-related environmental pressures, such as air pollution and global warming mainly depend on the energy sources and quantity of energy used. Approaches to reduce energy-related environmental challenges include using less energy, lowering the demand for energy-related activities, using energy more efficiently, or switching to renewable energy sources.

North Macedonia even though it primarily relies on non-renewable energy sources, during the analyzed period has made slight improvements to increase its renewable energy sources. This paper analyzes the relationship between three indicators (Renewable energy supply as % of total supply, annual CO2 emissions, and green GDP) using correlation and regression models. The results confirm that there is a moderate negative relationship between renewable energy sources and annual CO2 emissions and a very strong negative relationship between annual CO2 emissions and green GDP. Given that North Macedonia increases its renewable energy supply by 1% (with respect to its total energy supply), the annual carbon emissions would fall by 0.4 million tons, which in turn would positively impact green GDP.

KEYWORDS

emissions, energy, renewable, green GDP

JEL CLASSIFICATION CODES

Q42

1. INTRODUCTION

Although essential for economies to function, the production, supply, distribution, and consumption of energy put pressure on the environment. It is quite interesting to analyze and examine the relationship between these factors, the renewable energy sources, carbon emissions, and Green GDP since the findings provide important insight into whether a country or economy is developing and if this economic development is sustainable. Cutting down CO2 emissions is possible when countries start to rely on renewable energy sources

like wind, hydropower, and solar energy, which would replace unsustainable energy sources like fossil fuels. Unlike using fossil fuels, relying on renewable energy technologies would allow a country to create energy without emitting greenhouse gasses. By shifting and increasing the reliance on renewable energy sources, the emissions will be significantly reduced which is very crucial in the fight against climate change.

Authors have examined the relationship between renewable energy sources and carbon emissions, as well as the relationship between carbon emissions and economic growth, however, this research takes a step further and investigates how the increasing the renewable energy supplied affects the carbon emissions, which in turn affects green GDP. This study provides important information about the relationship between these indicators and how much the variations in the green GDP can be explained by renewable energy supplied and carbon emissions in North Macedonia.

During the analyzed period 1990-2019, North Macedonia has seen relatively positive progress in all three indicators. It has increased the energy supplied from renewable sources (as % of total energy supplied), and has an increasing trend in the green GDP, while at the same time has managed to decrease the annual CO2 emissions. Recording an increase in the green GDP, while maintaining similar levels or even managing to reduce annual CO2 emissions is a good sign for a country to make progress towards greener growth.

2. LITERATURE REVIEW

A lot of authors and researchers have analyzed renewable energy sources and how they affect carbon emissions, and economic growth. However, this research will contribute to the existing literature, since the indicator for measuring economic growth is the Green GDP indicator. Green GDP is the traditional GDP adjusted for social and environmental costs that come as a result of production in a country. Taking into consideration these costs offer a better perspective on whether a country is making progress toward sustainable economic growth, and authors should further explore this topic since it can give important insights into what positively or negatively influences the path towards a greener economy and a greener growth. Authors have proved that there exists a significant relationship between renewable energy, carbon emissions, and economic growth.

Voumik, (et. Al, 2023) when investigating the co2 emissions from renewable and non-renewable energy sources in G7 countries found the most harmful way of energy production is from coal, and oil, which contribute significantly to the release of co2 emissions and other gases, while renewable energy sources emit far less carbon and other harmful gases. Their research further supports the idea that renewable energy production can reduce carbon emissions.

Chen (et al, 2022), analyzed Asian economies from 1992 until 2018 using a variety of analytical techniques, such as heterogeneous panel analysis and panel cointegration analysis, and discovered that renewable energy sources have a significant impact on economic growth. Furthermore, economies gain from using renewable energy sources in two different ways. Firstly, using renewable energy sources significantly reduces carbon emissions, and secondly, this will accelerate economic growth.

Szetela (et al, 2022) when analyzing the relationship between renewable energy and CO2 emissions in 43 most natural resource-depending on countries, using OLS fixed effects generalized least square methods found that renewable energy consumption can reduce CO2 emissions and that a 1% increase in renewable energy consumption leads to 1.25% decrease in CO2 per capita.

Similarly, (Petruska, et.al, 2022) found that increasing the renewable energy sources results in a significant decrease in CO2 emissions when analyzing 22 EU countries. Majewski et. al (2022), investigated the relationship between renewable energy and CO2 emissions, in 94 countries and found that renewable energy has a negative impact on carbon emissions and that a 1% increase in renewable energy would result in a 0.18% drop in CO2 emissions. Mirziyoyeva and Salahodjaev (2023), made a similar analysis in 50 countries, and their results are similar to other authors' findings, concluding that there is a negative relationship between renewable energy and CO2 emissions, so that a 1% increase in the share of renewable energy in total energy consumption leads to 0.26% decrease in CO2 emissions per capita. Huang et al. (2021) Found out that a 1% increase in renewable energy tends to lead to a 0.28% decrease in carbon emissions.

Candra et al (2023), found that renewable energy sources have a greater impact on the green economy in selected middle-income countries than in selected high-income countries.

3. RESEARCH METHODOLOGY AND HYPOTHESIS

In this study, three indicators were analyzed for North Macedonia in the period 1990-2019. The analyzed indicators include Renewable energy supplied as % of total energy supplied, annual carbon emissions, and Green GDP. The data for the indicator renewable energy supplied as % of total energy supplied were taken from the OECD database (Green Growth Indicators), the annual CO2 emissions were retrieved from the Our World in Data database, and the Green GDP data was obtained from the Mendeley Database.

Firstly, a correlation analysis was made to examine whether there is a correlation between the indicators and whether they are positively or negatively correlated. Then regression analysis was made to further examine and predict how changes in the independent variable will affect the dependent variable.

In the first regression model, as an independent variable was taken the Renewable energy supplied as % of the total energy supplied indicator, while the dependent variable was taken the annual carbon emissions. In the second regression model, as independent variable was taken annual carbon emissions, while the dependent variable was the Green GDP. In the third regression model, the independent variable was taken the renewable energy supplied as a percentage of total energy supplied, while the dependent variable was taken the Green GDP.

The following hypotheses were tested:

Hypothesis 1:
H0: There exists no significant relationship between renewable energy supplied and annual carbon emissions.
Ha: There exists a significant relationship between renewable energy supplied and annual carbon emissions.

Hypothesis 2:
H0: There exists no significant relationship between renewable carbon emissions and green GDP.
Ha: There exists a significant relationship between carbon emissions and Green GDP.

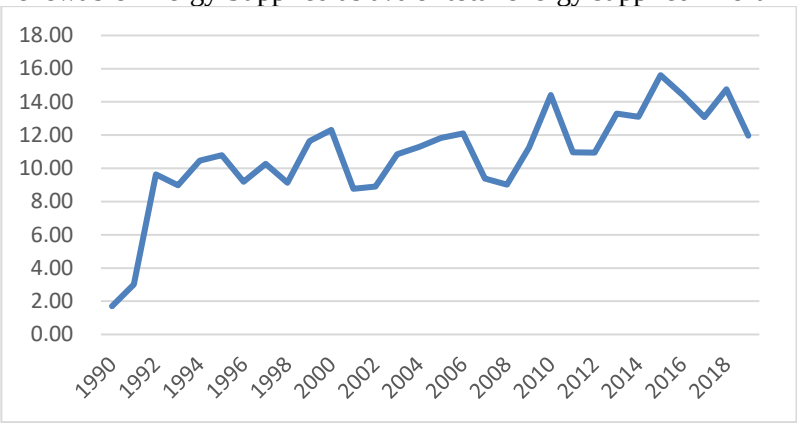
Hypothesis 3:
H0: There exists no significant relationship between renewable energy supplied and Green GDP.
Ha: There exists a significant relationship between renewable energy supplied and Green GDP.

4. TRENDS OF RENEWABLE ENERGY SUPPLY, CARBON EMISSIONS AND GREEN GDP IN NORTH MACEDONIA

4.1. Renewable energy supply

Renewable energy supply as a % of total energy supply is one of the indicators in the OECD database that is introduced to measure the progress of a country towards green growth.

Figure 1. Renewable Energy Supplied as a% of total energy supplied- North Macedonia



Source: OECD Database- Green Growth Indicators

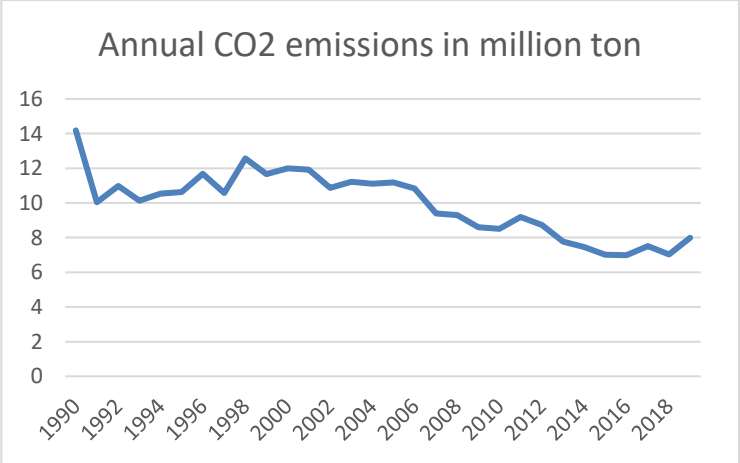
An increase in the percentage of renewable energy supplied would indicate that the country is making progress and raising its commitment towards cleaner, more sustainable, and resilient energy systems, at the same time moving away from non-renewable energy sources, therefore putting less pressure on the environment.

The data in the table shows how the renewable energy supplied as % of total energy supplied has changed over the analyzed period (1990-2019). In the early 90s, the percentage of renewables was quite low, around only 1.7%, and it started to gradually increase in the following years. The most significant increase occurred in 1992, when it went up to 9.6%, indicating a substantial shift toward renewable energy sources. In 2015 there was another substantial increase, to 15.6%, mostly due to the increased global awareness of climate change and all initiatives taken to reduce the reliance on fossil fuels and start to rely more on renewables. From 2015 onwards, the percentage of renewables continued to fluctuate but remained relatively high when compared with the early years. Overall, according to the data, there has been a positive shift toward renewable energy sources over the decades, but there is still so much progress to be made by North Macedonia, to increase this level in order to further improve the move towards a greener growth.

4.2. Carbon emissions

The data provided in the table show the annual CO2 emissions in millions of tons emitted over the years 1990-2019 in North Macedonia. The data show important information about the trends and fluctuations in carbon emissions over the analyzed period in the country.

Figure 2. Annual CO2 Emissions in North Macedonia



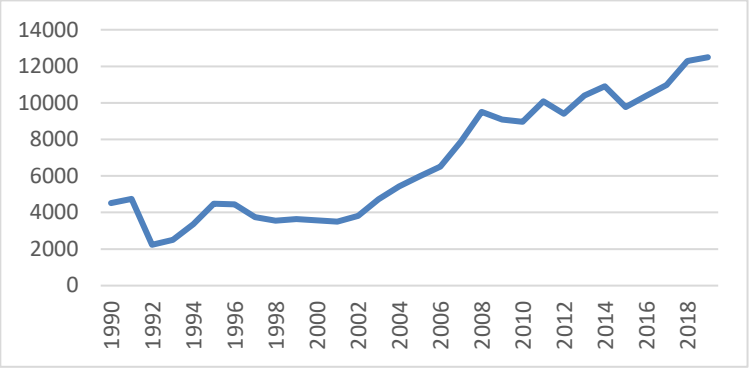
Source: Our World in Data

Carbon emissions in North Macedonia between 1990 and 1997, showed a general downward trend, however in 1998, the emissions increased by 18% and fluctuated from year to year. The most substantial decline in emissions was in 2007, when emissions dropped by 13.4%, while the highest year-to-year increase was recorded in 2019, when the emissions increased by 13.7%. On average, the annual carbon emissions have been decreasing by 1.5% every year, while when comparing with the beginning period the emissions have decreased by 43%, showing that North Macedonia has made slight positive improvements in lowering CO2 emissions.

4.3. Green GDP

The 'Green GDP' measure was introduced very recently and is a variation of the traditional GDP. This indicator, like traditional GDP, measures economic growth, but it also considers the negative environmental impacts that come at the expense of such growth, including natural resource depletion and environmental degradation. Green GDP includes a wide range of GDP indicators that are adjusted for social and environmental costs. This method quantifies the monetary impact of social and environmental damage that is caused by a country's economic growth. It refers to the remaining gross domestic product after deducting the social and environmental costs from the traditional GDP. Even though this indicator gives some insight into the country's sustainable development, it is a flawed indicator, due to data unavailability and because it is hard to measure due to the problems that arise when trying to evaluate and quantify the cost of natural resource depletion, ecological damage, and social costs (Stjepanovic. Et.al. 2019).

Figure 3. Green GDP (in million $) in North Macedonia



Source: Mendeley Database

The green GDP is expressed in millions of dollars for the years 1990 to 2019. The data obtained by the Mendeley database reveals that the Green GDP has experienced substantial fluctuations over the years, however, on average this indicator has experienced a year–to–year increase of 5%. This indicator saw a drastic decrease of 50% in 1992 from the previous year, but generally, it has been on an upward trend, with a few exceptions of negative growth in 2008 and 2015, likely influenced by global economic crises and the political situation in the country in 2015. Starting from the early 2000s the Green GDP has generally increased and when comparing the green GDP in 2019 with the beginning of the period (1990), this indicator has increased by 176%. Despite several fluctuations, there is in general a positive upward trend in this indicator, which indicates that there is a gradual shift towards a more sustainable economic development path over the years.

5. RESULTS AND DISCUSSION

To establish the relationship between the independent (renewable energy supply as % of total energy supply and annual CO2 emissions) and the dependent (green GDP) variables a correlation analysis was made.

According to the data that were analyzed for the period 1990-2019, there exists a relationship between the variables. The correlation coefficient between annual CO2 emissions and renewable energy supply is -0.66,

indicating that there is a moderate negative relationship between these two variables. Given that the percentage of the renewable energy supply in total energy supply increases, the annual CO2 emissions tend to decline.

When investigating the relationship between annual CO2 emissions and green GDP it can be seen that there is a very strong negative relationship, the correlation coefficient being -0.85. This strong negative correlation indicates that as annual CO2 emissions fall, there is an increase in the green GDP. This suggests that lowering CO2 emissions increases the green GDP of a country which means that the country is making progress towards a more sustainable economy, which is the case with North Macedonia. Lowering emissions, while maintaining or increasing the green GDP, suggests that a country is improving its economic activity and becoming more sustainably developed.

Table 1. Correlation Results

Correlation Results	*Annual CO2 emissions in million ton*	*Renewable energy supply, % total energy supply*	*Green GDP in million $*
Annual CO2 emissions in million ton	1		
Renewable energy supply, % total energy supply	-0.661296787	1	
Green GDP in million $	-0.850774347	0.54200559	1

Source: Authors Calculations

The correlation coefficient between renewable energy supply and green GDP is 0.54, indicating that there is a moderate positive relationship between these two indicators. This suggests that as the percentage of renewable energy supply increases in the total energy supply, the green GDP tends to increase.

5.1. Renewable energy supplied and Carbon emissions

To further investigate and prove the relationship between these indicators, a regression analysis was made, the independent variable being renewable energy supplied as % of total energy supplied, while the dependent variable was annual carbon emissions.

Table 2. Regression Results - Renewable energy supplied and annual carbon emissions

Regression Statistics	
Multiple R	0.661296787
R Square	0.437313441
Adjusted R Square	0.417217492
Standard Error	1.421886457
Observations	30

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	43.996097	43.996097	21.76127389	6.93053E-05
Residual	28	56.60931074	2.021761098		
Total	29	100.6054077			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	14.38284989	0.991248153	14.50983778	1.49336E-14	12.3523701	16.41332969	12.3523701	16.41332969
Renewable energy supply, % total energy supply	-0.414374824	0.08882827	-4.664898058	6.93053E-05	-0.596331286	-0.232418361	-0.596331286	-0.23241836

Source: Authors calculations

As seen from the correlation analysis above, these two variables have a moderately strong negative correlation relationship, and approximately 43.73% of the variation in the annual carbon emissions is explained by the renewable energy supplied. This model is statistically significant, which is proved by a very small P-value, very close to zero (6.93053E-05). Further results, show that given a 1% increase in the renewable energy supplied as % of total energy supplied, the annual carbon emissions are expected to be approximately decline, for 0.41 million tons. Since this model is statistically significant, it indicates that renewable energy supplied is an important predictor or influencer on carbon emissions, therefore, the first null hypothesis is rejected, and the alternative hypothesis is accepted.

5.2. Carbon Emissions and Green GDP

To test the second hypothesis, the relationship among carbon emissions as an independent variable, and green GDP as a dependent variable was analyzed through a regression model. According to the results, there exists a very strong negative linear relationship between annual carbon emissions and Green GDP, having a correlation coefficient of -0.85. Approximately 72.3% of the variations in the green GDP, can be explained by the annual carbon emissions. The analysis further indicates that given that annual carbon emissions increase by 1 million tons, the green GDP is expected to be approximately decline by 1.5 billion$. This is because, as carbon emissions increase it means that there would be a higher environmental cost in a country, and therefore the green GDP would decrease. The p-value associated with the indicator is very low (2.6065E-09), indicating that this model is highly statistically significant. According to the results of this analysis, the second null hypothesis is rejected, and the alternative hypothesis that there is a significant relationship between these two indicators is accepted.

Table 3. Regression Results- Carbon Emissions and Green GDP

Regression Statistics	
Multiple R	0.850774347
R Square	0.723816989
Adjusted R Square	0.71395331
Standard Error	1737.392021
Observations	30

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	221505997	221505996.9	73.3820505	2.6065E-09
Residual	28	84518869	3018531.036		
Total	29	306024866			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0*
Intercept	21482.9447	1747.3615	12.29450475	8.3899E-13	17903.63685	25062.25255	17903.63685	25062.252
Annual CO2 emissions in million ton	-1483.82294	173.21566	-8.56633238	2.6065E-09	-1838.639142	-1129.00674	-1838.63914	-1129.0067

Source: Authors Calculations

5.3. Renewable energy supplied and Green GDP

The third regression model analyzed how the renewable energy supplied affects Green GDP. According to the data, renewable energy supplied, and green GDP are moderately positively correlated (with a correlation coefficient of 0.542). The coefficient of determination in this analysis is only 0.2938, which indicates that only about 29% of the variance in the Green GDP, can be explained by the renewable energy supplied, however, the p-value indicates that the regression model is highly significant.

Table 4. Regression Results-Renewable Energy Supplied and Green GDP

Regression Statistics	
Multiple R	0.54200559
R Square	0.29377006
Adjusted R Square	0.268547562
Standard Error	2778.256923
Observations	30

ANOVA					
	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	89900943.12	89900943.12	11.647144	0.001976207
Residual	28	216123922.8	7718711.529		
Total	29	306024865.9			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	383.9017319	1936.822752	0.198212114	0.8443112	-3583.499827	4351.30329	-3583.49983	4351.303
Renewable energy supply, % total energy supply	592.3363838	173.5636165	3.412791204	0.0019762	236.8074321	947.865335	236.8074321	947.8653

Source: Authors calculations

Further analysis shows that given that renewable energy supplied increases by 1%, the green GDP is expected to approximately increase for 592 million dollars.

6. CONCLUSION

The results of this study show important information on the relationship between these indicators. Increasing the percentage of renewables will cut down carbon emissions, so a 1% increase in renewables will reduce carbon emissions by 0.4 million tons. Furthermore, when the impact of carbon emissions on green GDP was analyzed, the results showed that as annual CO2 emissions increase, the green GDP tends to decrease. The analysis also indicates that as the percentage of renewables increases, the green GDP tends to increase in North Macedonia. According to the results, the null hypothesis that there exists no significant relationship between these indicators was rejected, and the alternative hypothesis was accepted. Even though, this research uncovered a statistically significant relationship between these indicators, a furthermore extensive research is needed to gain a more comprehensive understanding of other factors that might influence carbon emissions and green GDP.

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