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CO_2 Emission and Research and Development Relationship for Azerbaijan

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ABSTRACT

Countries take different measures to reduce environmental pollution. Countries sometimes choose taxation as a method for environmentally friendly production and consumption activities. On the other hand, they also make additional environmental expenditures to protect the environment. The method and implementation of the decisions to be taken differ from country to country. In this study, the relationship between CO_2 emissions and government R&D expenditures for Azerbaijan is examined. In the study, causality analysis was carried out using annual data for the period 1998-2022. After performing the necessary assumption tests in the analysis, the Granger method was preferred. According to the findings of the study, no causal relationship could be determined between R&D expenditures and CO_2 emissions. In other words, there is no causal relationship between these variables.

Keywords: Environmental Pollution, CO_2, Research and Development, Granger Casuality, Azerbaijan
JEL Classifications: C13, Q50, O30, O38

1. INTRODUCTION

The last few decades have witnessed an unprecedented increase in greenhouse gases (GHG) and the emergence of global warming as a major policy concern around the world. By some estimates, anthropogenic activities have caused global warming of about 1°C compared to pre-industrial levels (1850-1900). If current trends continue, it is estimated that global warming will reach approximately 1.5°C between 2030 and 2052. Also, reflecting the long-term trend in global warming, the global average surface temperature increased by about 0.87°C over the pre-industrial period in 2006-2015. Recent estimates show that GHG emissions such as carbon dioxide, methane and nitrous oxide emissions cause an increase in anthropogenic global warming of about 0.2°C every decade. If GHG emissions continue to increase at the current rate, we can expect more frequent and longer heatwaves, more frequent and more abundant precipitation, further increases in temperature and ocean acidity, and global average sea level rise (IPCC, 2018).

Environmental scientists argue that the use of energy consumption producing CO_2 emissions, which is one of the main causes of GHG formation; causes climate change and global warming, and as a result, there is more awareness around the world about the environmental friendliness of economic growth and its consequences, so countries have shifted their attention from economic growth to environmentally friendly economic growth (Raghutla and Chittedi, 2020). Studies on GHG emissions, economic growth, R&D and oil price and oil price volatility can be seen as an extension of the standard endogenous economic growth theory, in which R&D and other energy inputs facilitate economic production at a different level (Romer, 1986; Stokey, 1998). R&D creates technological innovations that can alleviate key global challenges (Mohamued et al., 2021).

Considering cognitive capital and the number of researchers engaged in research and development as components of national human capital, it can indeed reduce pollution levels and encourage public and private commitment to cleaner and environmentally friendly technologies (Larkin and Hystad, 2017; Mentel et al., 2022). Studies on R&D, innovation, pollution, and economic growth generally show that more human capital, as measured by intelligence or cognitive abilities, means greater commitment to environmentalism and pollution reduction.

Despite the positive effects of R&D development, especially in business, there is conflicting debate as to whether R&D development and digitization reduces or increases CO_2 emissions (Umar et al., 2020; Ramos-Meza et al., 2021). An important aspect of R&D activities is that it makes proposals for green transportation infrastructures such as electrified rails and electric vehicles. In the transport sector, these green solutions have contributed to significant reductions in CO_2 emissions (Sohail et al., 2021).

Regarding the relationship between R&D and CO_2 emissions, France (Shahbaz et al., 2018), Denmark (Petrovic and Lobanov, 2020), Japan (Lee and Min, 2015), China (Zhang et al., 2017; Lin et al., 2021) and organizations such as OECD (Ganda, 2019; Petrovic and Lobanov, 2020), G7 (Wahab et al., 2021), G20 (Nguyen et al., 2020). There is a bidirectional causality relationship between economic growth and foreign investments in Azerbaijan (Huseynli, 2023a). This supports economic growth to attract foreign investments to the country. Requiring that only incoming foreign investments support the green economy is also very important for the country's future goals. The relationship between emissions and R&D expenditures has been investigated in the example of Azerbaijan.The slowdown in global warming, the sustainable reduction of all GHG emissions, especially CO_2 emissions, is an issue on the agenda of the whole world. In this context, academic studies are carried out in different fields in the literature. From this point of view, the aim of this study is to examine the relationship between CO_2 emissions and government R&D expenditures for Azerbaijan.

2. LITERATURE REVIEW ON CO_2 EMISSION AND RESEARCH AND DEVELOPMENT

Carbon emissions are one of the main causes of global warming. There is a large literature examining the causes of carbon emissions in energy economics and alternative strategies to reduce them. Montgomery (2017) emphasized that climate change can also have serious consequences on human health and general well-being. The effects of climate change on human health and general well-being can be direct and indirect. Direct ones are reflected in an increase in infectious diseases and aquatic toxicity and a decrease in air quality. Indirect effects may include forced migration of the population and frequent conflicts, as well as starvation due to extreme weather conditions (Montgomery, 2017).

In general, R&D expenditures are related to the GDP of that country. In general, it should be noted that the larger the GDP of a country, the more prosperous the population of that country will be (Huseynli, 2022). The purpose of R&D is to push the limits of knowledge and explore the unknown (Deeney et al., 2021). This type of uncertainty makes it difficult to determine the value of an investment in R&D. As income increases, countries can better meet their R&D investment and therefore better adopt efficient technologies. More efficient technologies reduce the burden on natural resources. An environmental perspective suggests that economic growth based on the consumption of fossil fuels is closely related to environmental degradation, and economic theory considers R&D accumulation to be essential for economic growth (Fernández et al., 2018).

Research and development (R&D) has guided humanity's progress and improved living standards for centuries (Pinker, 2018). The endogenous growth theory suggests that technological progress resulting from investments in research and development (R&D) can lead to greater efficiency in production and use of natural resources and energy (Deeney et al., 2021). While Li and Wang (2017) pointed to the negative impact on total CO_2 emissions, Churchill et al. (2019) suggested a mixed result, with a negative effect for about three-quarters of the period covered by the study and a positive effect for the remainder. Churchill et al. (2019) examined regression models for a very long time, starting from the view that the relationship between R&D investments and CO_2 emissions is a long-term phenomenon.

Empirical testing of the effect of public energy R&D investments on carbon emissions per GDP was conducted for 13 developed economies between 1980 and 2004, and it was found that public energy R&D investments did not have a significant effect on CO_2 intensity (Garrone and Grilli, 2010). The impact of green research and development investment on CO_2 emissions and financial performance for Japanese manufacturing firms between 2001 and 2010 was examined (Lee and Min, 2015).

Zhang et al. (2017) tested the impact of environmental innovations on CO_2 emissions in 30 provinces of China between 2000 and 2013 and found that most of the environmental innovation variables in China effectively reduced CO_2 emissions. A study by Shahbaz et al. (2018) examined the impact of energy research innovations on CO_2 emissions in France from 1955 to 2016 and found negative effects. Ganda (2019) observed a negative correlation between innovations – particularly renewable energy consumption and R&D spending – and carbon emissions in OECD countries. Koçak and Ulucak (2019) investigated how R&D expenditures affect energy consumption in transportation infrastructures and transportation in OECD member countries using the 2003-2015 period.

A study by Petrovic and Lobanov (2020) analyzed the impact of research and development (R&D) expenditures on CO_2 emissions in 16 Organization for Economic Cooperation and Development (OECD) countries between 1981 and 2014. Erdoğan et al. (2020), it has been determined that since the effects of technological innovation on carbon emissions vary, policies to reduce carbon emissions should be designed and implemented separately in each sector. A study by Nguyen et al. (2020) conducted in 13 countries of the G20 identified spending on technology and innovation as the main drivers of reducing carbon emissions.

In a study by Petrovic and Lobanov (2020), the long-term impact of R&D expenditures on CO_2 emissions was found to be from -0.79% in Denmark to 0.52% in Belgium. Wahab et al. (2021), it was suggested that the adoption of new technologies for cleaner production in the G7 economies during the 1996-2017 period could reduce carbon emissions. Lin et al. (2021) examined the relationship between innovative human capital, carbon dioxide emissions and economic growth in Chinese provinces between 2003 and 2017. Innovative human capital was measured by the number of patents per million full-time R&D personnel.

3. RESEARCH METHODOLOGY

3.1. Data Set

In this study, which was applied on Azerbaijan, the data set constitutes the years 1998-2022. Values for the data set are taken on an annual basis. R&D expenditures are included in the analysis with the percentage data kept in GDP over the years. Therefore, it is not necessary to take the logarithmic values of this variable. CO_2 emission was included in the analysis after converting to logarithmic values.

3.2. Analysis Method

Granger (1969) developed a methodology for analyzing causal relationships between time series. Granger causality means that knowing the past values of one variable (X) helps to improve the predictions of another variable (Y). Recent theoretical developments in Granger causality methods have made possible tests using relatively short time series through the use of panel data (Larrain et al., 1997; Hurlin and Venet, 2001).

As with Granger (1969), the procedure for determining the existence of causality is to test the significant effects of past values of x on the present value of y. In a bivariate framework, if the prediction for the second variable improves when lagging variables are taken into account for the first variable, the first variable is said to cause the second variable in the Granger sense (Granger, 1969). The introduction of a panel data dimension allows the use of both cross-section and time series information to test causality relationships between two variables (Hurlin and Venet, 2001). In the context of panel data, Granger causality can be tested using a finite order panel vector autoregression (VAR) model, in which a random variable can be expressed as a function of its own historical values and the past values of other variables in the system (Peng et al., 2016). Especially by increasing the number of observations, this process increases the degree of freedom. Thus, Granger significantly increases the effectiveness of causality tests (Hoffmann et al., 2005).

Table 1: Level values of series

ADF test resault	CO_2 emission		R&D expenditures	
	t-statistics	Possibility	t-statistics	Possibility
ADF testing statistics	−1.406775	0.5619	−2.670986	0.0643
Test critical values				
1%	−3.737853		−3.752946	
5%	−2.991878		−2.998064	
10%	−2.635542		−2.838752	

One of the basic criteria in time series data is the requirement that the data set used be stationary. In the studies, the concept of stationarity is confirmed with the help of unit root tests. There may be a number of reasons for non-stationarity, including that the mean of the series depends on time and the autocorrelations of the series depend on time.

In order to examine stationarity, first of all, the existence of unit root in the time series must be determined. The DF test developed by Dickey and Fuller (1979) is one of the most frequently encountered tests in the literature. The Generalized Dickey and Fuller (ADF) test, which was developed over time, and dependent variable models were also included in the analysis. In order to troubleshoot first when a stationarity problem is encountered, information criteria such as AIC or SIC can be used in ADF testing to determine the number of lags to include in the model.

4. ANALYSES AND RESULTS

Before applying the analysis methods in the study, the necessary model was established. The function used in the mathematical determination of the relationship between CO_2 emissions and R&D expenditures is included in equation 1 as stated:

$$Y = f\,(CO_2, R\&D) \quad (1)$$

where CO_2 is the amount of carbon emissions; R&D represents the research and development expenditures made by the government. When the function is revised, the following equation is finally obtained:

$$Y = \beta_0 + \beta_1 CO_2 + \beta_2\, R\&D \quad (2)$$

Since the R&D expenditures included in the analysis were taken as a percentage of GDP, there was no need to take logarithmic values. The logarithms of the CO_2 emission data used in the analysis were taken and the Augmented Dickey-Fuller (ADF) unit root test was applied to examine the stationarity of both series. It has been observed that not all R&D expenditures and CO_2 emission data are stationary at the level (Table 1).

ADF unit root test, one of the unit root tests applied by taking the first differences, is given in Table 2. After taking the first-order differences, the series became stationary. Thus, it was observed that the autocorrelation problem disappeared. It was determined that the data used in the study were first-order integrated.

Table 2: Stationarity level of first order series

ADF test resault	CO_2 emission		R&D expenditures	
ADF testing statistics	t-statistics	Possibility	t-statistics	Possibility
Test critical values	−5.666529	0.0001	−4.379924	0.0024
1%	−3.752946		−3.752946	
5%	−2.998064		−2.998064	
10%	−2.638752		−2.638752	

Table 3: Appropriate delay length

Lag	LogL	LR	FPE	AIC	SC	HQ
0	71.22267	NA	9.96e-07	−8.143843	−8.045818	−8.134100
1	80.92618	15.98226	5.13e-07	−8.814845	−8.520770	−8.785613
2	87.55385	9.356713	3.87e-07	−9.123983	−8.633857	−9.075263
3	99.39913	13.93562*	1.65e-07	−10.04696	−9.360781	−9.978749
4	105.6424	5.875996	1.45e-07	−10.31087	−9.428642	−10.22317
5	113.0364	5.219331	1.25e-07	−10.71017	−9.631892	−10.60299
6	122.4757	4.441989	1.07e-07	−11.35008	−10.07575	−11.22341
7	137.8818	3.624982	7.91e-08*	−12.69198	−11.22160	−12.54582
8	843.3616	0.000000	NA	−95.21901*	−93.55259*	−95.05337*

*Indicates the appropriate lag length for the relevant test

Table 4: Johansen cointegration test results

Hypothesized		Trace	0.05	
No. of CE (s)	Eigenvalue	Statistic	Critical value	Prob.**
None	0.231641	6.916738	15.49471	0.5874
At most 1	0.049626	1.119791	3.841466	0.2900

Table 5: Granger causality test

Hypotheses	F-value	Probability value (P)	Decision at 1% significance level
CO_2 emissions are the reason for R&D expenditures	0.559050	0.7561	Rejected
R&D expenditures are the cause of CO_2 emissions	3.190683	0.2028	Rejected

The series being stationary of the same order allows the widely used Engle&Granger and Johansen cointegration tests to be applied. Cointegration tests developed by Engel-Granger and Johansen were applied to examine the long-term relationship between the variables.

In determining the appropriate delay for the data set, the most appropriate delay length was determined as 8. The results for the appropriate lag length are given in Table 3. The line with the highest number of stars represents the appropriate delay length Table 3.

When the Johansen test results are examined, it is seen that the H_0 hypothesis cannot be rejected according to both the trace statistics and the maximum eigenvalue statistics. As a result, it was found that there is no long-term relationship between dependent and independent variables (Table 4).

In Table 5, it was tested whether the variables were the cause of each other by applying the Granger causality test. The test results are shown in Table 5 below. According to the test results, no causality could be detected between the variables. In other words, the existence of a Granger causality relationship from CO_2 emissions to R&D expenditures and from R&D expenditures to CO_2 emissions could not be determined.

5. CONCLUSION

As a result of the regression analysis conducted by Koçak and Ulucak (2019), it has been determined that there is no relationship between R&D expenditures and CO_2 emissions in OECD countries. As a result of the study conducted by Petrovic and Lobanov (2020) with the data of 16 OECD countries, it was found that the expected average effect of R&D expenditures on CO_2 emissions is negative. That is, an increase in R&D investments by 1% reduces CO_2 emissions by an average of 0.09-0.15%. Lin et al. (2021), it has been suggested that innovative human capital reduces carbon dioxide emissions and that its further development will increase China's environmental sustainability.

Countries take different measures to reduce environmental pollution. Countries sometimes choose to apply taxation for environmentally friendly production and consumption activities. On the other hand, they also make environmental expenditures to protect the environment. In this study, the relationship between CO_2 emissions and government R&D expenditures for Azerbaijan is examined. Causality analysis was carried out using annual data for the period 1998-2022. After performing the necessary assumption tests in the analysis, the Granger method was preferred. As a result of the study, no causal relationship was found between R&D expenditures and CO_2 emissions. Therefore, there is no causal relationship between the variables in the research model.

Generally speaking, one of the main directions of Azerbaijan's 2030 energy strategy is to become a green energy venue (Huseynli, 2023b). The most important feature of green energy is related to increasing the use of renewable energy resources, reducing the consumption of traditional energy resources, reducing waste materials discharged into nature, minimizing air pollution, etc. Considered from this perspective, it would be beneficial to continue scientific studies on the relationship between R&D expenditures and CO2 emissions in the future.

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