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Carbon Emissions and Economic Growth in Azerbaijan: An Empirical Analysis

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ABSTRACT

The increasing energy consumption and industrial activities that release CO_2 emissions into the atmosphere have become one of the most serious environmental issues of today. This article discusses the current status in Azerbaijan regarding the development of effective approaches to reduce carbon emissions and ensure sustainable development, and it proposes relevant strategies for managing the carbon footprint. It aims to develop more efficient policies to control CO_2 emissions by studying the relationship between the economy and environment in Azerbaijan. Based on the findings of the econometric model conducted within this research between 1990 and 2023 on Azerbaijan, as the economy grows, per capita CO_2 emissions tend to increase, which is due to rising industrial activities, energy consumption, and other economic drivers. A positive long-term relationship between population growth and per capita CO_2 emissions depicts higher overall energy usage, increased demand for goods and services, and rising transportation needs. Considering the strong correlation between economic growth and CO_2 emissions, it may be premature to assert the validity of the Kuznets curve for Azerbaijani economy as a developing country.

Keywords: CO_2 Emissions, Energy Consumption, Azerbaijani Economy, Kuznets Curve
JEL Classifications: Q43, Q30, O44

1. INTRODUCTION

Carbon footprints have a substantial effect on climate change. Greenhouse gas emissions in the atmosphere contribute to global warming. World Meteorological Organization claims that, 2011-2020 decade was the hottest on record and CO_2 emissions rose by 31% between 1990 and 2005. By 2008, these emissions had increased the Earth's radiative warming by 35% over 1990 levels (WMO, 2023). The Paris Agreement as an international treaty concerning climate change was adopted by 196 parties at the UN Climate Change Conference (COP21) and came into effect on November 04, 2016. The key objective is to keep the average global temperature rise below 2°C above pre-industrial levels and to limit the increase to 1.5° Cover those levels (UNCC, 2016). The energy sector as the primary source of global emissions, plays a crucial role in addressing the world's climate crisis. CO_2 emissions from energy and industry have risen by 60% since the United Nations Framework Convention on Climate Change was signed in 1992, despite numerous promises and efforts taken by nations to combat global warming.

The management of carbon footprint is crucial to combat global climate change. One of the vital environmental issues is the CO_2 emissions released into the atmosphere due to rise in energy consumption and industrial activities. This issue demands special attention in developing countries, where the environmental status made worse by rapid economic growth. Due to increased industrial activities and economic growth, notable changes in CO_2 emissions have been observed in recent years in Azerbaijan. Since the nation's energy consumption is primarily based on fossil fuels, carbon emissions are notably high. Therefore, the per capita CO_2 emissions in Azerbaijan should be analyzed from both ecological and economic standpoint.

The goal of this study is to investigate how various economic and ecological factors affect per capita CO_2 emissions in Azerbaijan by using economic modeling. Therefore, determine the key variables influencing CO_2 emissions and evaluate the scale of these impacts in respect to various economic sectors is vital. The findings will also be useful in developing suggestions for controlling the nation's carbon footprint. Furthermore, the information derived from this research will facilitate the development of recommendations aimed at improving Azerbaijan's ecological policies and formulating strategies for reducing carbon emission.

2. CARBON FOOTPRINT: INTERNATIONAL OUTLOOK

Carbon dioxide, a greenhouse gas, is the main driver of climate change and rising temperature. As of 2022, the United States was the largest historical emitter having released 427 billion metric tons of carbon dioxide ($GtCO_2$) since the industrial revolution, meanwhile China is the second with over 260 $GtCO_2$ (Tiseo, 2023). China's carbon dioxide emissions have five folded since 1990 and the country is responsible for about 34% of global CO_2 emissions by 2023. In contrast, CO_2 emissions in the UK have nearly halved compared to 1990 levels. Although developed nations like the UK, the US, Japan, and Germany have seen overall reductions in emissions since 1990, developing regions have experienced huge rises. For instance, in India, emissions have surged nearly fivefold due to rapid economic growth, while Vietnam's emissions have skyrocketed by 20 times (Tiseo, 2024a).

Global CO_2 emissions from fossil fuels and industry have risen by more than 60% since 1990, totaling 37.15 billion metric tons ($GtCO_2$) in 2022 and reaching 53 billion metric tons in 2023. China is the largest emitter of global greenhouse gases, followed by the US. Although it was not always the leading emitter, China`s emissions have surged dramatically in recent decades due to industrialization and economic growth rate. CO_2 emissions in China have risen by over 4 times, whereas the US CO_2 emissions have fell by 2.6% since 1990. Therefore, China was the world's greatest emitter by a significant margin in 2023, accounting for 30% of global greenhouse gas emissions (Tiseo, 2024; 2024b), (EDGAR, 2024).

In 2023, China, US, EU, India, Russia, and Brazil continued to be the largest CO_2 emitters globally. Collectively, these countries represent 49.8% of the world's population, 63.2% of global GDP and 64.2% of global fossil fuel consumption, and 62.7% of global fossil CO_2 emissions (EDGAR, 2024). Fossil CO_2 made up 73.7% of total greenhouse gas emissions, followed by methane (CH4) at 18.9%, nitrous oxide (N2O) at 4.7%, and fluorinated gases (F-gases) at 2.7% in 2023. Global fossil CO_2 emissions have increased by 72.1% since 1990 (EDGAR, 2024). In the EU-27, net greenhouse gas emissions, including those from international aviation, fell by 30% from 1990 to 2021. Projections from EU Member States suggest that net emissions will be reduced by 48% by 2030 from 1990 level. However, there will still be a 7%-point shortfall from the 2030 target. The European Green Deal for Europe set a firm target for achieving climate neutrality by 2050 at the latest and mandates a reduction in net greenhouse gas emissions of at least 55% by 2030 compared to 1990 levels (EEA, 2023). In advanced economies, GDP growth has led to a peak in CO_2 emissions in 2007, followed by a decrease. For instance, in US, GDP has doubled since 1990, but CO_2 emissions are back to 1990 levels. Similarly, in the EU, the economy has expanded by 66%, while CO_2 emissions have dropped by 30% compared to 1990. This pattern is also observed in other advanced economies. As these economies represent more than half of global GDP and over a third of energy demand, decrease in CO_2 emissions in these regions is also evident. In contrast, emerging and developing economies like China and India show diverging trends. China's economy has grown fourteenfold since 1990, but its CO_2 emissions are now five times higher than 1990 level. In India, GDP growth has exceeded CO_2 emissions growth by over 50%. Other emerging economies are also experiencing different trends in economic activity and emissions (IEA, 2024).

The COVID-19 pandemic led to a significant drop in global CO_2 emissions, falling by 5.5% in 2020 due to lockdowns and other measures. Besides, the global recession in 2009 resulted CO_2 levels to fall by nearly 2%, and the recession of the early 1980s also notably decreased emissions. The most ever substantial annual reduction occurred at the end of the World War II in 1945, when emissions fall by 17% (Tiseo, 2024).

3. CARBON FOOTPRINT: LITERATURE REVIEW

Meadows, et al. (1972) investigated how population growth, resource consumption, and industrial expansion interact with the Earth's finite resources. Their findings suggest that if current trends continue unchecked, the world will face economic and environmental collapse by the end of this century. The report highlights that economic growth is constrained by environmental limits, such as the availability of resources and the planet's ability to absorb pollution. The study highlights the need for regulations that restrict overconsumption and lessen environmental degradation, pointing to the long-term risks of ignoring ecological boundaries.

The Kyoto Protocol sets measurable target for greenhouse gas emissions specifically for industrialized countries since 2005. For policymakers to achieve targets for reducing emissions, it will be necessary to adjust the industrial structure by limiting high CO_2-emitting sectors and expanding or transferring to low-emission ones. However, this structural adjustment may diminish economic growth rate. As Chang (2015) resulted, for China to cut CO_2 emissions from 5707.16 to 5452.12 million tons as of 2007, restructure of industries would be needed, which could reduce GDP by 82.59 billion Yuan (11.6 bn USD as of 2024). Numerous studies have examined the connection between CO_2 emissions and economic growth in the literature, with a particular focus on the ways in which economic growth affects CO_2 emissions. An increase in population can lead to higher energy consumption, which in turn raises carbon emissions (Liddle, 2015). As countries strive to enhance their productive capacities, energy usage rises (Chindo and Abdul-Rahim, 2018), and this increase in energy consumption and urbanization level contributes to the growth of carbon emissions (Hossain, 2014; Begum et al., 2015). Former US President Obama in his article "The Irreversible Momentum of Clean Energy". emphasized the importance of "decoupling" energy sector emissions from economic growth. He highlighted that between 2008 and 2015 (during his presidency) CO_2 emissions from the energy sector decreased by 9.5% while the economy grew by over 10% (Obama, 2017).

The research on the relationship between CO_2 emissions and six major industrial sectors including agriculture, industry, construction, transportation, retail, and accommodation along with other industries in China from 2000 to 2017 yielded intriguing findings. The share of agriculture, industry, and transportation in GDP are significantly negatively related to CO_2 emissions, while the construction, retail, and other industries part in GDP is positively correlated with CO_2 emissions. This is consistent with the results of Xie and Liu's (2022) analysis of China's industrial sector, underlying a decoupling effect between economic growth in industry and CO_2 emissions. The share of value added and GDP in the construction sector is positively correlated with carbon emissions. This can be related to rapid pace of urbanization which in turn caused an increase in energy demand and eventually an increase in carbon emissions. In terms of the impact of industry types on CO_2 emissions, it has been noted that 1% increase in the share of value added to GDP from agriculture, industry, construction, transportation, retail, and accommodation in China has transformed total CO_2 emissions by −0.92%, 0.05%, 1.2%, 2.6%, 0.97%, and 0.098%, respectively. Lee and Brahmasrene (2013) explored relationship among tourism, CO_2 emissions, economic growth, and FDI in EU countries between 1988 and 2009. The analysis showed that tourism, CO_2 emissions, and FDI significantly boost economic growth. Conversely, while economic growth significantly increases CO_2 emissions, tourism and FDI have a notable negative impact on CO_2 emissions. As resulted, 1% increase in tourism receipts boosts economic growth by 0.498% and reduces CO_2 emissions by 0.105%, indicating that tourism has a positive effect on economic growth while also contributing to a decrease in CO_2 emissions. Also, 1% increase in FDI inflows reduces CO_2 emissions by 0.017%. Conversely, a 1% increase in economic growth leads to a 0.199% rise in CO_2 emissions. Dogru et al. (2020) analyzed the impacts of GDP, renewable energy consumption, and tourism receipts on CO_2 emissions in OECD countries. The results revealed that tourism development significantly reduces CO_2 emissions in Canada, Czechia, and Türkiye, while it significantly increases CO_2 emissions in Italy, Luxembourg, and the Slovak Republic. Saleem et al. (2022) analyzed the relationships between non-renewable energy production, healthcare expenditures, and CO_2 emissions between 2008 and 2018 in 38 OECD countries. Important conclusions included a strong correlation between fossil fuel energy production and healthcare expenditures in both directions and a bidirectional positive relationship between healthcare spending and CO_2 emissions. Ramos-Meza et al. (2023) found a favorable bidirectional relationship between health expenses and CO_2 emissions. The results revealed that increased energy production and consumption leads to pollution, therefore higher CO_2 emissions rise healthcare costs. However, energy consumption and healthcare expenditures positively impact environmental quality.

Grossman and Krueger (1991) examined how economic growth and environmental pollution interact within the framework of NAFTA. They explore the Environmental Kuznets Curve (EKC) hypothesis, which proposes that as a country's economy grows, environmental degradation initially increases but eventually decreases after income per capita reaches a particular threshold as inverse U-shaped curve. The study found that trade liberalization under NAFTA could result in increased pollution, especially in industries that are already highly polluting and have substantial production levels. Results also highlighted that, in the short term, the boost in economic activity and industrial growth might worsen environmental degradation. However, in the longer term, trade liberalization could improve environmental quality from increased efficiency, technological advancements, and the adoption of cleaner technologies as countries become wealthier and demand higher environmental standards. Osadume and University (2021) studied the economic growth and carbon emissions nexus in selected West African countries between 1980 and 2019. Study found that economic expansion has a significant impact on CO_2 emissions, as a 1% increase in economic growth leads to a 3.1% increase in CO_2. Chen and Huang (2014) research focused on the nonlinear relationship between CO_2 emissions per capita and economic growth in selected high-income and low-income countries for the period 1985-2012. They examined how this relationship changes across different stages of economic development and found that CO_2 emissions are not uniformly linked to economic growth; instead, the connection varies based on income levels and stages of development. Specifically, the findings show that high-income countries experience a decoupling effect, where economic growth is not associated with rise in CO_2 emissions. In contrast, in lower-income nations, economic growth tends to boost CO_2 emissions. The paper highlights the importance of tailored environmental policies, suggesting that as the economy grows, they should adopt more sustainable practices to mitigate the environmental impact of growth.

Dinda and Coondoo (2006) analyzed the connection between CO_2 emissions and GDP per capita in 88 nations from 1960 to 1990. According to their findings, there is only evidence for long-term cointegration between income and CO_2 emissions. The study identifies various causal patterns for the regions, like Africa: There is bidirectional causality between income and emissions; Central America: Causality runs from income to emissions; Europe: The causality appears to run from emissions to income. The results suggest that nations may need to restrict income growth in order to control CO_2 emissions, especially if they lack access to cleaner technologies. They also point out that economic openness has varying effects on emissions, it reduces CO_2 emissions in Western

Europe while raising in Africa and Central America. However, in their early research Coondoo and Dinda (2002) investigated for same countries and time period, and findings did not strongly support the Environmental Kuznets Curve (EKC) hypothesis. Instead, they identified distinct causality patterns among different country groups, like developed countries (in North America, Western and Eastern Europe), causality was observed running from CO_2 emissions to income; developing countries (in Japan, Central and South America, and Oceania) causality ran from income to CO_2 emissions; and in Asia and Africa, causality was found to be bidirectional. Lotfalipour et al. (2010) explored the cause-and-effect relationship among economic growth, carbon emissions, and fossil fuel consumption in Iran from 1967 to 2007. The findings from their research showed that economic growth and fuel consumption impact CO_2 emissions, but only in the short term. Hasanov et al., (2017) analyzed the correlation between energy consumption and economic growth in ten Eurasian oil-exporting countries. Panel data analysis showed that energy consumption is a significant contributor to economic growth in these countries, with some showing a bidirectional relationship between energy use and economic growth. Such economies heavily rely on oil and energy resources as their development backbone. The authors emphasize the need for policy measures to diversify energy sources, improve efficiency, and promote sustainability for long-term growth while mitigating environmental impacts. Hasanov, et al. (2019) found that as Kazakhstan's economy grows, CO_2 emissions initially increase but eventually decrease after attaining a certain threshold of income supporting Environmental Kuznets Curve (EKC). The study underscores the need for effective environmental policies and cleaner technologies as the economy develops. The authors recommend strategies to balance economic growth with environmental protection, emphasizing sustainable development in a developing context.

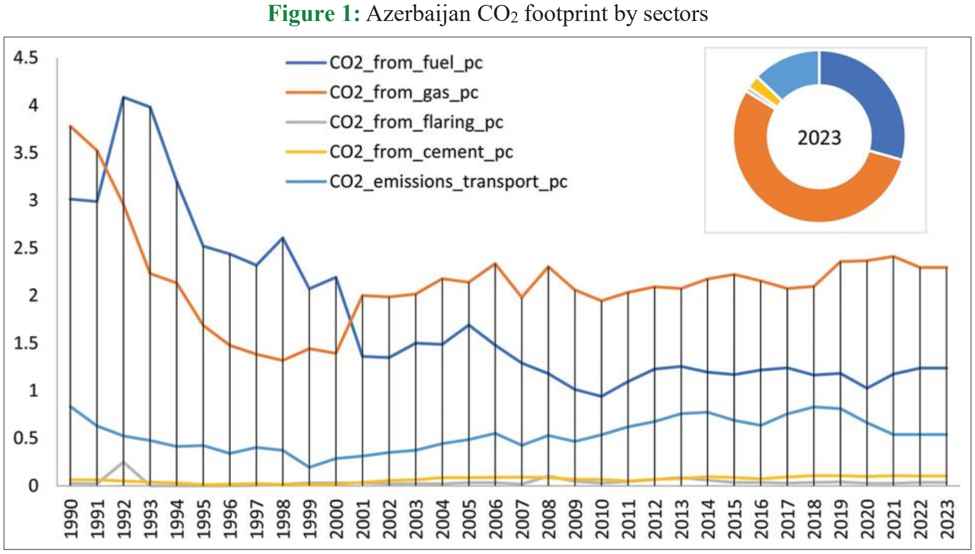
Based on a panel data approach, Nordin and Sek (2019) assessed the relationship between CO_2 emissions, energy consumption, and economic growth in 13 oil-importing and 11 oil-exporting countries. Their results revealed a strong relationship between energy consumption and economic growth for both oil-importing and oil-exporting countries. In many of the cases, increased energy consumption drives economic expansion. This relationship is particularly strong for oil-exporting countries where the economy is primarily driven by energy resources. The study indicates that higher energy consumption, especially from fossil fuels, increases the levels of CO_2 emissions. This is especially hold true for oil-exporting countries, since the extraction and usage of oil heavily contribute to CO_2 emissions. Oil-importing countries also show increased emissions with economic growth, though they tend to rely on a more diverse range of energy sources. However, oil-exporting countries, due to their heavy reliance on oil production and exports, face higher environmental impacts. On the other hand, oil-importing countries may have more flexibility in transitioning to cleaner energy sources, though economic growth is still bound to energy consumption in both groups. These findings suggest that oil-exporting countries face a more significant challenge in balancing economic growth with environmental sustainability. Thus, they need to shift towards alternative energy sources and reduce their dependence on fossil fuels to mitigate CO_2 emissions.

4. ECONOMETRIC ASSESSMENT OF CARBON FOOTPRINTS IN AZERBAIJAN: METHODOLOGY

4.1. Data and Descriptive Statistics

Carbon footprints in Azerbaijan by fields between 1990 and 2023 are depicted in Figure 1. According to the data, almost all types of carbon footprints have decreased since 1990. However, the clear and unknown reasons for this decrease have been investigated in many scientific materials (stagnation in the country's economy and industry due to the collapse of the former Soviet Union, etc.). On the other hand, it is necessary to take into account that the reduction is misleading as a description. Because the data here represents the amount of carbon dioxide per capita, and since population growth and economic development do not develop with the same acceleration, the non-linearity in the impact of emissions into the atmosphere should be taken into account. As can be seen from the graph, although there was a drop in all directions of carbon dioxide emission in the 90s, a sharp increase in gasoline consumption is observed since 2000. A gradual increase is observed in the field

Figure 1: Azerbaijan CO_2 footprint by sectors



of transport. At the same time, these increases have stabilized at a certain level since the 2000s.

In Figure 1, the main share of the amount of carbon dioxide emissions in 2023 falls on the share of gasoline consumption, which makes 55%.

For the period 1990-2023 GDP rate, population change, total carbon dioxide emissions, per capita CO_2 emissions from transportation, cement production, fuel and gasoline consumption, as well as per capita fossil fuel consumption, electricity from renewable energy resources (terawatt/hour), graphs of percentage of use of renewable resources in electricity production of the country are shown in Figure 2. First, let's try to explain the trends in the graph in a coherent way. In general, the amount of carbon dioxide per person for the period 1990-2023 in the country was between 7 and 8 tons per year in the early 90s, but as a result of a dramatic decrease by 2010, it settled between 3-4 tons and by 2023 this stability has been maintained. Along with these time series, the population growth rate was 7 million in 1990. 10 million people in 2023. Level with a stable trend. At the same time, the decrease in the population growth rate has been observed more prominently in recent years. However, we cannot say the same for GDP per capita. Because, during this time series, there was a decline until 95, a gradual increase between 1995 and 2005, a dramatic increase between 2005 and 2010, and then stability until 2023. The graph shows a high acceleration of the GDP growth rate mainly between 1993 and 1997, and then in 2004-2006.

4.2. Econometric Analysis

To understand the relationship of carbon dioxide emissions by country to the country's gross domestic product, population change, and per capita fossil fuel consumption over the time series presented in the Data and descriptive statistics section of the study, the growth rate of gross domestic product per capita (as GDPGH) as a percentage, per capita carbon dioxide emissions (as CO_2PC), population growth rate (as POPGH) and per capita fossil fuel consumption (kilowatt hours) (as FOSS) were used as variables. The natural logarithm of the CO_2PC and FOSS variables used in the analysis was obtained and the others were kept original. To perform the cointegration analysis, we first check whether these variables are stationary. Stationarity is a measure of the robustness of a time series to a particular shock. In other words, if the time series is stationary, it will return to its previous level even if it is affected by any shock and shows an upward or downward trend for a certain period of time. In order to carry out the cointegration analysis, all the time series mentioned above must show stationarity at the same lag degree. That is, the null hypothesis for testing stationarity suggests that the time series has a unit root. A stationarity test is performed for this hypothesis within the framework of a predetermined significance criterion (α level). If we want to measure the stationarity of the time series Y_t then for the unit root test the following regression equation is constructed:

$$Y_t = pY_{(t-1)} + u_t \quad (1)$$

If the parameter ρ in this equation is statistically equal to 1, then the time series has a unit root and is not stationary. Equation (1) can also be expressed as follows:

$$\Delta Y_t = (p-1)\, Y_{(t-1)} + u_t = \delta Y_{(t-1)} + u_t \quad (2)$$

Here, the parameter δ equal to 0 is investigated to check for stationarity. In this study, Augmented Dickey-Fuller, Phillips-Perron, Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests are used to test for stationarity. Tables 1-4 below describe these results. For cointegration analysis, all variables must have stationarity at the same lag level. Table 1 describes the results of the ADF, Phillips-Perron and KPSS tests on the logarithm of carbon dioxide emissions per capita. The results of these tests, both in this table and in others, were checked according to the 5% significance level. As can be seen from Table 1, according to the Augmented Dickey-Fuller test, it was found that the time series on the difference from degree 1 does not contain a single root, that is, it is stationary.

Figure 2: CO_2 and other tendencies between 1990 and 2023

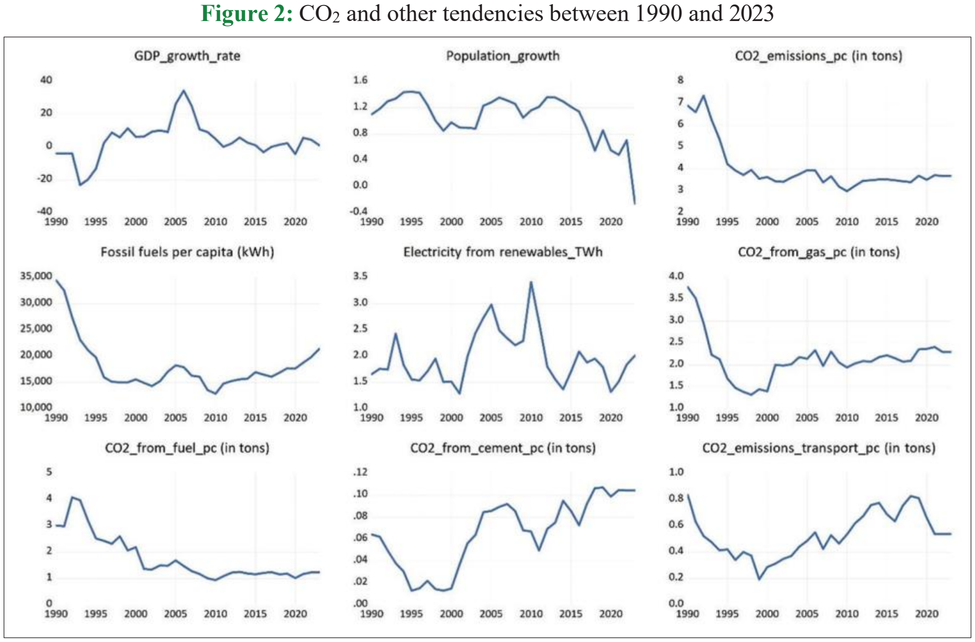


Table 1: Unit Root Test of CO_2 emissions per capita (CO_2PC)

Test / statistics	Level			1st difference		
	Intercept	Intercept and trend	None	Intercept	Intercept and trend	None
ADF						
t	−2.954021	−1.863301	−1.752988	−4.996442	−5.516533	−4.870561
P-value	(0.0676)	(0.6505)	(0.0756)	(0.0003)*	(0.0004)*	(0.0000)*
Phillips-Perron						
t	−3.358348	−1.750662	−1.752988	−4.996442	−5.586607	−4.866480
P-value	(0.0201)*	(0.7054)	(0.0756)	(0.0003)*	(0.0004)*	(0.0000)*
KPSS						
LM stat	0.473833*	0.169328*	-	0.401535	0.088744	-
LM crit	0.463000	0.146000	-	0.463000	0.146000	-

*The significance level for all tests is 5%

Table 2: Unit Root test of population growth rate (POPGH)

Test / statistics	Level			1st difference		
	Intercept	Intercept and trend	None	Intercept	Intercept and trend	None
ADF						
t	0.126502	−0.886014	−0.969255	−4.917985	−5.311521	−4.812110
P-value	(0.9631)	(0.9458)	(0.2904)	(0.0004)*	(0.0008)*	(0.0000)*
Phillips-Perron						
t	0.373326	−0.826182	−0.966817	−5.125394	−5.344690	−5.126759
P-value	(0.9787)	(0.9527)	(0.2914)	(0.0002)*	(0.0007)*	(0.0000)*
KPSS						
LM stat	0.389779	0.132822	-	0.348070	0.115364	-
LM crit	0.463000	0.146000	-	0.463000	0.146000	-

*The significance level for all tests is 5%

Table 3: Unit root test of GDP growth rate (GDPGH)

Test / statistics	Level			1st difference		
	Intercept	Intercept and trend	None	Intercept	Intercept and trend	None
ADF						
t	−1.961510	−1.873430	−1.812933	−4.730110	−4.681350	−4.807541
P-value	(0.3015)	(0.6454)	(0.0669)	(0.0006)*	(0.0037)*	(0.0000)*
Phillips-Perron						
t	−2.061285	−1.914568	−1.915739	−4.728673	−5.099046	−4.837864
P-value	(0.2608)	(0.6244)	(0.0539)	(0.0006)*	(0.0013)*	(0.0000)*
KPSS						
LM stat	0.174450	0.152080*	-	0.159896	0.120303	-
LM crit	0.463000	0.146000	-	0.463000	0.146000	-

*The significance level for all tests is 5%

Table 4: Unit root test of fossil fuel use per capita (FOSS)

Test / statistics	Level			1st difference		
	Intercept	Intercept and trend	None	Intercept	Intercept and trend	None
ADF						
t	−3.559267	−3.057327	−1.053065	−3.100454	−4.103805	−3.143778
P-value	(0.0126)*	(0.1334)	(0.2578)	(0.0366)*	(0.0149)*	(0.0027)*
Phillips-Perron						
t	−3.272940	−2.275362	−0.764131	−3.099765	−4.103805	−3.143778
P-value	(0.0245)*	(0.4349)	(0.3776)	(0.0366)*	(0.0149)*	(0.0027)*
KPSS						
LM stat	0.274653	0.173118*	-	0.528631*	0.089619	-
LM crit	0.463000	0.146000	-	0.463000	0.146000	-

*The significance level for all tests is 5%

This result was also obtained in the Phillips-Perron test. However, according to the KPSS test, there is stationarity only in the original values of the time series.

Similarly, in Tables 2-4, according to the ADF, Phillips-Perron test, the results were obtained in the time series of population growth rate, gross domestic product growth rate and per capita fuel obtained from fossil sources. In these time series, stationarity is also observed in the difference from the 1st degree.

According to the results of the stationarity test, the first preliminary Vector Auto Regression model (VAR model) is constructed to

Table 5: VAR lag order selection criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	38.59877	NA	1.17e-06	−2.306585	−2.119758	−2.246817
1	141.7407	171.9032	3.55e-09	−8.116048	−7.181916	−7.817211
2	173.3157	44.20504	1.34e-09	−9.154383	−7.472946*	−8.616477
3	194.0178	23.46236	1.16e-09	−9.467855	−7.039113	−8.690880
4	226.3940	28.05933*	5.60e-10*	−10.55960*	−7.383551	−9.543554*

perform the cointegration test. To determine the number of lags, after building the model with a maximum of 2 lags by default, we perform a lag rate determination test in the VAR model and determine that the maximum required lag is 2. The stability of the autoregression was tested and the resulting modulus values were <1. According to the model, no serial correlation was observed in the time series. When checking the normality of the residuals, it was observed that there is no normal distribution in the data (P = 0.0002), but according to the Chi-square test, the time series of the residuals are homoscedastic (P = 0.2181).

By conducting VAR lag order selection criteria in the software using logarithmic transformation of the growth rate of gross domestic product per capita (as GDPGH) as a percentage, per capita carbon dioxide emissions (as CO_2PC), population growth rate (as POPGH) and per capita fossil fuel consumption (kilowatt hours) (as FOSS), we obtained the following results in Table 5:

After investigating the table above we can conclude that for variance autoregression model our optimal lag order is 4, as it is obvious.

According to the corresponding results in Tables 6 and 7 obtained from the cointegration analysis, there is at least two cointegration relationship among the most variables. With the cointegration relationship established, the next step is to estimate the Vector Error Correction Model (VECM). VECM allows to analyze how long-term (co-integrated) deviations are corrected over time. It involves using the correction coefficients given by the cointegration to model the short-term dynamics. As we know, our series have trend therefore by including the following variable we got the following OLS regression result:

$$Ln(CO_2PC)_t = -5.940512 - 0.008586 * Trend + 0.761626 * Ln(FOSS) \quad (3)$$

0.501186	0.001139	0.050511
0.0000	0.0000	0.000

It is obvious that our series has significant negative trend. In the above regression output, we got the residuals and by conducting at 0.1% alpha level unit root test in 0 level we got the result that explaining of existing stationarity (t-stat: −4.411222, P = 0.0001). Using the per capita fossil fuel consumption (kilowatt hours) (as FOSS) in the VECM model to predict the amount of carbon dioxide emissions per capita, we obtain the following result:

$$D(Ln(CO_2PC)) = -0.009551 + 0.550081 * D(FOSS) - 0.747372 * RESID(-1) \quad (4)$$

Table 6: Cointegration analysis (unrestricted cointegration rank test [trace])

Unrestricted cointegration rank test (trace)				
Hypothesized No. of CE (s)	Eigenvalue	Trace Statistic	0.05 Critical value	Prob.**
None *	0.852400	108.2706	55.24578	0.0000
At most 1*	0.655219	48.95985	35.01090	0.0009
At most 2	0.378395	15.94961	18.39771	0.1065
At most 3	0.038301	1.210669	3.841465	0.2712

Table 7: Cointegration analysis (unrestricted cointegration rank test [maximum eigenvalue])

Unrestricted cointegration rank test (maximum eigenvalue)				
Hypothesized No. of CE (s)	Eigenvalue	Max-eigen Statistic	0.05 Critical value	Prob.**
None *	0.852400	59.31075	30.81507	0.0000
At most 1*	0.655219	33.01023	24.25202	0.0027
At most 2	0.378395	14.73894	17.14769	0.1084
At most 3	0.038301	1.210669	3.841465	0.2712

0.009585	0.113514	0.164726
0.3270	0.0000	0.0001

Equation (4) is the result of the error correction model. Here −0.7474 lambda coefficient is the speed of error correction. We see that the error correction coefficient standard error is 0.164726 and P = 0.0001. The fact that this coefficient is negative and statistically significant indicates that a 74.74% deviation from the long-term equilibrium is corrected in each period. As can be seen from the 4th regression equations, 0.7474 of the coefficient deviation in the previous period is corrected in the next period. This means that 0.7474 part of 1 per capita carbon dioxide emissions will return to their regular trend relatively quickly.

To further understand the dynamic interactions among per capita CO_2 emissions, economic growth, population change, and fossil fuel consumption in Azerbaijan, we conducted a Forecast Error Variance Decomposition (FEVD) analysis using the estimated VECM model. The purpose of this analysis is to quantify the extent to which each endogenous variable contributes to the forecast error variance of others over time.

4.2.1. Variance decomposition of CO_2 emissions (LN_CO_2_PC)

In the short run (period 1), the forecast variance of per capita CO_2 emissions is entirely explained by its own innovations (100%). However, as the forecast horizon extends to period 5:

- Own past values explain 70.7% of the variation in CO_2 emissions,

- Shocks to GDP growth account for 19.7%,
- Population growth explains 7.0%,
- Fossil fuel consumption contributes only 2.6%.

This finding suggests that CO_2 emissions in Azerbaijan are largely self-reinforcing in the short term but increasingly influenced by economic activity over time — particularly GDP growth.

4.2.2. Variance decomposition of GDP growth

Over five periods, the explanatory power of CO_2 emissions and fossil fuel consumption on GDP increases steadily:

- At period 5, GDP growth itself explains 79.1% of its forecast error,
- CO_2 emissions account for 6.0%,
- Population growth and fossil fuel consumption explain 7.3% and 7.7%, respectively.

This demonstrates a moderate two-way linkage between environmental and economic variables.

4.2.3. Variance decomposition of population growth

Population growth is relatively exogenous, with:

- 63.6% of its variance at period 5 explained by its own innovations,
- CO_2 emissions explain 32.1%,
- GDP and fossil fuel consumption together explain <5%.

This indicates that population growth in Azerbaijan is not heavily influenced by the other macro-environmental factors modeled here.

4.2.4. Variance decomposition of fossil fuel consumption

Interestingly, the variance in fossil fuel consumption is heavily explained by its own shocks in early periods (82.3% at period 1), but this influence diminishes to 62.0% by period 5. Meanwhile:

- CO_2 emissions contribute to 14.8% of the variation,
- GDP growth rises to explain 16.7% of the variance,
- Population growth explains only 6.5%.

These results reinforce the feedback loop between energy usage and macroeconomic growth.

Forecast error variance decomposition of LN_CO_2_PC (Periods 1-5)

Period	CO_2 emissions (%)	GDP growth (%)	Population growth (%)	Fossil fuel use (%)
1	100.0	0.00	0.00	0.00
2	99.6	0.13	0.02	0.21
3	94.0	0.29	2.75	2.97
4	86.3	3.71	7.24	2.78
5	70.7	19.7	6.99	2.57
1	100.0	0.00	0.00	0.00

5. CONCLUSION AND SUGGESTIONS

This study provides compelling empirical evidence of the significant impact that per capita fossil fuel consumption has on carbon dioxide (CO_2) emissions in Azerbaijan. Specifically, regression analysis indicates that a one kilowatt-hour increase in fossil fuel use per capita results in a 0.55 unit rise in total CO_2 emissions. Moreover, the analysis reveals that approximately 75% of the effects of external shocks and policy interventions on CO_2 emissions are absorbed and corrected in the following period, suggesting a high degree of mean reversion and structural stability in the emission patterns. The positive and robust correlation identified between GDP growth and CO_2 emissions implies that economic expansion in Azerbaijan is currently aligned with increased environmental degradation. This confirms a classic growth-environment trade-off and underscores the urgent need for decoupling strategies. Policymakers are advised to promote cleaner growth by investing in green technologies, improving energy efficiency, and accelerating the transition to renewable energy sources. Additionally, the observed positive relationship between population growth and emissions emphasizes the environmental implications of demographic trends. Sustainable urban planning, enhanced public transportation infrastructure, and policies that encourage eco-conscious living could mitigate these effects and help manage the emissions trajectory. Although the short-run effect of fossil fuel consumption on emissions is statistically strong, the relatively weaker long-term elasticity suggests that energy policy should focus not only on consumption levels but also on structural improvements in the energy mix. Enhancing the share of renewables and implementing energy-saving technologies can help achieve long-term environmental goals without necessarily suppressing energy demand. The tendency of both fossil fuel consumption and CO_2 emissions to revert to their long-term trends highlights their predictable dynamics. This predictability enables the formulation of coherent, long-term decarbonization policies with stable expectations about future behavior of key variables.

In addition, this study represents one of the first detailed time series analyses investigating the relationship between income and CO_2 emissions in Azerbaijan. Employing a cubic functional form as guided by the Environmental Kuznets Curve (EKC) literature and addressing small-sample bias through multiple estimation techniques, the findings reveal a long-run U-shaped relationship between income and emissions. However, the turning point of this curve lies beyond the observed sample period (1992-2013), indicating that Azerbaijan has not yet reached the stage where income growth leads to emission reductions. This suggests that the EKC hypothesis does not hold for Azerbaijan in its current phase of development. The persistent one-to-one relationship between income and CO_2 emissions underscores the carbon-intensive nature of Azerbaijan's growth model, particularly given its heavy reliance on energy and extractive industries. In light of this, economic diversification toward lower-emission sectors such as services and digital technologies is critical. To support this transition, a comprehensive policy mix should include fiscal instruments such as carbon taxation, the introduction of emissions trading systems, and investment in carbon capture and storage (CCS) technologies. Ultimately, sustainable economic growth in Azerbaijan will depend on balancing development priorities with environmental imperatives. The findings of this study offer a roadmap for integrating climate-conscious strategies into national development plans and provide a solid empirical foundation for evidence-based policymaking aimed at reducing emissions without stifling economic progress.

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