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Examining Sectoral Contributions and Determinants of Carbon Emission Reduction in Azerbaijan: An Empirical Analysis

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ABSTRACT

This study investigates the dynamics of carbon emissions in Azerbaijan from 1990 to 2020, analyzing trends, influencing factors, and policy implications. Azerbaijan initially exceeded global averages in per capita carbon emissions but has since achieved significant reductions, driven by ongoing policy initiatives and other factors. Sector-specific analyses underscore the energy sector's central role in emissions, highlighting the importance of technological innovation and targeted strategies to achieve sustainable development goals. The industrial sector is the primary energy consumer, relying heavily on crude oil and natural gas. Conversely, advancements in fuel quality and vehicle replacement have resulted in the transport sector, despite its increased energy consumption and pollutant outputs, having relatively lower impacts compared to stationary sources. The research reveals a significant positive relationship between energy consumption in the transport sector and atmospheric pollution. Specifically, a one-unit increase in energy consumption leads to an approximate 0.1548 unit increase in pollutants.

1. INTRODUCTION

Research on the global climate change challenge, a pressing concern for the future of humanity, is progressively expanding globally, including within Azerbaijan. Multiple scientific investigations have been undertaken to examine the environmental impacts of diverse industrial sectors, particularly energy, from the perspective of green economics [1-4]. Despite Azerbaijan's substantial progress in reducing carbon emissions, there remains a gap in detailed econometric and empirical analysis concerning sector-specific contributions and the effects of recent technological advancements. This study aims to bridge this gap by applying an econometric approach to investigate sectoral impacts and evaluate the effectiveness of new technologies and policies.

When viewed from a global perspective, Azerbaijan's emission profile illustrates notable changes in carbon output over recent decades. After the mid-1990s, Azerbaijan achieved substantial reductions in carbon emissions, consistently maintaining levels below the global average. The correlation between a country's economic prosperity and its emission levels is well-established, with wealthier nations generally exhibiting higher emissions compared to less affluent ones. Azerbaijan's emission trends mirror those typical of middle-income countries, emphasizing the economic factors influencing its carbon footprint.

The carbon footprint of Azerbaijan is predominantly influenced by its energy sector, characterized by technological advancements that have significantly reduced emissions from stationary sources involved in oil production, transportation, and refining. Despite efforts to improve fuel quality and shift towards environmentally sustainable vehicles, emissions from the transportation sector remain high. A thorough examination of greenhouse gas emissions across sectors in Azerbaijan emphasizes the substantial role played by the energy sector, which constitutes a significant portion of the country's total emissions. Despite economic expansion, technological innovation has played a critical role in mitigating emissions, highlighting prospects for further reductions through ongoing technological advancements and enhanced efficiency across all sectors. The environmental impact of battery-electric and conventional plug-in hybrid vehicles in Azerbaijan, using qualitative methods to gather insights from automobile industry representatives, vehicle users, pedestrians, and government regulations, highlighting the need for advancements and support for urban mobility and low CO_2 emissions [5].

Based on World Bank data from 1990, Azerbaijan exhibited a notably elevated per capita carbon emissions level at 7.45 tons, surpassing the global average of 3.9 tons [6]. However, in subsequent years, Azerbaijan experienced a substantial reduction in carbon emissions, consistently falling below the global average from 1996 onward. By 2019, Azerbaijan's carbon emissions had decreased to 3.5 tons, while the global average stood at 4.47 tons. The year 2020 witnessed a global decline in carbon emissions, attributable to the widespread impact of the COVID-19 pandemic, with Azerbaijan also registering a significant decrease. In this context, it can be argued that Azerbaijan has, to a certain extent, successfully fulfilled its commitment under the Paris Agreement. Azerbaijan has committed to reducing GHG emissions by 35% by 2030 under the Paris Agreement [7]. Notably, emission levels vary based on a country's income, with high-income countries exhibiting substantially higher emissions compared to low, lower-middle, middle, and upper-middle-income nations (see Figures 1 and 2). Azerbaijan's emission volume aligns closely with the average for middle-income countries.

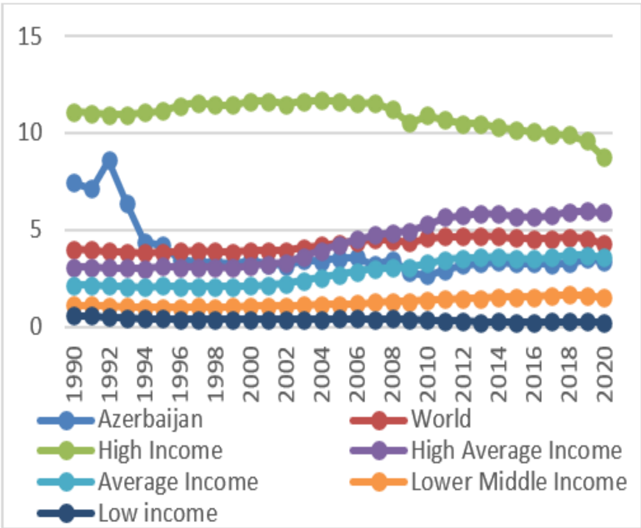

Figure 1. Carbon emissions per person in Azerbaijan and the world (metric tons)
Source: WB (2023) [7]

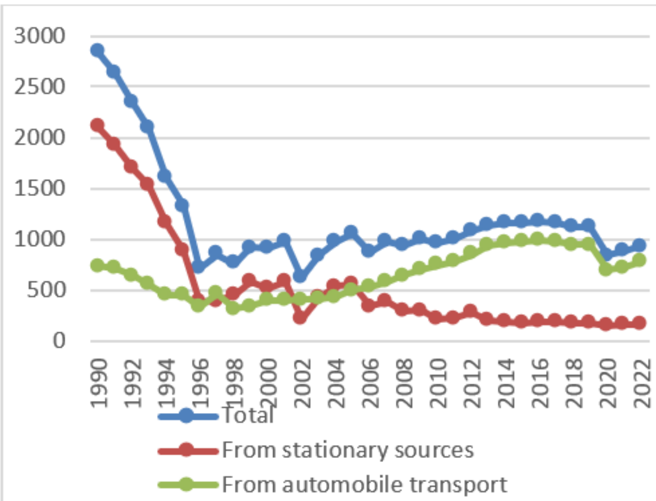

Figure 2. Pollutants released into the atmosphere from stationary sources and road transport (thousand tons)
Source: ARDSK (2023)

2. LITERATURE REVIEW

Many academic studies have explored methods to decrease carbon dioxide emissions within economic systems. Dietz and Venmans [8] explored recent developments in climate science that highlight notable disparities in economic models' assessments of the lag between carbon emissions and warming, and the capacity of carbon sinks to absorb CO_2, emphasizing the urgency of promptly reducing emissions to minimize harm and enhance climate policy effectiveness, advocating for early and assertive escalation of carbon pricing to achieve favorable long-term results. Li et al. [9] found that while research and development (R&D) investment is crucial for reducing carbon emissions, its effectiveness diminishes over time, showing an inverted U-shaped relationship where optimal emission reduction occurs when R&D input reaches 22.91% of a firm's operational expenses, proposing a dynamic model to sustainably manage technological progress for achieving carbon emission reduction targets. Casey and Galor [10] investigated the dual benefits of reducing fertility rates: increasing income per capita and decreasing carbon emissions, challenging conventional trade-offs in climate policies. They found that a 1% slower population growth could potentially raise income per capita by nearly 7% while lowering carbon emissions. Their analysis, including a Nigeria-focused economic-demographic model, projected significant reductions in emissions and increases in income per capita by 2100, highlighting the potential of population policies in addressing global climate challenges. Parker and Bhatti [11] analyzed CO_2 emissions trends across fourteen Asian countries from 1971 to 2017, using a sequential method tied to policy indicators. They found that while per capita CO_2 emissions, energy intensity, carbonization, and per capita incomes showed gradual convergence over the period, the role of per capita income was pivotal in explaining emission dynamics, suggesting caution against overly focusing on carbon intensity targets in climate policy.

Morrow et al. [12] investigated the transportation sector, highlighting its significant oil consumption and GHG emissions, and found that various targeted policy scenarios, including fuel taxes and increased fuel economy standards, are insufficient to achieve the 2020 emission reduction goals. There is a considerable amount of research focused on the automotive sector and its efforts to reduce carbon emissions. Morgadinho et al. [13] explored stakeholder perceptions across European automotive manufacturers, oil, tire, electric battery, IT industries, and academia regarding technological advancements for lowering greenhouse gas emissions from individual passenger vehicles through semi-structured interviews, highlighting the critical role of technological and behavioral factors in reducing fossil fuel consumption and carbon dioxide emissions, and advocating for holistic, inclusive approaches in sustainable mobility policy. Bosupeng [14] examined the impact of the automotive industry on carbon dioxide emissions across various economies from 1997 to 2010, finding long-term associations between passenger car numbers and emissions in several countries, alongside significant relationships between economic output and emissions in multiple nations, underscoring the sector's importance in carbon mitigation policies. Numerous additional articles have addressed strategies for reducing CO_2 emissions within the transportation sector [15-19]. In the context of Mikayilov et al. [20] investigated the effects of energy consumption, real GDP, and population on automobile transport pollution using annual time series data spanning 1990 to 2014. They identified significant impacts of population on transport emissions, noted non-trivial effects of energy consumption, and found a statistically insignificant yet positive influence of real GDP, offering valuable insights for policymaking aimed at mitigating atmospheric pollution from automotive sources.

A comprehensive analysis of the literature will highlight gaps in current research, such as limited exploration of specific regions or sectors and a need for more detailed examination of policy implications. By comparing and contrasting existing methodologies and findings, this review will justify the proposed study's relevance by addressing these gaps and extending previous research, thereby making a significant contribution to future scholarly work and investigations.

3. METHODOLOGY

This study utilizes comprehensive data primarily sourced from the World Bank (WB) and The State Statistical Committee of the Republic of Azerbaijan (In Azerbaijani: ARDSK). The World Bank data provide insights into global trends in carbon emissions and per capita emissions across various income categories, crucial for framing Azerbaijan's emission profile. Meanwhile, ARDSK data, specifically from its annual reports, offer detailed statistics on pollutant emissions from stationary and road transport sources within Azerbaijan.

The research spans from 1990 to 2020, encompassing substantial historical changes in Azerbaijan's carbon emissions and economic indicators. This timeframe allows for a longitudinal analysis of emission trends in the context of economic developments and global environmental policies, such as the Paris Agreement. From 1990 to 2020, this research scrutinizes the enduring trends in Azerbaijan's per capita carbon emissions, aiming to discern evolving patterns and shifts over this significant timeframe.

Regression models are employed to examine the relationship between economic indicators, such as GDP per capita, and carbon emissions, encompassing analysis of both short-term fluctuations and long-term trends. The regression formula employed in this study is presented as follows:

$$\Delta APol_t = \beta_2 \cdot \Delta trans_t + \epsilon_t \quad (1)$$

The term $\Delta APol_t$ signifies how pollutants released into the atmosphere from the transport sector change over time. $\Delta trans_t$ represents how transportation activity, or energy consumption in this sector, changes over time. The coefficient β_2 quantifies the extent and direction of the relationship between changes in transportation activity and changes in pollutants, while ϵ_t accounts for other factors affecting pollutants that are not included in the model. The methodology employed in this study integrates rigorous techniques of data analysis with qualitative insights to thoroughly assess the dynamics of carbon emissions in Azerbaijan.

4. RESULTS

4.1 Understanding emission dynamics, economic development in Azerbaijan, and ınternational comparison

The variation in emission volumes, contingent upon income levels, implies a correlation between emissions and economic development, coupled with energy consumption levels. Higher incomes are associated with heightened energy usage, leading to an escalation in emission levels. An analysis based on 2014 indicators for 175 countries and country groups supports the assertion that an upswing in energy utilization corresponds with an increase in per capita carbon emissions (see Figure 3). Energy consumption spans diverse sectors, encompassing households, industries, and agriculture. Across all sectors, an augmentation in energy usage invariably correlates with an elevation in carbon emissions.

A parallel outcome emerges from a time series analysis conducted for Azerbaijan (see Figure 4). In the interval spanning 1990-2014, per capita energy consumption in terms of oil equivalent surpassed the levels observed between 1990-1995 (3.2-1.8 tons). Concurrently, the per capita carbon emissions underwent a shift from 8.6 metric tons to 4.2 metric tons. Subsequent years witnessed a decline in both these indicators.

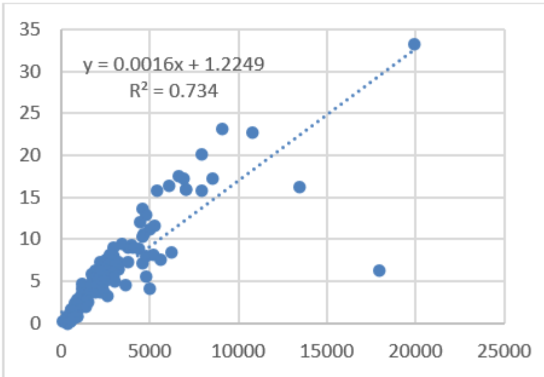

Figure 3. Dependence of the volume of emissions on the volume of energy use (in kg of oil equivalent per capita) (cross-analysis of 175 countries and country groups)
Source: WB [20]

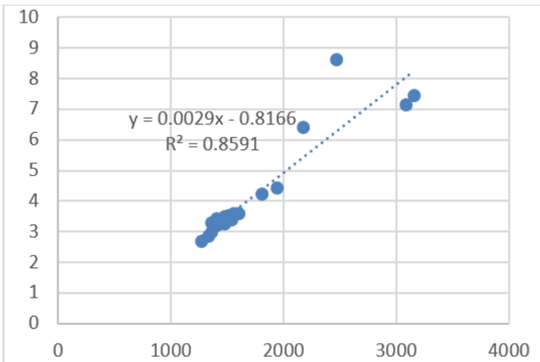

Figure 4. Dependence of the volume of emissions in Azerbaijan on the volume of energy use (per capita in kg of oil equivalent)
Source: WB [21]

Despite Azerbaijan's carbon emissions being lower than the global average, ongoing efforts are being undertaken to further reduce them. Notably, the carbon footprint of the country is significantly influenced by activities related to oil and gas production, processing, and transportation. Additionally, the transport system and electricity production contribute to carbon emissions. The Intergovernmental Panel on Climate Change (IPCC) categorizes greenhouse gases into two groups:

stationary sources and mobile sources [20]. Stationary sources encompass electricity production, industrial enterprises, and construction sites, while mobile sources include various transportation systems utilizing hydrocarbon energy, covering air, land, and water transport.

It is essential to highlight that the ARDSK database in Azerbaijan specifically considers road transport as a mobile pollutant source. Despite substantial activities in oil production, transportation, and refining, the percentage of pollutants released from stationary sources in the overall pollutant volume has consistently declined annually. This reduction is attributed to the implementation of advanced technologies in these sectors. Figure 3 illustrates the emissions dynamics from the stationary source of road transport in Azerbaijan. Notably, the COVID-19 pandemic led to a sharp decrease in emissions from cars in 2020. However, emissions steadily increased from 1997 to 2017. Over the last 16 years, emissions from stationary sources have continued to decrease, while the total emissions from these two sources exhibit a growth trend.

An analysis of emissions contributing to the greenhouse effect across various economic sectors in Azerbaijan reveals the pivotal role of the energy sector. According to the 2021 ARDSK report, the energy sector accounted for 81.2% of the total emissions, equivalent to 53.4 million tons of CO_2. In the same year, the industrial and agricultural sectors constituted 5% and 11.7.6% of the total emission volume, amounting to 3.3 million tons and 7.6 million tons of greenhouse gases, respectively.

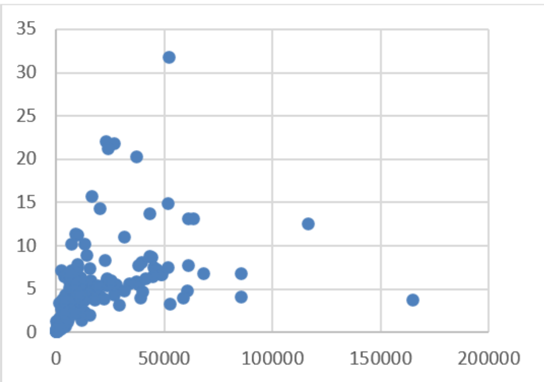

Figure 5. Dependence of per capita carbon emission volume on per capita GDP volume (X-USD, Y-emission volume – metric tons) (235 countries and groups of countries) (2020)

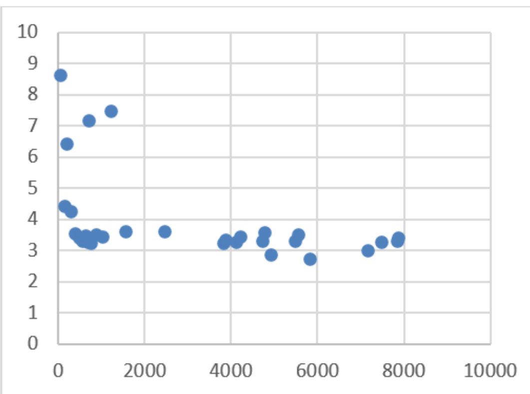

Figure 6. Dependence of carbon emissions per capita on GDP per capita (X-US dollars, Y-emission volume – metric tons) (1990-2020)

The surge in atmospheric greenhouse gases is primarily attributed to human activities, indicating a certain correlation with economic development. However, the increasing influence of innovation in economic progress, coupled with the widespread adoption of advanced technological equipment, particularly in sectors like industry, energy, and agriculture, which contribute significantly to greenhouse gas emissions—has led to positive outcomes in emissions reduction in recent decades. Despite a global positive correlation between greenhouse gas volume and GDP per capita, as demonstrated by cross-analysis of indicators for 235 countries and country groups (see Figure 5), such a relationship is not apparent in the case of Azerbaijan.

Over the period from 1990 to 2020 (see Figure 6), Azerbaijan witnessed an augmentation in GDP per capita in both nominal and real US dollars. Notably, during this timeframe, an initial substantial decline in greenhouse gas volume was observed, succeeded by stabilization within a specific range (2.8-3.6 metric tons). This implies that in Azerbaijan, economic development, as gauged by GDP per capita, has not displayed a direct positive association with increased greenhouse gas emissions. The observed stabilization of greenhouse gas levels despite economic growth can be ascribed to the effective implementation of technological advancements and innovation in sectors prone to high emissions.

4.2 Dependence of the volume of carbon emission in Azerbaijan on the volume of energy use in economic activities

According to ARDSK data (2023a), the industrial sector is the most energy-intensive economic activity in Azerbaijan, consuming over 238 million NET of energy between 2007 and 2022, averaging 14.9 million NET per year. The primary energy sources in this sector are crude oil (including gas condensate) with an average consumption of 6.6 million NET per year, and natural gas with an average of 6.45 million NET per year. In the agricultural sector, 6.9 million NET energy was consumed during the same period, predominantly from diesel fuel (average of 260 thousand NET per year), natural gas (average of 67 thousand NET per year), and electricity (average of 88.8 thousand NET per year). The transport sector consumed 36.6 million NET energy, with car gasoline (average of 1.2 million NET per year) and diesel fuel (average of 768 thousand NET per year) being the dominant energy sources. The construction sector's energy consumption was 5.2 million NET over the period, averaging 325 thousand NET per year, with petroleum bitumen (average of 183 thousand NET per year) and diesel fuel (average of 44.2 thousand NET per year) prevailing.

In communal economy, 10.3 million NET energy was consumed on average 645 thousand NET per year, and households consumed 57.2 million NET (average of 3.6 million NET) energy. Natural gas and electricity were the dominant sources in both sectors, with an average consumption of 175,000 NET natural gas per year in communal economy and 2.8 million NET natural gas in households. Average annual electricity consumption was 416,000 NET in communal economy and 595,000 NET in households.

It is crucial to note that attributing carbon emissions to the types of energy consumed in various economic sectors is not accurate. For instance, using electricity generally results in lower carbon emissions. Therefore, a more accurate assessment involves subtracting the amount of electricity consumed from the total energy consumption. Conversely, the combustion of fuel oil or natural gas for electricity production is a significant contributor to carbon emissions. Additionally, processing automobile gasoline and diesel fuel leads to substantial carbon emissions during consumption (burning). Considering these factors, the analysis of the impact of energy consumption in economic sectors on carbon emissions should not solely rely on one indicator, such as the amount of consumed electricity.

Between 2007 and 2022, stationary sources released various pollutants into the atmosphere, with sulfur anhydride (0.4-6.8%), nitrogen oxides (2.8-14.3%), carbon oxide (2.5-17.9%), volatile organic compounds (0.5-7%), ammonia (0-0.3%), and hydrocarbons (51.2-83%) being the predominant substances. The varying share of pollution by ingredients in different years is linked to changes in the volume of different types of energy used in stationary sources. Technological advancements and the replacement of old equipment with newer ones have led to a decrease in pollutants released into the atmosphere in stationary areas, akin to the trend observed in the industrial sector.

Among the pollutants emitted by road transport, carbon monoxide accounts for approximately 70-80%, nitrogen oxides for 4-12%, and hydrocarbons for 12-18%. Between 2007 and 2016, there was an increase in atmospheric pollutants from the transport sector, followed by a steady decline in the subsequent years. Despite ongoing growth in passenger and cargo volumes and energy consumption in the transport sector (rising from 1,293 thousand NET in 2007 to 3,116.5 thousand NET in 2022, with some exceptions), there has not been a corresponding rise in atmospheric pollutants. This trend can be attributed to three primary factors:

a) Improvements in the quality of energy used in the transport sector.
b) The replacement of older vehicles with newer, more environmentally friendly models.
c) A greater use of less environmentally harmful energy sources.

In the transport sector, automobile gasoline and diesel fuel are the primary energy sources. Despite improvements in the quality of both fuels over the last 15 years, the importation of newer vehicles into the country, and the renewal of a significant portion of the national car fleet, the impact of the transport sector on atmospheric air pollution remains higher than that of stationary sources.

The relationship between the variable ($Trans_t$) and its change $\Delta trans_t$), as well as the volume of pollutants released into the atmosphere ($APol_t$) and its change ($\Delta APol_t$), was examined through regression analysis. To ensure the robustness of the results and avoid a "spurious relationship," it is crucial to assess the stationarity of the time series ($Trans_t$) and ($APol_t$) or, if necessary, their cointegration (Table 1). Table 2 presents information on the stationarity of the time series ($Trans_t$) and ($APol_t$) at degrees I(0) and I(1).

The results indicate that the time series $APol_t$ is non-stationary in all three cases, encompassing scenarios a) with no intercept and trend; b) with an intercept but no trend; and c) when both the intercept and the trend are present. Similarly, the time series $Trans_t$ is non-stationary in all three cases. However, the first difference of the time series $APol_t$, representing the change in pollutants released into the atmosphere, is stationary with 1% confidence in case 1 (absence of intercept and trend). In case 2 (presence of an intercept but no trend), it is stationary with 10% confidence. The time series $Trans_t$, depicting the change in transportation activity, is stationary with 1% reliability in two cases: "intersection and no trend" and "intersection but no trend." It is non-stationary "in the case of both the intercept and the trend."

Table 1. The relationship between the volume of energy consumption in the transport sector ($trans_t$) and its change ($\Delta trans_t$) and, accordingly, the volume of pollutants released into the atmosphere from this source ($Apol_t$) and its change ($\Delta APol_t$)

	$APol_t = \beta_1 + \beta_2 * trans_t + \varepsilon_t$	$\Delta APol_t = \beta_2 * \Delta trans_t + \varepsilon_t$
R^2	0.3955	0.3950
Number of observations	16	15
β_1		
Coefficient	478.6112	0
Standard error	118.1472	0
T-statistics	4.0510	0
P-value	0.0012	0
β_2		
Coefficient	0.1548	0.1658
Standart Error	0.0511	0.0531
T-statistics	3.0265	3.1236
P-value	0.0091	0.0075
Durbin-Watson coefficient	0.3154	1.5140

Note: Calculated by the authors using the eViews software package.

Table 2. Stationarity of the volume of energy consumption ($Trans_t$) and the volume of pollutants released into the atmosphere from this source $APol_t$) in the transport sector

	The Case Where There Is No Intersection and No Trend		**The Case Where There Is an Intersection and No Trend**		**The Case Where There Is an Intersection and a Trend**	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
$APol_t$	-	+(***)	-	+(*)	-	-
$Trans_t$	-	+(***)	-	+(***)	-	+(*)
residuals	+(**)	+(***)	-	-	-	+(**)

Note: Calculated by the author using the eViews software package. (*denotes -10%; **-5%; ***-1% confidence).

Considering the results from Tables 1 and 2, the cointegration of $Trans_t$ and $APol_t$ time series needs to be examined. Calculations reveal that these time series cointegrate in three cases: a) at degree I(0) and I(1) in the absence of an intercept and trend, and b) at degree I(1) in the presence of both intercept and trend. Based on the outcomes, it can be asserted that there exists a positive relationship between the indicators $Trans_t$ and $APol_t$ in both the short and long term. Acknowledging the substantial impact of transportation on atmospheric pollution in the country, continuous renewal of the transport fleet and an increase in electric vehicles are essential measures to mitigate pollution.

5. CONCLUSION

Azerbaijan's trajectory in carbon emissions reflects significant changes influenced by economic development and patterns of energy consumption. This study conducted an ecological-economic analysis to explore the correlation between energy consumption across diverse economic sectors and carbon emissions in Azerbaijan. The findings highlight the crucial importance of regularly updating vehicle fleets and integrating electric vehicles as essential measures in effectively addressing air pollution challenges, particularly within the transportation sector. Despite increased energy usage, there has been a decline in pollutants in the transport sector, credited to advancements in fuel quality, vehicle replacements, and adoption of cleaner energy sources, underscoring the ongoing need for fleet modernization and adoption of electric vehicles to mitigate air pollution. Future strategies should prioritize further efforts to decarbonize key sectors while enhancing resilience to global environmental challenges.

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