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ANALYZING GHG EMISSIONS AND OTHER KEY ECONOMIC DRIVERS IN AZERBAIJAN

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Abstract. A primary challenge in contemporary scientific research revolves around the intricate interplay between economic functioning and environmental considerations. Green economic principles aim to mitigate the impact of key contributors to global climate change within the macroeconomic system, paving the way for a sustainable future. This article delves into the economic and environmental dynamics of Azerbaijan, with a focal point on critical elements including greenhouse gas (GHG) emissions, Gross Domestic Product (GDP), population, the potential for renewable energy and various other economic factors. Least Squares and Vector Autoregression estimates have elucidated the connection between the economic landscape and the driving forces behind greenhouse gas emissions in Azerbaijan. Furthermore, the study indicates the significant impact of population growth, industrial activity and renewable energy consumption on the levels of emissions.

Keywords: *Economics, green economics, macroeconomics, GHG, GDP, time series, regression analysis.*

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1. Introduction

Indicators including GDP, export figures, energy consumption, manufacturing value and population are widely recognized as principal macroeconomic measures on a global scale. The examination of these parameters enables a thorough economic analysis of a chosen country, region or the entire world. Notably, the escalating global issue of climate change has seamlessly integrated economic and ecological considerations into a unified framework (Hasanov, 2023a). In this context, GHG emissions have become a focal point in scientific research, serving as crucial eco-economic data. The contemporary shift of Azerbaijan towards environmentally sustainable strategies has underscored the importance of evaluating this subject throughout the country.

GDP represents the monetary value of ultimate consumer-acquired final goods and services produced within a country's geographic borders over a defined period, like a quarter or a year, encompassing the entirety of the country's output (IMF, 2024). In the global economic landscape of 2021, Azerbaijan was situated as the 87th largest economy based on GDP (current US$). Its international trade activity was notable, ranking 71st in total exports and 103rd in total imports. In terms of individual economic well-being, Azerbaijan was positioned as the 114th country in GDP per capita (current US$). Additionally, the country's economic complexity was recognized by its 85th place in the Economic Complexity Index (ECI), indicating a level of intricacy and diversity in its economic structure (OEC, 2023). In 2022, Azerbaijan experienced a Real GDP (adjusted for inflation) of $51,533,742,962, coupled with a GDP Growth Rate of 4.62%. This growth rate denotes a deviation of $2,501,728,075 from the 2021 level, when the Real GDP amounted to $54,190,742,583 (Worldometer, 2023). In this time frame, Azerbaijan experienced a significant surge of 9.1% in its non-oil GDP, juxtaposed with a decline of 2.7% in the oil GDP. The economic landscape demonstrated a diversified structure, with the industrial sector playing a predominant role, contributing 51.1% to the overall GDP. Additionally, trade and automotive repair accounted for 8.2%, transport and logistics for 6%, construction for 4.8%, agriculture, forestry and fisheries for 4.8%, hospitality services for 1.6%, information and communications for 1.4% and taxes for 7.4% (ITA, 2023).

Azerbaijan, the most dynamic nation in the South Caucasus in demographic development, reached a population of 10 million in 2018, with sustained growth primarily attributed to a surplus of births over deaths, while external migration's impact remains insignificant. Urban areas house 52.8% of the population (UNFPA, 2020).

Azerbaijan stands out for its significant potential in renewable energy, boasting a technical capacity of 135 GW for onshore and 157 GW for offshore sources. The economic potential is estimated at 27 GW, encompassing 3,000 MW in wind energy, 23,000 MW in solar energy, 380 MW in bioenergy and 520 MW from mountain rivers. Despite being a prominent global energy exporter, Azerbaijan places notable emphasis on the adoption and development of renewable energy sources (Minenergy, 2023). Azerbaijan's renewable energy potential holds substantial advantages for the country. Embracing renewable sources would preserve natural gas for exports and the petrochemical industry, align with the commitment to reduce greenhouse gas emissions as per the 2030 Paris Agreement and enhance electricity security by diversifying the generation mix. As part of planned energy market reforms, the government has formulated a renewable electricity law, with the target of achieving a 30% share of renewable energy in electricity generating capacity by 2030, nearly doubling the 2018 share of 16% (IEA, 2023).

Azerbaijan's contribution to global GHG emissions is relatively minor, accounting for approximately 0.15% of the total. Specifically, the predominant sources within the country's emission profile are the energy sector, comprising 74% and the agriculture sector, representing 14% (Eu4climate, 2023). These sectors collectively constitute the primary contributors to Azerbaijan's overall GHG emissions. Azerbaijan has set a target to reduce its GHG emissions by 35% by 2030, using 1990 as the baseline year. Additionally, in 2021, the country reinforced its commitment by aiming for a 40% reduction in GHG emissions by 2050, although the specific reference year for this target was not explicitly specified (Enerdata, 2023).

The graphs depicted in Figure 1 illustrate the trajectory of GHG emissions, the trend in GDP and various other economic and social factors in Azerbaijan spanning the past 25 years.

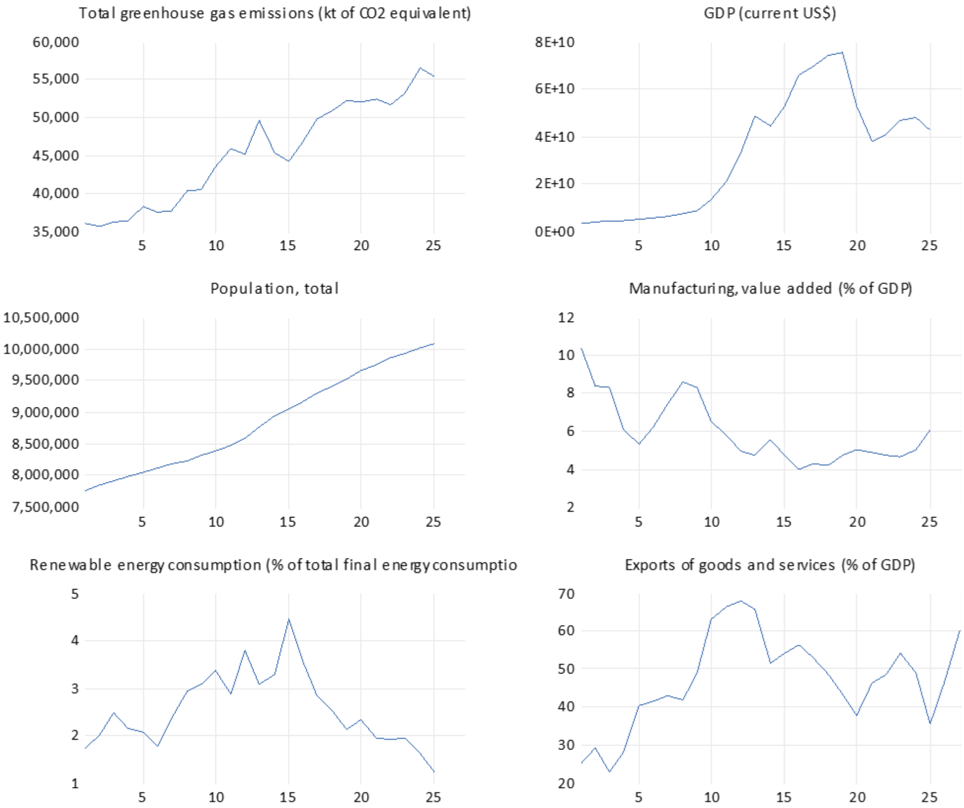

Figure 1. Macroeconomic and environmental trends in Azerbaijan (1996-2021).
Source: World Bank

The eco-economic system places considerable importance on indicators such as manufacturing value and export. Notably, recent years have witnessed substantial advancements in modern innovation, robotics, and artificial intelligence research, all of which have played a constructive role in promoting principles aligned with sustainable and green practices (Eaton, 2013; Wagner *et al*., 2001; Yatsun *et al*., 2004a; 2004b). The advancement of sustainability objectives heavily relies on the active involvement of global business entities and scientific foundations (Hasanov, 2023b). Within the intricate interplay of economic development and environmental sustainability, there has been a notable focus on understanding the relationship between GHG emissions and GDP. As nations actively pursue economic growth, there is a growing concern regarding the environmental implications and the feasibility of disentangling economic activities from carbon emissions. The intricate relationship between GHG emissions and GDP is a subject of extensive debate. While economic growth frequently relies on activities that generate GHGs, such as energy consumption and industrial production, indicating a positive correlation, the association is multifaceted and nuanced. This scholarly article delves into the nuanced dynamics that characterize the relationship between GHG emissions and GDP, thoroughly examining the complexities and addressing challenges.

2. Literature Review

Economic development, particularly the escalation of industrial production, triggers concurrent growth across various sectors. Addressing the challenge of global climate change necessitates a form of economic development that safeguards the environment. Consequently, the ongoing predicament stands as one of the most pressing issues in contemporary scientific discourse, with numerous studies in the scientific literature dedicated to exploring this imperative direction.

Azevedo *et al*., (2018) scrutinized the magnitude of CO_2 emissions in relation to both the time lag of emissions and the GDP for the BRICS countries. Cifci & Oliver (2018) utilized standard regression techniques to investigate a multi-country dataset that includes GHG emissions, GDP per capita growth and various other factors. In their study, Huang *et al*., (2018) identified a quasi-L-shape curve pattern in the association between economic development and GHG emissions in Economies in Transition (EITs), producing substantial "hot air". Additionally, their analysis of single-country time series and GDP data refuted the applicability of the Environmental Kuznets Curve (EKC) hypothesis for GHG emissions in the majority of Annex II countries. Achiele & Felbermayr (2012) applied a Differences-in-Differences (DiD) methodology to assess the changes in CO_2 emissions, carbon footprints and carbon embodied in imports for a group of 40 countries before and after the ratification of the Kyoto Protocol (KP). Haberl *et al*. (2020) systematically reviewed and categorized policies in the decoupling literature into three groups: Green growth, Degrowth and Others. Their conclusion highlights the improbability of achieving substantial and rapid absolute reductions in resource use and greenhouse gas emissions solely through observed decoupling rates. They advocate for the integration of decoupling with sufficiency-oriented strategies and the strict enforcement of absolute reduction targets. Additionally, the authors underscore the need for further research to explore the intricate interdependencies between well-being, resource consumption and emissions.

In alignment with the prevailing research trajectory, numerous scholars in Azerbaijan have contributed to the scientific literature on the subject. In their study, Mikayilov *et al*. (2018) delved into the relationship between economic growth and CO_2 emissions in Azerbaijan. The analysis covered the period from 1992 to 2013, employing cointegration analysis. To ensure robust findings, the researchers utilized a range of methodologies, including Johansen, ARDLBT, DOLS, FMOLS and CCR methods, to investigate cointegration and estimate long-run coefficients. In the contemporary period, several researchers have engaged in green economic studies in Azerbaijan (Gasimli *et al*., 2022; Hasanov & Safarli, 2023). Hasanov (2023c) conducted a comprehensive evaluation of the current state of the renewable energy sector in Azerbaijan in his article.

3. Methodology

The focal variable under examination, Total Greenhouse Gas Emissions (GHG), is quantified in terms of carbon dioxide equivalent (CO_2). The variables considered as predictors in this analysis encompass GDP denominated in current USD, Population (POP), Manufacturing Value expressed as a percentage of GDP (MANU), Exports of Goods and Services as a percentage of GDP (EXPO) and Renewable Energy Consumption (CONS). The selection of these variables is predicated on their perceived capacity to influence greenhouse gas emissions. This section on methodology articulates the intricacies of the data selection process and elucidates the regression model formula earmarked for application in scrutinizing the intricate relationships among the variables. The data pertaining to both the dependent and independent variables were meticulously sourced from reputable repositories, namely the World Bank (2023) and The State Statistical Committee of the Republic of Azerbaijan (2023).

The examination of the association between the dependent variable, Total Greenhouse Gas Emissions and the independent variables will be conducted through the application of a multiple linear regression model. The overarching structure of the regression equation is expressed as:

$$Y = \beta 0 + \beta 1\ X1 + \beta 2\ X2 + \beta 3\ X3 + \beta 4\ X4 + \beta 5\ X5 + \epsilon$$

In the context of the model, Y symbolizes the dependent variable, where β0 stands for the intercept term, β1 to β5 represent the coefficients corresponding to each independent variable (X1 through X5) and ϵ encompasses the error term, incorporating unobserved factors that are not explicitly included in the model. According to this formula we place data subsequently as following:

$$GHG = \beta 0 + \beta 1\ GDP + \beta 2\ EXPO + \beta 3\ MANU + \beta 4\ POP + \beta 5\ CONS + \epsilon$$

To conduct the econometric analysis, the current formula is converted into a logarithmic form and a regression model is implemented. As part of the testing process, the Least Squares and Vector Autoregression Estimates methods are employed.

$$\ln(GHG) = \ln(\beta 0) + \beta 1 * \ln(GDP) + \beta 2 * \ln(EXPO) + \beta 3 * \ln(MANU) + \beta 4 * \ln(POP) + \beta 5 * CONS + \ln(\epsilon)$$

4. Results

Table 1 presents the outcomes of Least Square techniques, utilizing natural logarithm-transformed variables, including GHG emissions (LNGHG), GDP (LNGDP), population (LNPOP), manufacturing as a percentage of GDP (LNMANU), exports as a percentage of GDP (LNEXPO) and renewable energy consumption (LNCONS). The regression coefficient is 0.0793, which means that a 1% increase in Gross Domestic Product leads to a 0.0793% rise in long-lived greenhouse gas emissions. This observed correlation is statistically significant and suggests that economic growth acts as a significant driver for the increase in greenhouse gas emissions within the scope of this analytical framework. In the other variables, population growth is significantly associated with higher LNGHG emissions, while an increased share of manufacturing in GDP and a higher share of renewables both demonstrate statistically significant associations with emissions, suggesting the potential impact of industrial activities and renewable energy consumption on emissions levels. However, the relationship between exports as a share of GDP and emissions is inconclusive in this model.

Table 1. Least Squares Method.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-3.864822	3.676087	-1.051341	0.3063
LNGDP	0.079330	0.023188	3.421129	0.0029
LNEXPO	0.108440	0.031722	3.418489	0.0029
LNMANU	0.095146	0.045188	2.105538	0.0488
LNPOP	0.763819	0.259460	2.943877	0.0083
LNCONS	-0.114723	0.038656	-2.967819	0.0079

Table 2 presents the results of a Vector Autoregression (VAR) analysis. The coefficients in the LNGHG rows elucidate the degree to which a one-unit change in each independent variable corresponds to variations in GHG emissions. For instance, an increase in LNGDP is associated with a rise in LNGHG, suggesting that economic growth may contribute to an increase in emissions. Furthermore, the coefficients below the LNGDP rows explicate how changes in other factors, such as population or manufacturing, are linked to variations in GDP. Positive coefficients indicate direct associations, while negative coefficients indicate inverse relationships. The model exhibits an R-squared value of 0.970843, signifying its ability to account for approximately 97% of the variability in LNGHG. The VAR analysis indicates that GHG emissions are primarily influenced by economic growth, population expansion and the utilization of renewable energy. However, the relationship between manufacturing, exports and emissions appears intricate, necessitating additional scrutiny for a comprehensive understanding.

Table 2. Vector Autoregression Estimates.

	LNGHG	LNGDP	LNMANU	LNPOP	LNEXPO	LNCONS
LNGHG(-1)	0.375699	-1.795687	0.156994	0.027691	0.742408	-3.046377
	(0.26987)	(0.95644)	(0.61603)	(0.01974)	(0.90840)	(0.99503)
	[1.39216]	[-1.87746]	[0.25485]	[1.40242]	[0.81727]	[-3.06159]
LNGHG(-2)	0.146528	2.537515	-3.357750	0.014440	3.600548	1.715295
	(0.37956)	(1.34520)	(0.86642)	(0.02777)	(1.27763)	(1.39947)
	[0.38605]	[1.88634]	[-3.87541]	[0.51998]	[2.81816]	[1.22567]
LNGDP(-1)	0.037536	0.868881	-0.105167	0.006515	-0.538819	0.335232
	(0.10226)	(0.36243)	(0.23343)	(0.00748)	(0.34422)	(0.37705)
	[0.36706]	[2.39740]	[-0.45052]	[0.87078]	[-1.56533]	[0.88909]
LNGDP(-2)	0.015832	-0.237854	0.486675	-0.003635	-0.209223	-0.016968
	(0.11714)	(0.41518)	(0.26741)	(0.00857)	(0.39432)	(0.43193)
	[0.13515]	[-0.57290]	[1.81996]	[-0.42411]	[-0.53059]	[-0.03928]
LNMANU(-1)	-0.060660	-0.176177	0.680908	-0.003627	-0.033365	1.247220
	(0.14388)	(0.50993)	(0.32844)	(0.01053)	(0.48431)	(0.53050)
	[-0.42160]	[-0.34549]	[2.07317]	[-0.34458]	[-0.06889]	[2.35102]
LNMANU(-2)	0.113296	0.256500	0.308793	-0.000891	-0.781618	-0.308639
	(0.16563)	(0.58700)	(0.37808)	(0.01212)	(0.55751)	(0.61068)
	[0.68405]	[0.43697]	[0.81675]	[-0.07351]	[-1.40198]	[-0.50540]
LNPOP(-1)	-9.768561	-12.35858	6.257637	1.116596	-15.39417	13.76128
	(3.80817)	(13.4966)	(8.69298)	(0.27862)	(12.8186)	(14.0411)
	[-2.56516]	[-0.91568]	[0.71985]	[4.00754]	[-1.20092]	[0.98007]
LNPOP(-2)	10.09322	14.26802	-6.795712	-0.213365	16.04162	-15.33815
	(3.48375)	(12.3468)	(7.95242)	(0.25489)	(11.7266)	(12.8450)
	[2.89723]	[1.15560]	[-0.85455]	[-0.83709]	[1.36797]	[-1.19410]
LNEXPO(-1)	0.031734	0.295647	0.577051	0.000488	0.422374	0.660055
	(0.07696)	(0.27277)	(0.17569)	(0.00563)	(0.25906)	(0.28377)
	[0.41233]	[1.08388]	[3.28458]	[0.08660]	[1.63038]	[2.32601]
LNEXPO(-2)	0.031797	0.150222	0.244395	-0.004505	-0.268321	-0.281234
	(0.14540)	(0.51530)	(0.33190)	(0.01064)	(0.48942)	(0.53609)
	[0.21869]	[0.29152]	[0.73636]	[-0.42347]	[-0.54825]	[-0.52460]
LNCONS(-1)	0.028034	0.209520	-0.616003	0.006785	0.943570	0.010675
	(0.08395)	(0.29754)	(0.19164)	(0.00614)	(0.28259)	(0.30954)
	[0.33393]	[0.70418]	[-3.21436]	[1.10457]	[3.33898]	[0.03449]
LNCONS(-2)	-0.019300	0.472444	-0.598984	-0.005441	0.707962	0.385929
	(0.07566)	(0.26814)	(0.17270)	(0.00554)	(0.25467)	(0.27896)
	[-0.25510]	[1.76193]	[-3.46825]	[-0.98284]	[2.77992]	[1.38347]
C	-1.553081	-31.90642	31.71082	1.058054	-35.71624	29.23731
	(7.00369)	(24.8220)	(15.9875)	(0.51242)	(23.5750)	(25.8234)
	[-0.22175]	[-1.28541]	[1.98348]	[2.06480]	[-1.51500]	[1.13220]
R-squared	0.979538	0.995046	0.956713	0.999668	0.932744	0.938958
Adj. R-squared	0.954983	0.989102	0.904769	0.999270	0.852037	0.865709
Sum sq. resids	0.009200	0.115561	0.047940	4.92E-05	0.104242	0.125073
S.E. equation	0.030332	0.107499	0.069239	0.002219	0.102099	0.111836
F-statistic	39.89190	167.3919	18.41808	2508.976	11.55718	12.81857
Log likelihood	57.34085	28.23913	38.35739	117.4868	29.42458	27.32943
Akaike AIC	-3.855726	-1.325141	-2.204991	-9.085808	-1.428224	-1.246038
Schwarz SC	-3.213925	-0.683340	-1.563190	-8.444007	-0.786423	-0.604237
Mean dependent	10.73062	23.89828	1.705809	16.00335	3.843419	0.908473
S.D. dependent	0.142957	1.029746	0.224367	0.082110	0.265427	0.305181

The models demonstrate a commendable fit, elucidating a significant proportion of the variability in the dependent variable. Across all models, the F-statistic attains statistical significance, affirming the models' overall statistical relevance. Notably, the model featuring LNEXPO(-1) as the independent variable stands out as superior, as evidenced by lower AIC and SC values, indicating greater parsimony and generalizability compared to alternative models. Moreover, it is noteworthy that this analysis is conducted solely on data from a single country, whereas a more comprehensive examination could involve multiple regression analyses across various countries. The overarching objective is to discern the broader landscape of these indicators on a global scale. The analysis's shortcomings stem from its narrow dataset, undermining the generalizability of findings, and its failure to account for pertinent factors in elucidating LNGHG. Furthermore, the potential overfitting of models poses a risk, potentially undermining their effectiveness when applied to new datasets. When interpreting the regression analysis results, it's vital to acknowledge some limitations and consider alternative analytical approaches better suited to the available data. Further research is imperative to gather additional data and explore the potential influence of other relevant factors on LNGHG for a more comprehensive understanding.

5. Conclusion

To encapsulate the essence of the regression analysis, it can be asserted that GDP, population size, manufacturing output and the utilization of renewable energy collectively emerge as consequential factors shaping the levels of greenhouse gas emissions. The outcomes imply that greenhouse gas emissions in this model are predominantly influenced by GDP, population growth and the share of manufacturing in GDP. Additionally, the adoption of renewable energy emerges as an effective strategy for mitigating emissions, highlighting the importance of sustainable energy practices in addressing environmental concerns. This study scrutinizes the determinants of GHG emissions in Azerbaijan, particularly focusing on their association with economic growth. Statistical analyses, incorporating Least Squares and Vector Autoregression models, reveal a positive correlation between economic growth and GHG emissions, highlighting economic growth as a significant driver with a 0.0793% increase in emissions for every 1% rise in GDP, while also emphasizing the noteworthy influence of population growth and renewable energy consumption.

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