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THE RELATIONSHIP BETWEEN OIL PRODUCTION AND RENEWABLE ENERGY CONSUMPTION IN AZERBAIJAN (2005-2024)

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Abstract: *This study investigates the relationship between oil production, renewable energy consumption, and economic growth in Azerbaijan from 2005 to 2024, offering empirical insights into the country's dual energy structure and diversification challenges. As a hydrocarbon-dependent yet renewable-resource-rich nation, Azerbaijan represents a distinctive case for assessing whether oil wealth supports or hinders the transition toward sustainable energy. The research aims to evaluate how oil production and renewable energy variables interact with each other and with economic growth, thereby determining whether the country's development trajectory reflects complementarity or substitution between fossil and renewable resources. Using annual time-series data from the State Statistical Committee of Azerbaijan and the World Bank, the study applies descriptive statistics, Pearson correlation, hypothesis testing, and linear regression analysis to examine the strength and direction of these relationships. The results reveal a statistically significant positive correlation between oil production and the share of renewables in total energy consumption, suggesting that oil revenues may be reinvested into renewable projects, indicating a complementary rather than competing dynamic between the two sectors. In contrast, the weak correlations between GDP and energy variables imply that economic growth has become partially decoupled from short-term energy fluctuations. These findings highlight the potential for resource-rich economies to leverage hydrocarbon income to accelerate renewable energy deployment. The paper concludes that integrated policy planning, institutional strengthening, and targeted reinvestment of oil revenues are essential to achieving a balanced and sustainable energy transition in Azerbaijan.*

Keywords: *Renewable energy, Oil production, Economic growth, Azerbaijan, Energy diversification*

1. Introduction

Energy resources are of paramount importance when it comes to global sustainable economic growth and development. Current trends also underscore this dependency that sustaining economic progress will require a growing demand for energy resources. This demand is further enhanced by the rapid population growth in developing countries, which in turn intensifies the aforementioned dependency on conventional energy sources within existing systems (Hajizade, 2021; Mukhtarov et., 2020). As energy sources are the primary input materials in production, exchange, and distribution across virtually all sectors, their role in supporting economic performance is undeniable. In this regard, expansion of economic activity with increased production of goods and services will come in parallel with even higher levels of energy consumption (Zhe, et., 2021).

Meanwhile, growing energy demand has also led to rising concerns over climate change issues. International Energy Agency (IEA) reports that compared to pre-industrial levels, CO2 emissions have increased by almost 50%, mainly driven by the combustion of fossil fuels (IEA, 2025). Consequently, global warming issues are also heightened by this continuous energy demand growth (Inal et., 2022). According to the British Petroleum Energy Outlook 2025 report, global final energy consumption is currently at 511 exajoules (EJ) and will reach 572 EJ by 2050, assuming current trends prevail (BP, 2025). As mentioned earlier, the use of fossil fuels accounts for the main part of the global carbon dioxide emissions and contributes to the escalation of climate change issues, especially global warming. Despite their environmentally harmful effects, the traditional fossil fuels remain dominant in the global energy mix (Mukhtarov et., 2020). Whereas, renewable energy resources, such as wind, solar, hydropower, geothermal and biomass are environmentally non-degrading and naturally non-depletable. Hence, a more extensive use of these alternatives can significantly alleviate the carbon emission problem (Zhe, et., 2021). Additionally, the oil price volatility also enhances the appeal of renewable energy resources, as countries explore ways to decrease dependency on oil and manage sensitivity to price shocks (Deniz, 2019).

The use of renewable energy resources not only mitigates the effects of climate change but also enhances energy security and provides further economic and social benefits (Edenhofer et., 2011). The International Energy Agency nominates renewable energy resources as the only effective pathway to decarbonizing the energy mix and reducing reliance on fossil fuels (IEA, 2014). These resources are sustainable and continuous by their nature, derived from naturally occurring elements, which makes their wider application economically strategic. Therefore, renewable energy resources are to be a driver of long-term economic growth, boosting energy security and independence, on top of being an environmental necessity (Yuksel et., 2020).

For governments, increasing the share of green and renewable energy resources in national energy mixes can translate into reduced dependency on finite resources, a diversified economy, and contributions to the adoption of environmentally clean technologies, new employment opportunities and sustainable economic development and GDP growth (İnternational Renewable Energy Agency, 2019; Yuksel et., 2020). Additionally, renewable energies can stimulate financial sector development and strengthen the relationship between renewable energy use and financial growth by attracting financial investments to the country (Zhe, et., 2021). Over the past four decades, rising global energy use and increasing worries about climate change, fossil fuel exhaustion, and pollution have led to a growing agreement worldwide on the necessity for alternative, clean, and renewable energy sources.

Overall, the importance of renewable energy has grown significantly due to the increasing need for energy security and addressing climate change. As energy consumption rises, it brings negative consequences like increased greenhouse gas emissions and environmental harm. In this scenario, renewable resources are emerging as a practical option for creating cleaner, more resilient global energy systems, offering a sustainable and cost-effective alternative to fossil fuels. (Alnifro et, 2017). The recent trends suggest that the share of renewables in global electricity generation and capacity installations has substantially increased. However, high initial costs, financing gaps and limited policy support continue to pose a significant challenge to their widespread use. That said, few major oil exporters have already demonstrated commitments to diversifying their energy mix by investing in solar, wind and geothermal power projects (Bahrami and Abbaszadeh, 2013).

The Republic of Azerbaijan presents a particularly compelling case study for examining the nexus between oil production and renewable energy development. Country is located in a geographically advantageous area, therefore, it is rich with both renewable and non-renewable energy resources. From the 19th century, with the discovery of oil and gas resources in offshore deposits in the Caspian Sea and onshore fields, Azerbaijan gained a major economic advantage and its economy improved over the years. During this period, the oil and gas sector was responsible for the majority of the income in the annual fiscal budget, which account for 48.35% state budget revenue and 88.21% of total export in 2024. Conversely, dependence on fossil fuels creates environmental degradation, climate change, and energy shortages. Also with global sensitive demand, fluctuations in oil prices and limited resource capacity, the sustainability of continuous development is uncertain. However, Azerbaijan has great potential for renewable energy resources due to its favorable geographical location with rich energy resources. There are wind, solar, water, and biomass resources in various regions of the country. According to calculations, the potential for renewable energy resources in the entire country is approximately 27,000 MW. (Hajizade, 2023). The share of existing energy resources in circulation is lower than the total potential, approximately only 0.5 percent of the total energy potential. (Hajizade, 2020). Still, the country has also demonstrated significant commitment to renewable energy development, with the government setting ambitious targets to generate 30% of electricity from renewable sources by 2030 (Ministry of Energy of Azerbaijan, 2023). This provides additional context for renewable energy development possibilities. This dual energy profile makes Azerbaijan an ideal laboratory for understanding whether oil wealth facilitates or constrains renewable energy adoption.

Despite the growing literature on energy transitions in resource-rich economies, the relationship between oil production and renewable energy development remains theoretically ambiguous and empirically underexplored, particularly in the context of post-Soviet oil producers. For Azerbaijan specifically, an insufficient amount of empirical research exists on the quantitative relationships between these energy variables and economic performance. Shifting to renewable energies is crucial, especially for oil-producing nations in order to mitigate ecological and economic issues created by reliance on fossil fuels (Belloumi and Aljazea, 2024). Renewable energy technologies offer a solution to decrease energy costs and emissions, and preserve oil and gas resources for higher-value uses. Hence, it is vital to investigate renewable energy consumption and drivers influencing its trajectory. The main agents affecting countries' renewable energy consumption levels are country-specific macroeconomic factors, such as crude oil prices, oil rents, oil production, and net energy imports (Makki, 2024).

The purpose of this research paper is to understand the dynamics of renewable energy consumption, within the broader context of economic and energy production variables, specifically examining the interrelationships between Gross Domestic Product (GDP), oil production, and renewable energy consumption in Azerbaijan. The analysis is conducted within the time frame of 2005 to 2024, capturing both the oil boom years and the recent renewable energy expansion phase, helping to understand how these factors interact and influence one another in the evolving energy consumption ecosystem and economic development.

The paper investigates the following research questions: (1) What is the nature and strength of the relationship between oil production levels and renewable energy consumption in Azerbaijan? (2) How do oil production and renewable energy variables correlate with economic growth as measured by GDP? (3) Does oil production suppress or complement renewable energy development? Based on these questions, subsequent hypothesis questions are formulated:

- H_1 - Is there a statistically significant correlation between Azerbaijan's GDP and oil production levels during 2005 _2024?
- H_2 - Does GDP have a significant correlation with renewable energy generation in Azerbaijan over the study period?
- H_3 - Is there a meaningful linear relationship between GDP and the share of renewable energy in total energy consumption?
- H_4 - Is oil production significantly correlated with renewable energy generation in Azerbaijan between 2005 and 2024?
- H_5 - Does oil production show a statistically significant correlation with the renewable energy share in the national energy mix?
- H_6 - Is there a significant relationship between renewable energy generation and its share of total energy supply in Azerbaijan?

This study makes several contributions to the energy economics literature. First, it provides the quantitative analysis of the oil-renewable energy nexus in Azerbaijan using two decades of data (2005-2024), offering empirical evidence for theoretical debates about resource complementarity versus substitution. Second, it employs different statistical methods including correlation analysis and regression modeling to establish the strength and significance of relationships between energy variables and economic performance. The rest of the paper is organized as follows: Section 2 reviews the relevant literature; Section 3 describes the data and the methodology; Section 4 presents the findings and discussion; Section 5 gives a conclusion and Section 6 lists references.

2. Literature Review

The global transition to renewable energy has stimulated a large amount of empirical literature studying the determinants of renewable energy consumption (REC), the association between REC and financial development, oil dependence and economic growth. The literature reviewed shows considerable variations in the results across country groups, which is consistent with differences in institutional quality, technological capacity, and resource endowment. This section combines the findings of 17 empirical studies (see Table 1), focusing largely on oil-exporting and resource-dependent economies.

Table 1. *Summary of the empirical studies*

Study	Time Period	Country	Method(s)	Variables	Results
Li et al. (2021)	1990-2015	Turkey	VAR	REC, FD, GDP	Bidirectional causality between FD and REC
Ericson, Engel-Cox and Arent (2019)	N/A	Oil & gas operations (global)	Qualitative case analysis	RE Integration technologies	REC reduces costs and CO_2
Inal et al. (2022)	1990-2014	10 African oil-producing countries	Panel econometric tests	GDP, REC, CO_2	No significant LR effect on REC and CO_2
Awodumi and Adewuyi (2020)	1980-2015	5 African oil-producing economies	NARDL	Petroleum and natural gas consumption, GDP, CO_2	LR asymmetric effects between oil prices and REC
Belloumi and Aljazea (2024)	1990-2020	13 major oil-exporting countries	PMG-ARDL, DOLS	GDP growth, REC, FD, CPI	Positive LR relationships, SR insignificant
Aidarova et al. (2024)	1990-2024	OPEC member countries	Panel ARDL (PMG)	GDP pc, Oil exports, REC	Positive LR between Oil export and GDP, negative LR between REC and GDP
Makki et al. (2023)	2004-2015	44 countries	FMOLS, DOLS, Granger	REC, FDI, GDP	Positive
Ackah and Kizys (2014)	1980-2010	12 African oil-producing countries	FE/RE_1, GMM	REC, CO_2, GDP, labor, caapital, energy price	Presence of asymmetric relationship between variables
Guliyev (2024)	2004-2022	Azerbaijan and Kazakhstan	Comparative policy analysis	GDP, FDI, Energy transition policy	Positive link between governance quality and RE share, stronger in KZ
Rong G. and Qamruzzaman M. (2022)	1990-2021	U.S., China, India, Japan and S.Korea	Linear & NARDL, Bayer-Hanck, Granger	REC, EPU, Oil price volatility, tech innovation	Bidirectional causality, Positive effects of oil prices and innovation on REC, EPU negative
Pagliaro et al. (2021)	2013-2019	Russia	Qualitative analysis	Energy transition, EV uptake, Storage innovation	Slow RE growth; fossil dominance and institutional barriers persists
Deniz (2019)	1995-2014	Oil-importing countries	FE (LSDV), GMM, Panel VAR	Oil price, GDP pc, CO_2, trade openness, REC	Asymmetric effects across countries
Bahrami and Abbaszadeh (2014)	1971-2010	Iran	Descriptive analysis	Installed renewables capacity, policy targets	RE growth slow, limited diversification
Makki et al. (2024)	1990-2018	24-country panel	Panel regression (FE, SUR)	REC, GDP growth, oil price, inflation, income	Asymmetric effects across variables
Zhang et al. (2020)	1990-2018	Germany	ARDL, Cointegration	Crude oil imports, REC, trade openness	Transport and industry raise oil imports; REC lowers oil dependence
Tambari, Failler,and Jaffry (2023)	1990-2021	10 African countries	P-VECM, System GMM	RE generation, GDP, oil prices, interest & exchange rates	Asymmetric effects of oil prices, Positive relationship between GDP and RE
Mukhtarov et al. (2020)	1993-2018	Azerbaijan	ARDL, VECM, Toda-Yamamoto	REC, FD, GDP pc, CPI	Bidirectional causality between GDP, FD and REC

Legend: *ARDL = Autoregressive Distributed Lag; CO_2, = Carbon Dioxide Emissions; CPI = Consumer Price Index; DOLS = Dynamic Ordinary Least Squares; EPU = Economic Policy Uncertainty; FDI = Foreign Direct Investment; FD = Financial Development, FE = Fixed effects, FMOLS = Fully Modified Ordinary Least Squares; GMM = Generalized Method of Moments; GDP = Gross Domestic Product; LSDV = Least Squares Dummy Variable model; LR = Long-run, NARDL – Nonlinear Autoregressive Distributed Lag; pc = per capita; P-VECM = Panel Vector Error Correction Model; PMG = Pooled Mean Group; RE = Renewable Energy ; REC = Renewable Energy Consumption; RE_1 = Random Effects; SR = Short-run; SUR = Seemingly Unrelated Regression; VAR = Vector Autoregression; VECM = Vector Error Correction Model*

2.1 Financial Development, Economic Growth, and Renewable Energy Nexus

An increasing number of studies have examined the relationship between financial and economic development and renewable energy consumption (REC).

Li et al. (2021) addressed the interrelationships between REC, financial development, and economic growth in Turkey for the years 1990–2015 using a VAR framework. Their findings showed bidirectional causality between financial development and REC, but neither had a significant impact on economic growth, indicating that the financial systems have limited integration in supporting renewables. Likewise, Belloumi and Aljazea (2024) examined 13 oil-exporting countries for the years 1990 and 2020 by applying PMG-ARDL and DOLS, and found that in the long-run both economic growth and financial development have a positive impact on REC but in the short-run both impacts are statistically insignificant

Mukhtarov et al. (2020) produced country-specific results for Azerbaijan using ARDL bounds testing and Toda-Yamamoto causality analysis for 1993 – 2015. They found both financial development and economic growth increases REC significantly and increases in energy prices constrain it. Additionally, they identified bidirectional causation between financial development and renewable consumption, providing emphasis on the importance of financial inclusivity to energy transition policy actions.

These studies indicate a stable long-term relationship between financial deepening and renewable energy growth. However, this relationship varies in strength across countries based on economic structure and policy alignment.

2.2 Oil Dependence, Resource Dynamics, and Renewable Transition

A large number of studies have looked at the role of oil rents, prices, and dependence in renewable energy development, especially in resource-rich countries.

Aidarova et al. (2024) examined nine OPEC countries from 1990-2024 using a Panel ARDL model and wrote that oil exports exert a meaningful positive long-run impact on economic growth, while REC has a negative long-run effect. This implies that sustained structural dependence on hydrocarbons could impede the renewable transition. On the other hand, Deniz (2019) utilized data for 24 oil dependent nations (1995-2014) and found that oil prices stimulate REC in oil importers, but crowd it out for oil exporters, demonstrating asymmetric policy effects.

Makki et al. (2024) analyzed 24 countries (12 oil exporters and 12 oil importers) from 1990-2018 using panel multiple regression and found that oil rents and GDP growth decrease REC for oil exporters, but increase for importers, which suggests that energy dependence strongly conditions the direction of causality. Equally, Tambari et al. (2023) used a Panel Vector Error Correction Model (P-VECM) with ten African countries (1990-2021) and found that oil prices have a positive relationship for renewable development in oil-importing countries, but are insignificant to exporters, while GDP positively and consistently affects renewable development for both groups.

Another study by Makki et al. (2023) using a dataset of 44 nations from 2004-2015 also confirms this pattern: oil rents positively affect REC, fiscal incentives (such as investment taxes) motivate renewable investments, while oil prices themselves have little direct impact. Similarly, Awodumi and Adewuyi (2020) share that petroleum and natural gas consumption have asymmetric effects on growth and CO_2 emissions in five oil-producing African economies (1980-2015), where positive shocks of non-renewable energy generally support growth but also increase emissions.

Descriptive studies also echo these econometrics. In their study of Iran's renewable policies between 2004-2014, Bahrami & Abbaszadeh (2013) reported that Iran made only little progress on capacity expansion despite the significant potential due to institutional and fiscal dependence on fossil fuels. Contextually, Guliyev (2023) researched on Azerbaijan and Kazakhstan between 2004-2022 and found Kazakhstan's earlier reforms and stronger governance led to greater share of renewable energy, while oil still dominates Azerbaijan's energy mix.

Overall, these studies suggest that oil-rich economies are restrained in the renewable transition by long-standing dependency on fossil fuels, weak institutions, and reliance on oil revenue. In contrast, oil-importing countries have stronger economic and policy motivations to pursue a diversification of energy sources.

2.3 Drivers of Technological Innovation, Policy and Governance

A separate line of research has examined how technological innovations, quality of governance, and policy integration can support the development of renewable energy.

Ericson, Engel-Cox, and Arent (2019) provided a global technical review of integrating renewables into oil and gas operations, concluding that solar, wind and geothermal technologies could reduce operational costs, emissions, and energy intensity. Pagliaro (2020) offered a critical analysis of Russia's renewable transition in 2013–2019, noting that technological innovation increased wind and solar capacity but fossil fuels continue to dominate markets due to structural inertia and institutional barriers.

At the country level, Rong and Qamruzzaman (2022), identified factors that determine REC across the U.S., China, India, Japan, and South Korea during 1990–2021 using linear and nonlinear ARDL models. Their analysis showed that oil prices and technological innovation had a positive effect on REC, while economic policy uncertainty demonstrated a negative effect. Bidirectional causality was also found among their key variables in several countries, demonstrating the importance of stable policy environment. Zhang et al. (2022) studied Germany using ARDL cointegration with time series data (1990-2020) and concluded that renewable expansion significantly reduces crude oil imports, providing evidence that adopting clean sources can effectively reduce dependence on imported oil.

Ackah and Kizys (2015) offered another perspective by conducting analysis using data from 12 oil-producing African countries (1985 – 2010). They determined that economic growth and energy depletion are positively linked to renewable energy demand, whereas higher energy prices and CO_2 emissions are negatively linked. These nuances suggest that structural and environmental factors, such as technology and policy effectiveness operate simultaneously to define the speed of renewables adoption.

In summary, three main findings arise from the literature. First, financial development and economic growth have long-run positive links to renewable energy adoption, short-run links are generally weak. Second, oil-exporting economies face structural barriers in separating growth from hydrocarbons, while oil-importing countries seem to be more motivated to employ renewable technologies as a hedge against price volatility and supply insecurity. Third, technological innovation and governance quality are the key enabling factors of energy transition, rather than the abundancy of resources.

While many studies in relation of oil production, renewable energy and economic factors have accumulated, there is a narrow literature focus on Azerbaijan specifically. The current literature highlights complexity and evidence surrounding different results dependent on group of countries, tests and methods. In this regard, studying Azerbaijan's case in terms of how oil production and adaptation of renewable energy sources relate to the country's economic performance will provide useful information to academia and policy-makers.

3. Methodology
3.1 Data

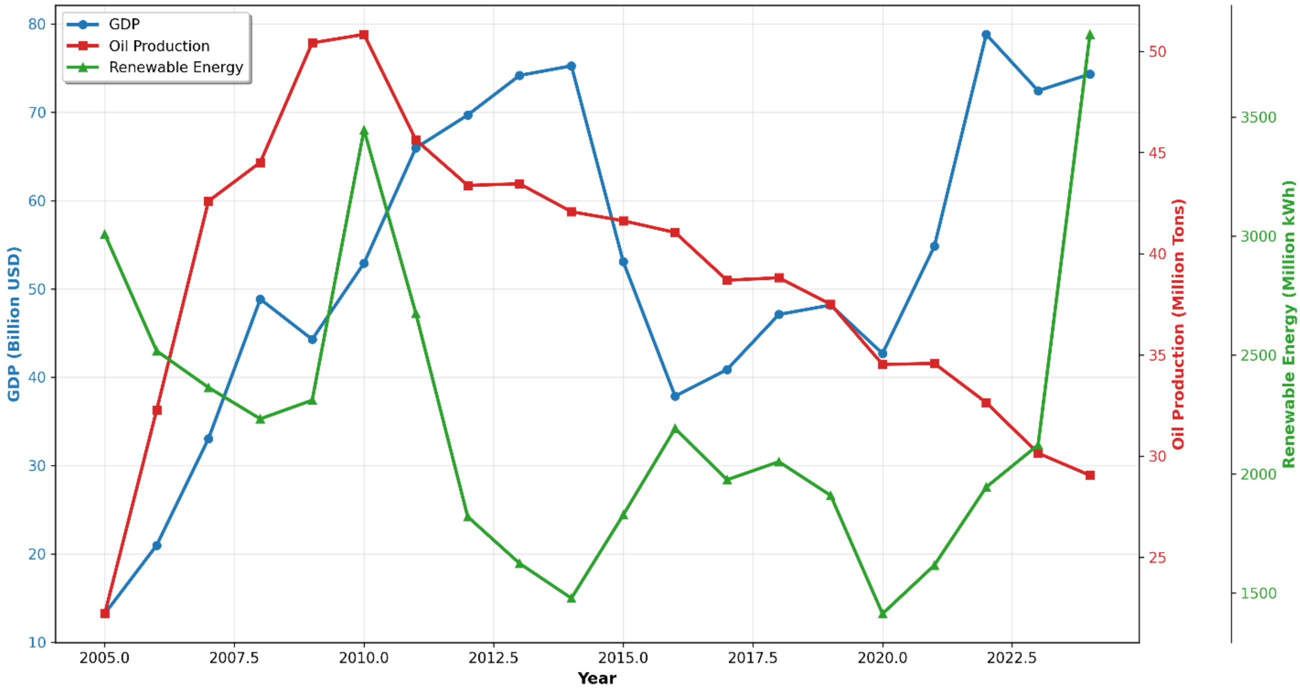
In order to accomplish the objectives of the research, corresponding data had been obtained from The State Statistical Committee of the Republic of Azerbaijan (oil production, renewable energy consumption and renewable energy share) and World Bank database (Gross Domestic Product). The research was conducted using data spanning the period from 2005 to 2024 (n = 20).

Table 2. *Nature and data sources of the variables*

Variable	Unit	Description	Role	Source
GDP	USD (billions)	Gross Domestic Product	Economic indicator	World Bank database
Oil production	Million tons	Annual oil production	Traditional energy	The State Statistical Committee of the Republic of Azerbaijan
Renewable energy consumption	Million kWh	Annual renewable energy output	Clean energy	
Renewable energy share	Percentage	Share of total energy consumption	Transition indicator	

Table 2 summarizes the variables used in the analysis, providing brief information about each one. Initially, for the purpose of determining the obtained dataset whether distributed normally or not, the Shapiro–Wilk Test is executed. The integrated graphs of the used variables are given in Figure 1.

Figure 1. *Azerbaijan: Economic and Energy Trends (2005-2024)*



3.2 Methods

3.2.1 Descriptive Statistics

Descriptive statistics were used to know central tendency and variability in Azerbaijan's economy and energy indicators from 2005 to 2024. The statistical analysis employed standard descriptive measures including central tendency (mean and median), variability (standard deviation, range, and interquartile range (IQR)), and relative dispersion (coefficient of variation (CV)). The CV was calculated as the ratio of standard deviation to the mean multiplied by 100, providing a normalized measure of variability between various units of measurement. The IQR range (Q3-Q1) was used to assess the spread of the middle 50% of observations, offering insights into data distribution and potential outliers. The prior analysis helped assess data suitability and provided a foundational overview of the dataset for further regression and correlation analysis.

3.2.2 Time Trend Analysis

Additionally, the time trend analysis with a linear regression model used to examine changes in key economic and energy variables over selected period of time. The employed regression analysis:

$$\textbf{Variable} = \beta_0 + \beta_1(\textbf{Year}) + \varepsilon,$$

In this model, β_1 represents the annual rate of change for each variable. Statistical significance was assessed at $\alpha = 0.05$ level, with trend strength evaluated using R^2 values. The time trend regression analysis quantified annual change rates, trend coefficients (R^2), p-values, and provided binary significance classifications (Yes/No) along with directional interpretations (increase/decline/no significant trend) to uncover statistically relevant temporal trends for each variable.

3.2.3 Correlation Analysis

Besides that, to examine the linear relationships among the selected economic and energy variables, the Pearson Product-Moment Correlation Coefficient was applied.

$$r = \Sigma(x-\bar{x})(y-\bar{y}) / \sqrt{[\Sigma(x-\bar{x})^2\Sigma(y-\bar{y})^2]}$$

This method measures the strength and direction of the linear association between two continuous variables. The values ranging from -1 (perfect negative correlation) to +1 (perfect positive correlation) with ineligible ($|r| < 0.1$), weak ($0.1< |r| <0.3$), moderate ($0.3 < |r < 0.5$), strong ($|r|>0.5$) interpretations.

3.2.4 Hypothesis Testing

Following the correlation analysis, hypothesis testing for Pearson correlation coefficients was performed to determine whether the observed relationships were statistically significant. The null hypothesis (Ho) assumes no correlation ($p = 0$), while the alternative hypothesis (H_1) assumes a correlation exists ($p \neq 0$). The t-test for correlation significance was applied at the 5% significance level ($\alpha = 0.05$). For each variable pair, the computed p-value determined whether the correlation coefficient differed significantly from zero. Cohen's conversions are a standardized way to describe the magnitude of correlation. Effect sizes were also evaluated to classify the magnitude of correlations as small, moderate, or large.

3.2.5 Linear Regression Analysis

The study employed linear regression analysis to examine the relationships between economic and energy variables across six distinct model specifications.

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

In the equation, β_0 is the intercept, β_1 is the slope, which gives the expected change in the dependent variable (Y) for a unit change in the independent variable (X), and ϵ is the random error term. For each model, key statistical measures were calculated: The explanatory power of the regression model was determined by the coefficient of determination (R^2) and adjusted R^2 which indicates the proportion of the variation in the dependent variable which is caused by the independent variable. The F-statistic was used to test the overall significance of the regression model. The standard error was used to evaluate the precision with which the predictions and parameters estimates are made. The study employed linear regression analysis to examine the relationships between economic and energy variables across six distinct model specifications.

All statistical analyses were conducted by using the software of Python 3.8 (scipy, statsmodels, sklearn).

4. Results

4.1 Descriptive Statistics Summary

The descriptive analysis presented in Table 3. highlights notable variability across Azerbaijan's key economic and energy indicators during the 2005-2024 period. GDP exhibited substantial growth alongside pronounced volatility, averaging \$52.4 ± 18.5 billion with a median of \$50.9 billion. Oil production remained more stable, averaging 38.8 ± 7.3 million tons with a median of 39.9 million tons and a moderate CV of 18.7%, though the range of 28.6 million tons. Renewable energy generation averaged 2,219 ± 633 million kWh, with a CV of 28.5%. Meanwhile, the renewable energy share remained consistently low, averaging 1.86 ± 0.42%, with minimal variation and narrow range of 1.8%.

Table 3. *Descriptive Statistics Summary (2005–2024 Azerbaijan Economic and Energy Data)*

Variable	Mean ± SD	Median	[min, max]	Range	CV%	IQR
GDP (Billion USD)	\$52.4 ± 18.5B	\$50.9B	[13.2, 78.8]B	\$65.6B	35.30%	\$28.1B
Oil Production (Million Tons)	38.8 ± 7.3 MT	39.9 MT	[22.2, 50.8] MT	28.6 MT	18.70%	9.3 MT
Renewable Energy (Million kWh)	2219 ± 633 MkWh	2087 MkWh	[1413, 3848] MkWh	2435 MkWh	28.50%	576 MkWh
Renewable Share (Percent)	1.86 ± 0.42%	1.80%	[1.3, 3.1]%	1.80%	22.80%	0.35%

Units: B\$ =billion USD; MT= Million Tons; MkWh= Million kilowatt-hours;%=Percent
CV% = Coefficient of Variation (standard deviation ÷ mean × 100) — measures relative variability.
IQR = Interquartile Range (Q3 – Q1) — measures middle 50% spread.

4.2 Time Trend Analysis Results

The time trend analysis in the Table 4. reveals contrasting trajectories in economic growth and energy transition patterns. GDP demonstrated a significant positive trend with an annual increase of \$1.753 billion ($p = 0.0102$, $R^2 = 0.313$). The renewable energy share showed a significant declining trend of -0.036% per year ($p = 0.0232$, $R^2 = 0.255$). Neither oil production nor absolute renewable energy generation showed statistically significant trends ($p = 0.1404$ and $p = 0.3672$, respectively).

Table 4. *Time Trend Analysis with Linear Regression Model*

VARIABLE	ANNUAL CHANGE	TREND R^2	P-VALUE	SIGNIF.	INTERPRETATION
GDP (Billion USD)	$1.753 B/year	0.313	0.0102	Yes	Significant increase
Oil Production (Million Tons)	-0.420 MT/year	0.117	0.1404	No	No significant trend
Renewable Energy (Million kWh)	-22.780 MkWh/year	0.045	0.3672	No	No significant trend
Renewable Share (%)	-0.036 %/year	0.255	0.0232	Yes	Significant decline

Model: $Variable = \beta_0 + \beta_1(Year) + \varepsilon$

Note: Significance tested at $\alpha = 0.05$ *level.* R^2 *indicates trend strength.*

4.3 Correlation Analysis Results

4.3.1 Economic Energy Relationships

In Table 5. the results of the correlation analysis revealed predominantly weak linear relationships between variables, highlighting several noteworthy patterns. GDP showed weak positive correlation with oil production (r= 0.187) and weak negative correlation with renewable energy (r= -0.161) and renewable share (r= -0.033). Oil production exhibited a moderate positive association with renewable share (r = 0.557). The strongest relationship observed was between renewable energy generation and renewable share (r = 0.679).

Table 5. *Pearson Correlation Matrix*

Variables	GDP	Oil Prod.	Renew. Energy	Renew. Share
GDP (Billion USD)	1	0.187	-0.161	-0.033
Oil Production (Million Tons)	0.187	1	-0.121	0.557
Renewable Energy (Million kWh)	-0.161	-0.121	1	0.679
Renewable Share (%)	-0.033	0.557	0.679	1

Interpretation: $|r| < 0.1$ *(negligible), 0.1–0.3 (weak), 0.3–0.5 (moderate),* > 0.5 *(strong)*

4.3.2 Statistical Significance Testing

In Table 6. the hypothesis testing results show that most relationships among Azerbaijan's macroeconomic and energy indicators in 2005–2024 are statistically insignificant at the 5% level, indicating limited linear relationships or insufficient evidence for a relationship. The relationships of GDP with all energy related variables: oil production, renewable energy consumption, and renewable energy share, show non-significant correlation coefficient ($p > 0.05$). The same applies to the relationships of oil production and renewable energy consumption, which show no significant interaction. Only two of the statistically significant relations could be identified, these being: oil production with renewable share (r = 0.5573, p = 0.0107) and renewable energy with renewable share (r = 0.6786, p = 0.0010) both showing large effect sizes.

Table 6. *Hypothesis Testing for Correlations*

HYPOTHESIS	VARIABLES	TEST STATISTIC	P-VALUE	DECISION	EFFECT SIZE
$H_{1.0}$: ρ = 0	GDP vs Oil Production	r = 0.1870	0.4299	Accept H_0	Small
$H_{2.0}$: ρ = 0	GDP vs Renewable Energy	r = -0.1608	0.4982	Accept H_0	Small
$H_{3.0}$: ρ = 0	GDP vs Renewable Share	r = -0.0330	0.8903	Accept H_0	Negligible
$H_{4.0}$: ρ = 0	Oil Production vs Renewable Energy	r = -0.1214	0.6102	Accept H_0	Small
$H_{5.0}$: ρ = 0	Oil Production vs Renewable Share	r = 0.5573	0.0107	Reject H_0	Large
$H_{6.0}$: ρ = 0	Renewable Energy vs Renewable Share	r = 0.6786	0.001	Reject H_0	Large

H_0: No correlation (ρ = 0) vs H_1: Correlation exists (ρ ≠ 0)

4.4 Regression Analysis Findings

The regression results presented in Table 7 reveal that most models exhibit poor predictive power, with R^2 values below 0.04 and p-values exceeding 0.05, indicating no statistically significant linear dependence between GDP and the examined energy variables. Only the models of oil production versus renewable share and renewable energy versus renewable share showed relatively moderate results, with R^2 values of 0.31 and 0.46, respectively.

Table 7. *Linear Regression Analysis Summary*

REGRESSION	R^2	ADJ. R^2	F-STAT	P-VALUE	SLOPE (SE)	QUALITY
GDP vs Oil Production	0.035	-0.0186	0.652	0.4299	0.0733 (0.0908)	Poor
GDP vs Renewable Energy	0.0259	-0.0283	0.478	0.4982	-5.4920 (7.9448)	Poor
GDP vs Renewable Share	0.0011	-0.0544	0.02	0.8903	-0.0008 (0.0054)	Poor
Oil Production vs Renewable Energy	0.0147	-0.04	0.269	0.6102	-10.5697 (20.3698)	Poor
Oil Production vs Renewable Share	0.3106	0.2723	8.11	0.0107	0.0326 (0.0114)	Moderate
Renewable Energy vs Renewable Share	0.4606	0.4306	15.368	0.001	0.0005 (0.0001)	Moderate

Model: $Y = \beta_0 + \beta_1 X + \varepsilon$

5. Discussion

In the section the findings from applied statistical methods were interpreted, limitations, future recommendations and policy implementations were mentioned.

5.1 Interpretation of results

During the descriptive analysis the relatively symmetric distribution and a high coefficient of variation (35.3%) in GDP may indicate considerable economic fluctuations, largely reflecting shifts in global oil prices and external shocks. Also oil production demonstrated a relatively consistent trend over the analyzed period showing some variations linked to the market conditions. Renewable energy generation remained moderately variable, possibly due to hydrological changes or project-level developments. The proportion of renewable energy in the total energy mix remained persistently low, indicating limited structural transformation within Azerbaijan’s energy sector. Overall, these results illustrate that while Azerbaijan's economy has experienced dynamic expansion, its energy sector-especially the renewable component-has undergone limited structural transformation over the past two decades.

In the time trend analysis, the sustained upward movement in GDP indicates sustained economic growth over the study period. Despite this economic expansion, the share of renewable energy displayed a downward trend. This may suggests that economic growth has not translated into increased renewable energy adoption. Both oil production and overall renewable energy output remained comparatively stable over the study period. This finding implies that, while the economy continues to grow, the share of renewable energy within the energy mix has shrunk, reflecting limited progress towards the goals of global energy transition. The stable output in oil and renewable energy also indicates that the changes in production for these two energy sources were probably the result of short-term market and policy factors rather than a long-term structural shift.

The correlation analysis revealed that the weak relationships between GDP and energy variables. This may suggest that country’s economic growth from 2005 to 2024 was largely independent of short-term fluctuations in either oil or renewable energy output, possibly due to the country's broader economic diversification efforts beyond the energy sector. This pattern possibly reflecting that Azerbaijan’s economy has decoupled from oil production. The outcome of strong relationship between renewable energy generation and renewable share is logically expected, as increases in renewable generation directly improve its proportion in the total energy mix. Additionally, the limited interaction between fossil fuel production and renewable energy consumption further implies that changes in oil output do not directly influence renewable deployment. However, the result of moderately significant and positive relationship between oil production and the share of renewables is quite counterintuitive, as periods of higher oil output coincided with a greater presence of renewables in the energy mix. The observed relationships indicate that Azerbaijan's energy-economy dynamics are complex and not strictly linear, suggesting the need for more advanced analytical approaches to capture the mechanisms driving the energy transition. Overall, the findings point to a compatible internal relationship within the energy sector, where variations in renewable generation are mirrored in their share of total energy use, and rising oil production may indirectly support renewable development through reinvestment and policy-driven diversification.

The positive correlation between oil production and renewable energy share ($r = 0.5573$, $p = 0.0107$) found in this study aligns with emerging evidence from the literature on resource-rich countries' energy transitions. This suggests variations in oil output possibly reflect a positive association with renewable share. This also aligns with the findings of the research done by Mukhtarov et al. (2020). They demonstrated that financial development and GDP growth in Azerbaijan enable greater renewable energy consumption, indicating that oil revenues may facilitate the financial capacity needed for renewable investments.

The positive correlation could emerge from several factors: strategic government planning that views renewables as complementary to oil exports, the maturation of oil fields necessitating economic diversification, or the reinvestment of oil revenues into sustainable energy infrastructure. Additionally, international commitments and climate policies may have created incentives for simultaneous oil production and renewable development. That’s why, energy diversification strategy can be pursued without immediately sacrificing oil revenues. This finding contrasts with traditional resource curse theories, where traditional theory suggests that rich oil resources would discourage renewable energy investments.

However, this positive relationship should be interpreted cautiously within Azerbaijan's specific policy context. The moderate R^2 value (0.31) from regression analysis suggests that while statistically significant, oil production explains only 31% of the variance in renewable share, indicating that other policy, institutional, and technological factors play crucial roles in renewable energy deployment.

5.2 Limitation of reseach

The results should be interpreted based on several limitations. First, the analysis is constrained to linear relationships which may not capture possible non-linear relationships or other effects present in the oil-renewable energy interrelationship. Second, while the 20-year time series is exhaustive for the recent time period of the development of Azerbaijan, it may be inadequate to capture long-term structural shifts or cyclical aspects of energy transitions. Third, renewable energy is not classified by technology (solar, wind, hydro) which may reveal different relationships with oil production. Institutional factors, the quality of governance and some policy variables are not explicitly modeled even though they have been shown in the literature to be very significant in the explanation of resource-renewable interrelationships.

Overall, the relationships between economic output and energy variables are more complex and there is a need for more sophisticated modeling approaches or additional explanatory variables to better understand these multifaceted relationships.

5.3 Policy implementation and recommendations

The findings of this study suggest that Azerbaijan's oil production and the share of renewable energy consumption can proceed in a complementary manner, providing a strategic opportunity to convert hydrocarbons into a sustainable energy future. Realization of such a possibility will require an integrated policy approach that combines fiscal planning, structural reform, human capital development and the involvement of communities.

5.3.1 Strategic Revenue Allocation

To secure long-term financing for renewable energy, Azerbaijan should reinvest a certain proportion of its oil revenues into renewable energy projects. This investment will directly support solar and wind power projects, technology transfer partnerships and the local manufacture of renewable energy components, and will also boost research and innovation in technologies to exploit renewables. Constant investment ensures that oil income accelerates rather than delays the green transition.

5.3.2 Integrated Energy Portfolio Management

The energy policy should adopt an integrative portfolio approach, which will see oil and renewable sectors as mutually reinforcing. Oil revenues may be used to de-risk private sector renewable investment by way of government guarantees and fiscal incentives, diversifying the same into hybrid energy and smart grid developments which will aid system efficiency and stability.

5.3.3 Institutional and Regulatory Reforms

Azerbaijan has already established the Azerbaijan Renewable Energy Agency (AREA) under the Ministry of Energy, which plays a key role in promoting renewable energy development. To ensure more effective coordination of the national energy transition, the institutional framework should be strengthened by expanding AREA's mandate and operational capacity. AREA could evolve into a comprehensive coordination body responsible for integrating oil revenues into renewable investments, overseeing the implementation of incentive schemes such as feed-in tariffs, renewable energy certificates, and net metering policies, and streamlining the permitting and licensing processes for new renewable projects. Strengthening AREA's analytical and regulatory capabilities would enable more consistent monitoring of progress toward Azerbaijan's 30% renewable electricity target by 2030 and enhance transparency in investment management. Additionally, introducing competitive bidding frameworks, tax incentives, and carbon trading mechanisms would stimulate private sector participation and align Azerbaijan's regulatory framework with international standards of sustainable energy governance.

5.3.4 Human Capital Development

Developing skilled professionals is key to sustaining transition. Retraining oil-sector specialists, launching clean-energy programs at universities, and establishing vocational centers for solar and wind technologies will ensure a qualified workforce. Partnerships between academia and industry and international exchange programs will also help develop technical skills.

5.3.5 Economic Diversification and Innovation

Diversification should extend beyond the energy sector. Green hydrogen production, local manufacture of renewable energy equipment, carbon trading mechanisms, and digital energy management systems are some of the priority areas to be developed to improve the country's industrial capacity and make it a hub for renewable energy in the region.

5.3.6 International Cooperation and Technology Transfer

Cooperation with the European Union, United Nations and other multi-lateral organizations will provide Azerbaijan with access to advanced technologies and funding to implement them. Together, joint projects can facilitate technology transfer, infrastructure modernization and the adoption of best practices for Azerbaijan.

5.3.7 Community Engagement and Social Inclusion

The long-term success of renewable energy initiatives depends on local community involvement. Community based projects can increase energy access in rural areas, generate employment, and contribute to social inclusion. Integrating local input into project planning will foster sustainability and public acceptance of the energy transition process. For the long-term sustainability of renewable energy projects, they need to involve and engage the local communities where they are being implemented.

6 Conclusion

The paper studied the relationships between oil production and renewable energy consumption in Azerbaijan in time period of 2005 – 2024. Among the six hypotheses tested, only H_5 and H_6 were statistically significant. It was observed that, there is a positive and significant correlation between oil production and renewable enrgy share ($r = 0.5573$, $p = 0.0107$). This may be interpreted as Azerbaijan's oil production and renewable energy development have followed the complementary relationship, rather than competing during selected period. Based on that, it can be suggested that an energy diversification policy can be implemented without immediately sacrificing carbon oil gas revenues.

These findings have important implications both theoretically and practically for resource rich countries. From a theoretical perspective, the positive relationship between oil and renewable energy highlights the potential for strategic energy portfolio management in oil-dependent economies. Practically, the results suggests that countries like Azerbaijan can utilize oil revenues to finance transitions to renewable energy sources, creating a sustainable track both for long-term diversification of economic activity and short-term fiscal stability from hydrocarbon exports.

The realization of this goal will require persistent commitment to implementation of policy decisions, strong institutional structures and I continuous partnership among the government, the private sector, and civil society.

Overall, analyzing how economic and energy components affecting renewable energy in oil-dependent economies is significantly important to maintain sustainable economic growth and built strategic policy framework.

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APPENDIX

Figure 2. *Time trend analysis with linear regression model*

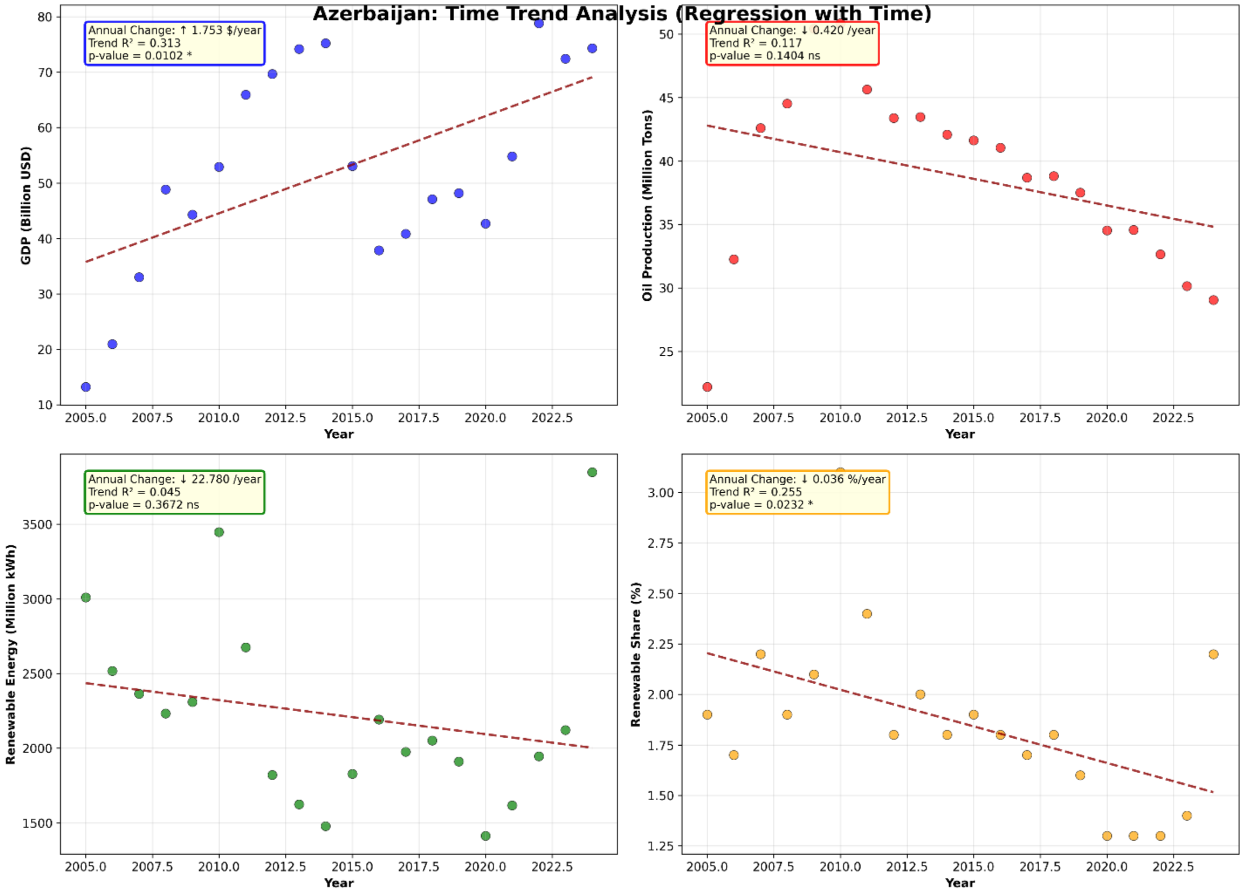

Figure 3. *Correlation analysis- substantive variables only*