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The Impact of Artificial Intelligence and Digital Transformation on Economic Growth: A Time Series Analysis of Azerbaijan

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Abstract

This study investigates how artificial intelligence and digital transformation have shaped economic growth in Azerbaijan, drawing on time series data spanning 1996 to 2025. Using correlation analysis, Augmented Dickey-Fuller unit root testing, Granger causality testing, and ordinary least squares regression, the analysis traces the relationship between a composite Digital Economy Index and both real and non-oil GDP growth. The Digital Economy Index is constructed as a weighted composite measure incorporating five standardized indicators: internet penetration (sourced from the International Telecommunication Union), mobile subscriptions per 100 inhabitants (ITU and State Statistical Committee of Azerbaijan), ICT sector value added as a percentage of GDP (State Statistical Committee of Azerbaijan and Ibadoghlu, 2025), the United Nations E-Government Development Index (UN DESA, 2024), and the ratio of cashless payments to total transactions (Central Bank of Azerbaijan, 2024). Each component was min-max normalized to a 0–100 scale and aggregated using equal weights to ensure transparency and replicability. The results reveal a marked structural shift after 2016: while overall GDP growth slowed as oil production declined, the Digital Economy Index rose sharply and became closely linked to non-oil growth. In the post-oil period (2016–2025), this relationship is strong and statistically robust ($R^2 = 0.823$, $p < 0.001$), with a one-unit rise in the index associated with a 0.208 percentage-point increase in non-oil GDP growth. These findings are interpreted alongside the objectives of the Azerbaijan Artificial Intelligence Strategy (2025–2028), and the study closes with policy recommendations aimed at translating digital gains into lasting, broad-based economic diversification beyond the hydrocarbon sector.

Keywords: Artificial intelligence; digital transformation; economic growth; time series analysis; non-oil economy; Azerbaijan; Digital Economy Index

Introduction

The global economy is undergoing a significant shift in the third decade of the twenty-first century, driven by advances in artificial intelligence (AI), machine learning, and big data analytics. Often described as the Fourth Industrial Revolution, this shift is reshaping production, public administration, financial services, education,

and healthcare alike. Resource-dependent economies have particular reason to pay attention: for them, digital transformation has become a central plank of strategies for diversification and sustainable development.

Azerbaijan has built its development strategy on hydrocarbon revenues since gaining independence in 1991. During the oil boom of 2006–2015, real GDP grew by roughly 9.5 percent a year on average.[1] However, this model also left the economy structurally exposed. Since 2016, falling petroleum output and volatile global energy prices have made the case for investing in non-oil sectors difficult to ignore. Against this backdrop, the digital economy and artificial intelligence offer Azerbaijan a genuine opportunity to escape the middle-income trap and move toward high-income status.

The clearest expression of this intent is the Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025–2028, approved by presidential decree on 19 March 2025.[2] It rests on four objectives: strengthening economic competitiveness, creating the conditions needed for AI applications to thrive, building qualified human capital, and spreading the benefits of AI across society. Its priority areas cover AI governance and regulation, data infrastructure, talent development, a more supportive business environment, and ethical standards consistent with international norms.

This study tests, empirically, whether digital transformation and AI potential have affected economic growth in Azerbaijan, using time series data from 1996 to 2025, and uses the results to inform policy recommendations linked to the 2025–2028 AI Strategy. Its central hypothesis is that, in the post-oil period (2016–2025), digital economy indicators are positively and significantly related to non-oil GDP growth.

Theoretical Framework

A substantial literature now examines how digital transformation affects economic growth. In the neoclassical growth model of Solow (1956) and Swan (1956), technological progress is the fundamental driver of long-run growth.[3,4] Endogenous growth theory, developed by Romer (1990) and Lucas (1988), goes further, showing that knowledge accumulation and human capital generate positive externalities that sustain growth over time.[5,6] Artificial intelligence and digital technologies fit naturally into this framework as forces that raise both knowledge production and productivity.

Acemoglu and Restrepo (2019) find that AI-driven automation raises labour productivity, though without adequate adjustment policies it can also create temporary labour-market frictions.[7] Brynjolfsson and McAfee (2014) describe this period as a "second machine age," in which digital transformation lifts potential growth by raising total factor productivity.[8] The Global Innovation Index 2019 adds that innovation ecosystems matter a great deal here: economies with stronger innovation infrastructure are better able to absorb and spread new technologies.[9]

Research focused specifically on Azerbaijan is still limited but growing quickly. Ibadoghlu (2025) reports that the ICT sector accounted for only 1.8 percent of GDP in 2024, and just 0.036 percent of total exports.[10] R&D spending, according to the same study, stays between 0.2 and 0.3 percent of GDP—well below regional norms. Guluzade (2025), looking at the country's digital economy potential, notes that internet penetration has passed 80 percent even as a rural digital divide persists.[11] Lloyd's Bank Trade (2026) situates these trends within Azerbaijan's broader economy, pointing to the structural difficulties of moving from resource dependence toward knowledge-based growth.[12]

Crude Accountability (2026) compares Azerbaijan's post-oil economy with the middle-income trap literature, warning that stagnation is a real risk absent sustained diversification.[13] The United Nations Economic Commission for Europe (UNECE, 2020) reaches a similar conclusion: its Innovation Policy Outlook for Azerbaijan points to persistent weaknesses in turning research into commercial applications—a gap that digital transformation strategies need to address.[14]

Azerbaijan ranks 94th of 139 economies in the WIPO Global Innovation Index 2025, performing better on innovation inputs (76th) than on outputs (112th)—a gap suggesting that turning potential into results remains difficult.[15] The Oxford Insights Government AI Readiness Index 2025 shows Azerbaijan climbing 41 places, a rise that tracks the country's recent policy documents.[16] Both the Center for Analysis of Economic Reforms and Communications (CAERC, 2025) and Ereforms.gov.az (2026) attribute this improvement to coordinated policy implementation and institutional reform.[17,18]

On the United Nations E-Government Development Index (EGDI) 2024, Azerbaijan ranks 74th of 193 countries, placing it in the "Very High EGDI" category—a result that owes much to digital public service platforms such as ASAN and myGov.[19] Digital Cooperation Organization data put digitally delivered service exports at roughly 5 percent of GDP.[20]

The legal and strategic groundwork for this transformation goes back to the Strategic Roadmap for the Development of Telecommunications and Information Technologies (2016), which set the stage for later policy initiatives.[21] Trade.gov (2026) notes in its market overview that Azerbaijan's regulatory environment has gradually opened up to foreign technology investment, though entry barriers remain in some sectors.[22]

Methodology

This study draws on economic and digital transformation indicators for Azerbaijan for the period 1996–2025. The analysis proceeds in three stages: descriptive statistics and correlation analysis; the Augmented Dickey-Fuller (ADF) unit root test; and Granger causality testing together with regression modelling.

Data and Variables

The variables employed in the analysis and their respective sources are summarised in Table 1. All data were collected from publicly available databases and official statistical publications. Where data gaps existed, linear interpolation was applied only for isolated missing years, and the methodology was kept consistent across the full time series.

Construction of the Digital Economy Index

The Digital Economy Index (DEI) is the study's principal explanatory variable. It was constructed as a composite measure to capture multidimensional digital transformation in Azerbaijan. The index incorporates five sub-indicators selected on the basis of data availability, theoretical relevance, and policy significance:

1. Internet Penetration Rate (%) — sourced from the ITU and the State Statistical Committee of Azerbaijan;
2. Mobile Cellular Subscriptions per 100 Inhabitants — sourced from the ITU and the State Statistical Committee of Azerbaijan;
3. ICT Sector Value Added (% of GDP) — sourced from the State Statistical Committee of Azerbaijan and Ibadoghlu (2025);
4. E-Government Development Index (EGDI) — sourced from the UN DESA E-Government Survey;
5. Cashless Payment Ratio (% of total payment transactions) — sourced from the Central Bank of Azerbaijan.

Each sub-indicator was first subjected to min-max normalization to transform the raw values into a common 0–100 scale:

Table 1. Variables, Notation, and Data Sources

Variable	Notation	Original Source	Period
Real GDP Growth (%)	`GDP_Growth`	World Bank, World Development Indicators; State Statistical Committee of Azerbaijan (SSCA)	1996–2025
GDP per Capita (current USD)	`GDP_per_Capita`	World Bank; International Monetary Fund, World Economic Outlook Database	1996–2025
ICT Sector Value Added (% of GDP)	`ICT_GDP_Share`	SSCA; Ibadoghlu (2025)	1996–2025
Internet Penetration (%)	`Internet_Penetration`	International Telecommunication Union (ITU); SSCA	1996–2025
Mobile Subscriptions (per 100)	`Mobile_Subscriptions`	ITU; SSCA	1996–2025
Non-Oil GDP Growth (%)	`NonOil_GDP_Growth`	SSCA; World Bank	1996–2025
R&D Expenditure (% of GDP)	`RD_Expenditure`	UNESCO Institute for Statistics; SSCA	1996–2025
Digital Economy Index (0–100)	`Digital_Economy_Index`	Author's calculations (see below)	1996–2025
FDI Inflows (% of GDP)	`FDI_Inflows`	World Bank; International Monetary Fund	1996–2025
E-Government Development Index	`EGDI`	United Nations Department of Economic and Social Affairs (UN DESA)	1996–2025
Cashless Payment Ratio (%)	`Cashless_Ratio`	Central Bank of Azerbaijan, Financial Stability Report 2024	1996–2025

$$X_{it}^{\text{norm}} = \frac{X_{it} - X_i^{\min}}{X_i^{\max} - X_i^{\min}} \times 100 \tag{1}$$

where X_{it} is the raw value of indicator i in year t, and $X_i^{\min}$ and $X_i^{\max}$ are the minimum and maximum values of that indicator over the 1996–2025 period. This normalization ensures that each component contributes proportionally regardless of its original unit of measurement.

The normalized components were then aggregated using equal weights (0.20 each) to produce the composite Digital Economy Index:

$$DEI_t = \sum_{i=1}^{5} w_i \, X_{it}^{\text{norm}} \tag{2}$$

where $w_i = 0.20$ for all i. Equal weighting was chosen to avoid arbitrary assumptions about the relative importance of each dimension and to ensure full transparency and replicability. The resulting index ranges from 0 to 100, with higher values indicating greater digital transformation. Sensitivity analysis using principal component analysis (PCA) weights yielded qualitatively similar results, confirming the robustness of the index construction.

Econometric Methods

Series stationarity is tested using the ADF test:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_i \delta_i \Delta y_{t-i} + \varepsilon_t \tag{3}$$

Granger causality tests examine whether the digital economy index predicts non-oil GDP growth:

$$Y_t = \alpha_0 + \sum_i \alpha_i Y_{t-i} + \sum_j \beta_j X_{t-j} + \varepsilon_t \tag{4}$$

For the post-oil period, the following regression model is estimated:

$$NonOilGDP_t = \beta_0 + \beta_1 DigitalIndex_t + \beta_2 R\&D_t + \beta_3 FDI_t + \varepsilon_t \tag{5}$$

Because the digital economy index and R&D expenditure are highly collinear in the post-oil period (r = 0.993), the simple regression models are treated as the primary results, and the multiple regression results are interpreted with caution.

Results and Discussion

Descriptive Statistics and Correlation Analysis

Analysis dividing the 1996–2025 period into three sub-periods reveals the presence of a structural break (Table 2).

Table 2. Period Comparison (Mean Values)

Indicator	**Pre-Oil** (1996–2005)	**Oil Boom** (2006–2015)	**Post-Oil** (2016–2025)
Real GDP Growth (%)	10.18	9.43	1.15
Digital Economy Index	13.1	54.1	74.4
Internet Penetration (%)	2.16	44.70	84.75
ICT Share (% of GDP)	1.25	1.93	1.89
Non-Oil Growth (%)	6.20	7.35	3.26
R&D Expenditure (% of GDP)	0.17	0.23	0.23

Table 2 shows that GDP growth stayed high through the oil boom while digital economy indicators lagged behind. That pattern reversed after 2016: total GDP growth fell to 1.15 percent, while the digital economy index climbed to 74.4 points and internet penetration reached 84.75 percent.

Across the full period, total GDP growth and the digital economy index are negatively correlated (-0.463). This is less puzzling than it looks: digitalisation was still low during the high-growth oil boom, and it accelerated only later, as the petroleum sector's decline pulled overall growth down.

Restricting the analysis to the post-oil period (2016–2025) produces a more informative picture. The digital economy index correlates strongly with non-oil GDP growth (+0.907), GDP per capita (+0.927), internet penetration (+0.971), and R&D expenditure (+0.993). Taken together, these correlations point to a close link between digital transformation and non-oil growth once the economy moved past its oil-dependent phase.

Unit Root Test Results

ADF tests show that most series are non-stationary at the full-period level, a result driven by structural breaks around 2005 and 2015, which mark the acceleration and subsequent slowdown of petroleum production. Within the post-oil sub-period (2016–2025), the digital economy index and internet penetration are stationary, while GDP-related series are not. Structural breaks are addressed here through sub-period analysis, with the 2016–2025 post-oil period as the main focus.

Granger Causality Test

Granger causality tests for the post-oil period ask whether the digital economy index predicts non-oil GDP growth. At lag 1, the F-statistic is 5.1065 with a p-value of 0.0646—significant at the 10 percent level but marginal at 5 percent. Given the small sample (n = 10), this is not surprising, and the result should be revisited once longer series become available.

Regression Analysis

The principal regression results of the study are summarised in Table 3.

Table 3. Regression Analysis Results

Model	Dependent Variable	Independent Variable	Coefficient	R^2	p-value
A	Non-Oil Growth	Digital Economy Index	+0.2084	0.8230	0.0003***
B	Non-Oil Growth	Internet Penetration	+0.2925	0.7165	0.0020**
C	GDP per Capita	Digital Economy Index	+244.04	0.8599	0.0001***
D	Total GDP Growth	Digital Economy, Post-Oil Dummy, FDI	Various	0.4484	0.0067**

Note. *** Significant at the 1% level; ** Significant at the 5% level.

Model A stands out: in the post-oil period, the digital economy index accounts for 82.3 percent of the variation in non-oil GDP growth. A one-unit rise in the index is associated with a 0.2084 percentage-point increase in non-oil GDP growth, significant at the 1 percent level.

Internet penetration alone (Model B) explains 71.7 percent of the variation in non-oil growth, with each one-percentage-point rise in penetration linked to a 0.2925 percentage-point increase in non-oil GDP growth.

Model C confirms a positive link between the digital economy index and GDP per capita: each one-unit increase in the index is associated with an average rise of USD 244 in GDP per capita.

In the full-period Model D, the post-oil dummy is negative (-4.78) but not significant, while FDI inflows are positive and significant (p = 0.007)—suggesting that foreign investment keeps supporting overall growth even as the petroleum sector contracts.

Discussion: Potential within the Azerbaijan AI Strategy (2025–2028)

These results suggest that digital transformation has become a genuine catalyst for economic diversification in Azerbaijan's post-oil economy. What follows reads the four objectives of the Artificial Intelligence Strategy of the Republic of Azerbaijan for 2025–2028 (approved 19 March 2025) against this evidence.

Economic competitiveness. The strong link between the digital economy index and non-oil growth (82.3 percent explanatory power) speaks directly to this objective. Planned investment in high-performance

computing, open datasets, and Azerbaijani natural language processing should push the digital economy index higher and, with it, non-oil growth. Expanding AI-focused production in techno-parks, in particular, could lift the ICT sector's share of GDP above its current 1.8 percent. The four AI standards already implemented under the national strategy give this objective an institutional footing, helping ensure interoperability and quality control across AI applications.

Enabling conditions for AI applications. The correlation between R&D expenditure and the digital economy index (+0.993) is close to perfect, and building public platforms, AI-specific infrastructure, and ethical standards aligned with international norms should help lock in this relationship. The persistent shortfall in R&D spending—still only 0.2 to 0.3 percent of GDP—makes financing the most pressing part of the strategy. Prompt implementation of the National Data Strategy, aimed at standardising data sharing across public institutions, is also essential.

Human capital development. The planned Artificial Intelligence Academy, designed around curricula comparable to MIT, Stanford, Harvard, and Carnegie Mellon, targets a real weakness: Azerbaijan's 88th-place ranking in human capital and research in the WIPO GII 2025 report. The Azerbaijan National Academy of Sciences has already begun drafting an action plan aligned with the AI strategy, signalling institutional commitment. Given the strong correlation between the digital economy index and GDP per capita (+0.927) found here, investment in human capital looks likely to pay off.

Spreading AI benefits across society. With internet penetration at 89 percent and mobile connections exceeding the population (120 subscriptions per 100 people), citizen-facing AI applications have a wide potential reach. Closing the rural digital divide will still require sustained infrastructure investment, including projects such as the Village Connection Programme.

Set against Azerbaijan's current economic structure, the strategy's sectoral potential spans several areas: smart farming, water management, and harvest optimisation in agriculture; intelligent logistics along the Baku–Tbilisi–Kars railway and the Middle Corridor; personalised digital services and language technologies in tourism; AI-driven fintech in a market where cashless payments already reach 64.2 percent; and AI integration into the ASAN and myGov platforms in public administration.

Conclusion

This study has tested, empirically, how digital transformation and AI potential relate to economic growth in Azerbaijan over 1996–2025. Four findings stand out.

First, the digital economy index and non-oil GDP growth are strongly and positively related in the post-oil period ($R^2 = 0.823$, $p < 0.001$), which suggests digital transformation can be an effective lever for reducing petroleum dependence and diversifying the economy.

Second, the positive relationship between the digital economy index and GDP per capita ($R^2 = 0.860$, $p < 0.001$) points to a welfare dimension of digital transformation as well.

Third, over the full period, total GDP growth and digitalisation are negatively related—not because digitalisation hurts growth, but because petroleum-sector decline drags down total growth even as digitalisation supports growth outside the oil sector.

Fourth, the objectives of the Azerbaijan Artificial Intelligence Strategy for 2025–2028 are broadly consistent with these findings and offer a reasonably comprehensive framework for turning digital potential into structural change.

The study has clear limitations: the post-oil sub-period sample is small (n = 10), the digital economy index is a composite measure, and structural breaks are handled only through sub-period analysis. Future work could use quarterly data, panel analysis with regional comparators, and sector-level assessments of AI adoption.

Between its existing digital infrastructure (89 percent internet penetration, 120 percent mobile penetration), its strategic location, and the 2025–2028 AI Strategy, Azerbaijan has real potential to build a sustainable, digitally driven growth model in the post-oil period. Realising that potential will depend on higher R&D investment, stronger private-sector participation, and continued investment in human capital.

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Conflicts of Interest

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