The Impact of Innovation, Digital Transformation, and Institutional Quality on Economic Growth: A Comparative Econometric Analysis of MENA Countries (2011–2024)

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Summary:

This study examines the impact of innovation, digital transformation, and institutional quality on economic growth in selected Middle East and North Africa (MENA) countries, with particular reference to Algeria. Using a balanced panel dataset covering 14 countries over the period 2011–2024, the research employs a Random Effects (RE) model validated through the Hausman specification test and supported by robust standard errors. The empirical findings indicate that innovation represents the most significant determinant of economic growth, where a one-unit increase in the Global Innovation Index (GII) contributes positively to GDP growth. Digital transformation, measured through ICT indicators, shows a positive but limited effect, suggesting that increased connectivity alone does not guarantee productivity gains. Institutional quality, proxied by the rule of law index, exhibits a statistically significant negative relationship with growth, reflecting structural governance inefficiencies that constrain the productive use of technological progress. The results highlight the importance of strengthening institutional frameworks alongside technological development to achieve sustainable growth and support the transition toward knowledge-based economies in Algeria and comparable emerging economies.

Keywords: Innovation; Digital Transformation; Institutional Quality; Economic Growth; MENA Region.

Jel Classification Codes: O31; O47; C23; O55.

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I- Introduction :

Over the past decade, the global economy has experienced a structural shift from traditional production factors toward knowledge-based drivers such as innovation and digital transformation. In this context, sustainable economic growth increasingly depends on the ability of countries to generate and effectively utilize technological and institutional resources.

Despite possessing significant natural resources and favorable demographic conditions, many countries in the Middle East and North Africa (MENA) region continue to experience relatively modest economic performance compared to other emerging economies. In resource-dependent economies such as Algeria, economic growth remains closely linked to hydrocarbon revenues, limiting productive diversification and weakening the contribution of knowledge-based sectors.

Although innovation and digital technologies are widely recognized as important drivers of productivity, their economic impact depends largely on institutional quality. Weak governance structures and limited regulatory efficiency may restrict the productive use of technological progress, thereby reducing its contribution to long-term economic growth.

I.1. Research Problem

In light of these challenges, the present study seeks to address the following central research question:

To what extent do innovation, digital transformation, and institutional quality influence economic growth in MENA countries, and can technological progress generate sustainable growth in the absence of strong institutional frameworks?

I.2. Research Objectives

This study aims to:

- Examine the impact of innovation on economic growth in selected MENA countries.
- Evaluate the contribution of digital transformation to economic performance.
- Analyze the role of institutional quality as a conditioning factor in the innovation–growth relationship.
- Provide empirical evidence relevant to the Algerian context within a comparative regional framework.

I.3. Research Hypotheses

Based on theoretical foundations and empirical observations, the study tests the following hypotheses:

H1: Innovation exerts a statistically significant positive effect on economic growth.

H2: Digital transformation contributes positively to economic growth, although its effect may remain limited in consumption-driven economies.

H3: Weak institutional quality negatively affects economic growth by limiting the productive use of technological progress.

I.4. Theoretical Background and Conceptual Foundations

The relationship between innovation and economic growth has been widely analyzed in economic theory, particularly through the contributions of Joseph Schumpeter (1942), who introduced the concept of creative destruction. According to this perspective, technological change represents a central mechanism through which new products, processes, and industries replace outdated structures, thereby generating productivity gains and long-term economic expansion. This theoretical foundation was later reinforced by endogenous growth theory, which emphasizes the role of research and development (R&D), human capital, and knowledge accumulation as internal drivers of sustained economic growth rather than external forces.

Digital transformation has also emerged as a major determinant of productivity and economic efficiency. By reducing transaction costs, improving information flows, and facilitating market integration, digital technologies create opportunities for firms and governments to operate more efficiently. However, empirical evidence demonstrates that the benefits of digitalization are not automatic. Recent studies confirm the persistence of the digital productivity paradox in emerging economies, where increased technological adoption does not necessarily result in proportional productivity gains or improved economic outcomes (Brynjolfsson & McAfee, 2014). This paradox suggests that the effectiveness of digital transformation depends on complementary factors such as skills, infrastructure, and institutional readiness.

Institutional economics provides an essential framework for understanding variations in economic performance across countries. According to Douglass North (1990), institutional quality , particularly the enforcement of property rights, governance transparency, and regulatory efficiency—plays a decisive role in shaping investment incentives and supporting innovation diffusion. Weak institutional systems, in contrast, increase uncertainty, reduce economic efficiency, and limit the growth benefits associated with technological progress.

Contemporary research further confirms that innovation performance depends not only on technological investment but also on institutional coordination and knowledge-sharing networks among firms, research institutions, and governments (OECD, 2019). This perspective highlights the importance of integrated national innovation systems capable of transforming knowledge into productive outputs. In this context, sustainable economic growth increasingly depends on the alignment between technological capabilities and institutional frameworks that support innovation-driven development.

I.5. Review of Previous Empirical Studies and Research Gap

Previous empirical studies have examined the relationship between innovation, digital transformation, and economic growth using different methodological approaches. Early contributions by Richard Nelson (1993) and Bengt-Åke Lundvall (1992) introduced the concept of national innovation systems, demonstrating that economic performance depends on the interaction between research institutions, firms, and government structures. Their work emphasized the importance of institutional coordination in facilitating technological progress and productivity growth across different economic environments.

More recent empirical research highlights the growing importance of digital technologies as drivers of economic transformation. Recent empirical studies emphasize that digital technologies contribute to productivity only when supported by complementary institutional reforms and human capital development (World Bank, 2016). Similarly, global development analyses indicate that technological diffusion alone is insufficient to generate inclusive economic growth, as structural constraints and limited institutional capacity may restrict the productive use of digital resources.

Recent global evidence also highlights persistent digital divides and uneven technological benefits across developing regions, particularly in economies characterized by infrastructure gaps and institutional inefficiencies (United Nations Conference on Trade and Development, 2021). These findings suggest that digital transformation must be accompanied by regulatory improvements, investment in skills, and enhanced governance systems in order to generate meaningful productivity gains.

In the context of the Middle East and North Africa region, recent regional assessments indicate that structural reforms remain essential for improving productivity and innovation performance in MENA economies (World Bank Group, 2018). Despite increasing investments in digital infrastructure and technological modernization, many countries in the region continue to face challenges related to weak institutional capacity, limited diversification, and insufficient integration between research systems and productive sectors.

Furthermore, contemporary innovation research confirms that innovation outcomes are strongly influenced by the effectiveness of institutional coordination mechanisms and knowledge-sharing networks (OECD, 2019). Countries that establish strong linkages between universities, industry, and public institutions tend to achieve higher levels of technological adoption and economic growth compared to economies characterized by fragmented governance structures.

However, despite the expanding body of literature on innovation and digital transformation, relatively limited empirical research has simultaneously examined the joint interaction between innovation, digitalization, and institutional quality within a unified econometric framework. Most previous studies tend to focus on individual drivers rather than their combined effect on growth dynamics.

Additionally, few studies provide comparative empirical evidence specific to the MENA region while incorporating institutional quality as a moderating variable in the innovation–growth relationship. This study addresses this gap by employing a panel data model covering multiple economies and examining whether institutional quality conditions the effectiveness of innovation and digital transformation in promoting sustainable economic growth.

II– Methods and Materials:

II.1. Data and Sample Selection

This study employs a regional panel dataset comprising 14 countries representing the MENA region and selected comparable emerging economies with similar structural characteristics. The sample includes Algeria, Morocco, Tunisia, Egypt, Jordan, Saudi Arabia, the United Arab Emirates, Qatar, Bahrain, Kuwait, Oman, Turkey, Malaysia, and South Africa.

The country selection is based on three methodological criteria: (i) the availability of consistent and comparable longitudinal data for innovation, digitalization, institutional quality, and macroeconomic indicators; (ii) structural heterogeneity, combining resource-dependent and more diversified economies to allow a robust assessment of innovation–growth dynamics across different development contexts; and (iii) regional and developmental comparability, ensuring that the selected economies share relevant macroeconomic and institutional characteristics.

The analysis covers the period 2011–2024, capturing four key structural phases: the post-global financial crisis recovery, the acceleration of digital transformation, the COVID-19 pandemic shock, and the subsequent uneven recovery phase. Missing observations were addressed using linear interpolation at the country level, applied only to short and non-consecutive gaps in the series in order to preserve data continuity and minimize distortion. The final balanced panel consists of 196 observations, ensuring sufficient degrees of freedom for reliable econometric estimation.

II.2. Variables and Data Sources

The dataset is constructed using internationally recognized databases and processed using R statistical software. The selection of variables is guided by theoretical relevance in endogenous growth theory and institutional economics, as well as data availability and cross-country comparability.

Table 1: Variable Definitions and Data Sources

Symbol	Variable	Measurement	Source
GDP	Economic Growth	Real GDP growth rate (annual %)	World Bank
GII	Innovation	Global Innovation Index (0–100)	WIPO
ICT	Digital Transformation	Internet users (% of population)	World Bank
ROL	Institutional Quality	Rule of Law Index (-2.5 to +2.5)	WGI

To mitigate omitted variable bias, the empirical specification is extended by incorporating standard macroeconomic control variables commonly used in growth regressions, including inflation (INF), gross fixed capital formation (GFCF) as a proxy for investment, human capital (HC), and trade openness (OPEN).

These additional variables are included because they represent key structural determinants of economic growth and help improve the robustness and reliability of the estimated relationships.

II.3. Econometric Specification

To examine the impact of innovation, digital transformation, and institutional quality on economic growth, the study employs a panel data framework. The baseline econometric model is specified as follows:

$$GDP_{it} = \alpha + \beta_1 GII_{it} + \beta_2 ICT_{it} + \beta_3 ROL_{it} + \gamma X_{it} + \epsilon_{it}$$

Where:

- i denotes the country and t represents the time period,
- X_{it} represents the vector of control variables (inflation, investment, human capital, and trade openness),
- ϵ_{it} is the error term.

The expected signs of the main coefficients are consistent with endogenous growth and institutional theories:

- $\beta_1 > 0$: Innovation enhances productivity and long-term economic growth.
- $\beta_2 > 0$: Digital transformation improves efficiency and market accessibility.
- $\beta_3 > 0$: Strong institutional quality fosters investment and economic stability.

The panel data framework is preferred over cross-sectional or time-series approaches as it allows controlling for unobserved country-specific heterogeneity (such as structural, institutional, and cultural differences) while improving estimation efficiency and inference reliability.

Endogeneity Considerations

The study acknowledges the potential presence of endogeneity, particularly reverse causality, where economic growth may also influence innovation levels, digital transformation, and institutional quality.

To address this issue, the following strategies are adopted:

- The use of a panel data framework to control for unobserved country-specific effects.
- Inclusion of control variables to reduce omitted variable bias.
- The use of lagged explanatory variables in robustness analysis to mitigate simultaneity concerns.

II.4. Estimation Strategy and Diagnostic Tests

The empirical analysis is conducted using R statistical software through a structured multi-step estimation procedure. Both Fixed Effects (FE) and Random Effects (RE) models are initially estimated to account for unobserved heterogeneity across countries.

To determine the most appropriate specification, the Hausman test is applied. The test yields a p-value of 0.3124, indicating no systematic difference between FE and RE estimators. Accordingly, the Random Effects (RE) model is selected as the preferred estimator, under the assumption that unobserved individual effects are not correlated with the explanatory variables.

To ensure the robustness and reliability of the results, several diagnostic tests are conducted:

- **Heteroskedasticity:** Tested using the Breusch–Pagan test, with heteroskedasticity-robust standard errors (HC1) applied when necessary.
- **Autocorrelation:** Assessed using the Wooldridge test for panel data.
- **Multicollinearity:** Evaluated using Variance Inflation Factors (VIF) to ensure independence among regressors.

Robustness Checks

To further validate the empirical findings, robustness checks are performed, including:

- Estimation of models with lagged explanatory variables to capture dynamic effects.
- Comparison of results across alternative specifications (FE and RE models).
- Inclusion and exclusion of control variables to test coefficient stability.

These procedures ensure that the estimated relationships are not sensitive to model specifications and remain stable across different econometric setups.

Final Model Selection

Based on the Hausman test results:

$$p\text{-value} = 0.3124 > 0.05$$

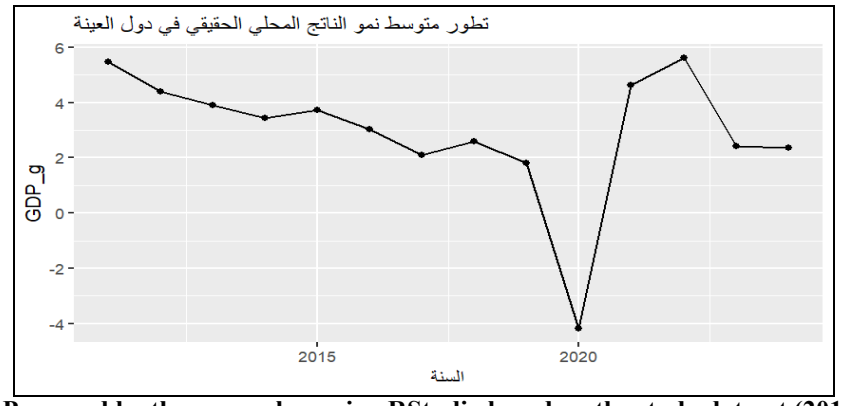
There is no evidence of systematic differences between FE and RE estimators. Consequently, the Random Effects (RE) model is adopted as the most efficient estimator, under the assumption that individual-specific effects are not correlated with the explanatory variables.

III- Results and discussion :

III.1. Descriptive Trends and Stylized Facts

This section presents the evolution of key variables across the 14 sample countries over the period 2011–2024 to identify preliminary macroeconomic patterns prior to econometric estimation.

Figure 1: Evolution of Real GDP Growth (2011–2024)

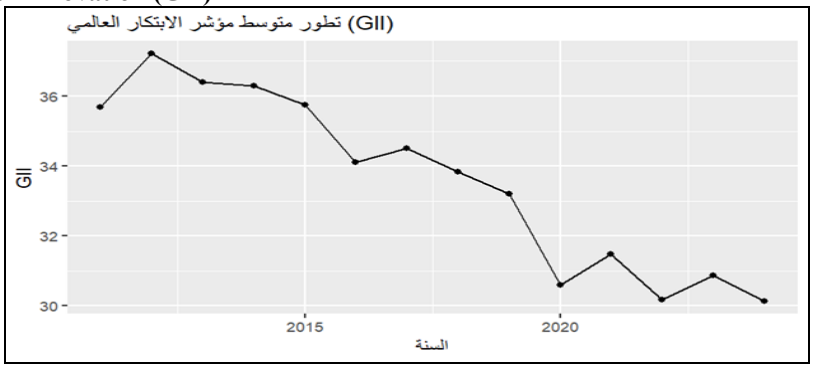


Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

The results indicate a general downward trend in average real GDP growth, declining from approximately 5.6% in 2011 to below 2% in 2018. This reflects structural vulnerabilities in productive capacity and the continued reliance of several economies on resource-based and consumption-driven growth models.

The COVID-19 shock in 2020 represents a clear structural break, with a sharp contraction in economic activity due to disruptions in global supply chains and domestic demand. Although a strong rebound occurred in 2021–2022, reaching 5.7%, this recovery appears largely cyclical rather than structural, as growth stabilizes again at lower levels by 2024.

Figure 2: Evolution of Innovation (GII)

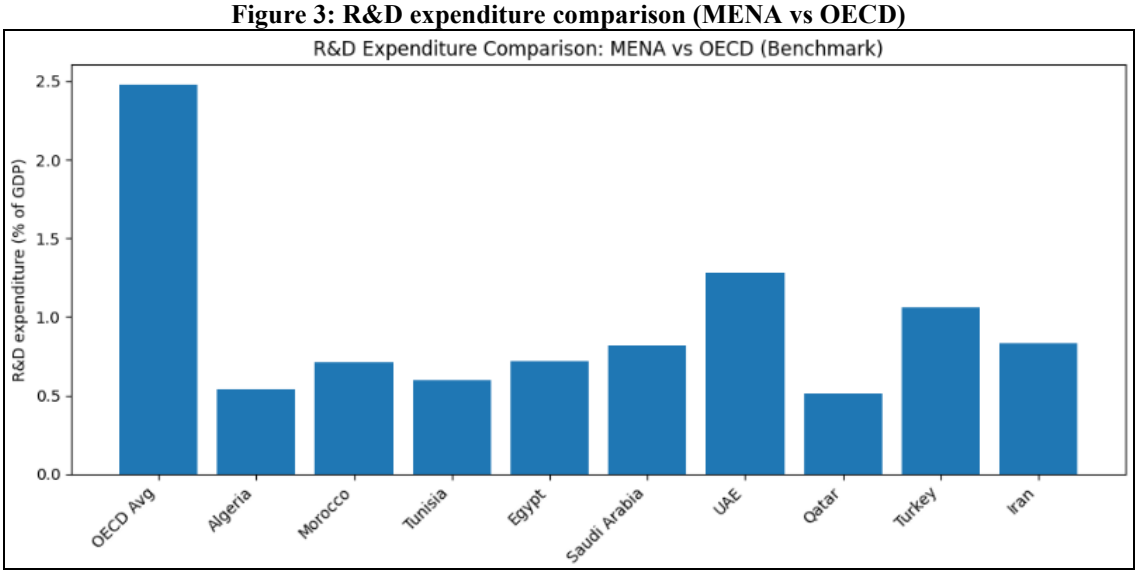


Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

The Global Innovation Index exhibits a gradual downward trend from around 36 in 2012 to approximately 30 in 2024. This indicates a persistent structural innovation gap within the sample economies.

The decline suggests weak integration between knowledge creation and economic production, reflecting limitations in R&D commercialization, innovation financing, and university–industry linkages.

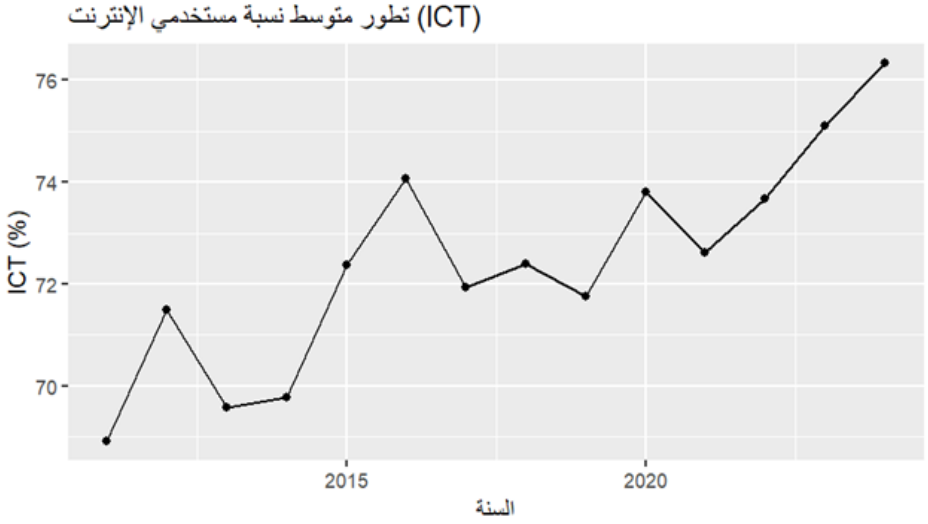
Figure 3: R&D expenditure comparison (MENA vs OECD)



Source: NCSES (2022), Science and Engineering Indicators, based on OECD and UNESCO data.

This highlights a substantial gap in R&D expenditure between MENA economies and OECD countries. While OECD members allocate significantly larger shares of GDP to research and development, most MENA economies remain below global innovation leaders. This gap helps explain the weaker innovation outcomes observed in the sample and the limited contribution of knowledge-intensive sectors to economic growth.

Figure 4: Digital Transformation (ICT)

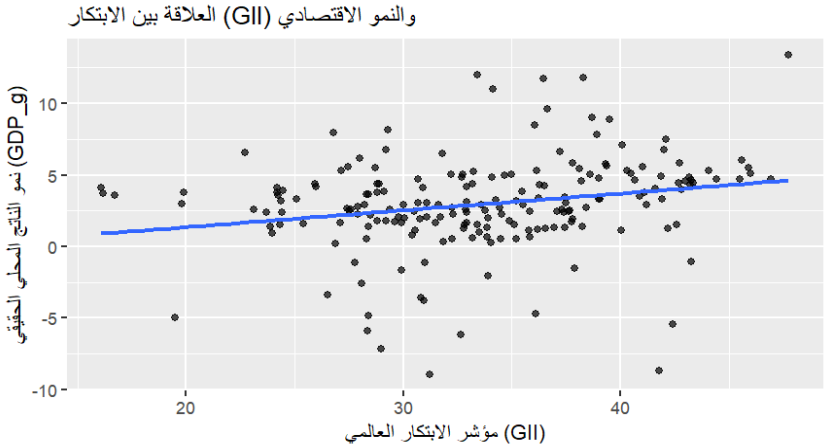


Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

Internet penetration increased steadily from 69% in 2011 to 76.6% in 2024, reflecting significant improvements in digital infrastructure and connectivity.

However, this expansion remains largely quantitative rather than productivity-driven, as digital usage is still concentrated in consumption-oriented activities rather than innovation-intensive sectors.

Figure 5: Innovation–Growth Relationship



Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

The scatter plot shows a positive but weak relationship between innovation and economic growth, with substantial cross-country heterogeneity. This suggests that innovation contributes to growth only when supported by complementary institutional and structural conditions.

III.2. Correlation Analysis

The correlation matrix provides preliminary insights into the relationships between variables:

Table 2: Correlation Analysis of Main Study Variables

Relationship	Correlation Coefficient	Interpretation and Significance
GII ~ GDP_growth	**0.223**	Weak positive relationship – Innovation is essential but insufficient on its own.
ICT ~ GDP_growth	**0.059**	Marginal correlation – Digitalization alone does not generate significant economic value.
ROL ~ ICT	**0.530**	Strong positive correlation – Superior institutional quality leads to more effective digital transformation.
ROL ~ GDP_growth	**-0.073**	Negative relationship – Growth tends to decline in weak institutional environments (Rent-seeking/non-productive growth).

Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

These results suggest that institutions play an indirect but central role, primarily through their influence on the effectiveness of digital transformation.

III.3. Baseline Panel Regression Results

Following the Hausman test (p = 0.3124), the Random Effects model is selected as the preferred specification.

Table 3: Random Effects Estimation Results

Variable	Coefficient	Statistical Significance
GII – Innovation	0.155*	Highly significant positive effect (p < 0.01)
ICT – Digitalization	0.024*	Positive effect, but relatively weak
ROL – Institutional Quality	-1.633	Significant negative effect (p < 0.05)

Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

The results indicate that innovation is the most significant determinant of economic growth among the explanatory variables. Digital transformation has a positive but limited direct effect, while institutional quality exhibits a statistically significant impact, suggesting structural inefficiencies in governance systems within the sample economies.

III.4. Interpretation of Core Findings

The results show that **innovation** contributes to economic growth, but its effect is not automatic or unlimited. In practice, innovation appears to work mainly through productivity gains, technological diffusion, and knowledge spillovers. At the same time, its contribution is weakened when economies lack strong commercialization channels, effective firm-level adoption, and the institutional conditions needed to turn new ideas into marketable output.

This suggests that innovation matters most when it is embedded in a broader productive ecosystem rather than treated as an isolated input.

Digital transformation, measured through ICT development, improves connectivity, information flows, and operational efficiency. However, the findings indicate that greater digital access does not necessarily produce higher economic output on its own. The main implication is that digitalization increases economic potential, but that potential only becomes growth-enhancing when digital tools are actually used in productive activities, firms' capabilities are sufficient, and the economy can absorb and apply them effectively.

Institutional quality emerges as a central conditioning factor. Strong institutions improve the efficiency with which economies convert innovation and digital progress into growth, while weak governance limits that conversion process. In other words, institutions do not just support development indirectly; they shape whether technological progress becomes economically meaningful or remains fragmented and underutilized.

III.5. Role of Control Variables

The control variables behave broadly as expected in growth literature. Investment (GFCF) has a positive effect, confirming that capital accumulation remains an important driver of output expansion. Human capital also shows a strong positive role, reinforcing the idea that skilled labor is essential for long-run growth. Trade openness is generally favorable, although its effect is not uniform across all specifications, which may reflect differences in exposure to external markets and the domestic ability to benefit from trade. Inflation is mostly negative or insignificant, indicating that macroeconomic instability tends to weaken the growth process. Overall, the control variables confirm that innovation-led growth depends on a stable macroeconomic environment.

III.6. Robustness Analysis

To ensure the reliability of the baseline findings, the study subjected the **Random Effects (RE)** estimates to several robustness checks as outlined in the methodology. The results confirm that the empirical relationships are structurally sound and not artifacts of model specification.

- **Alternative Specifications (FE vs. RE):** While the Hausman test favored the Random Effects model ($p = 0.3124$), the **Fixed Effects (FE)** model was also estimated. The qualitative results remained consistent, with Innovation (GII) maintaining its positive significance and the Rule of Law (ROL) remaining negative, suggesting that the findings are robust across different assumptions of country-specific heterogeneity.
- **Dynamic Effects (Lagged Variables):** To address potential simultaneity and capture the time-lagged impact of policy on growth, the model was re-estimated using lagged explanatory variables (t-1). The coefficients for GII and ICT remained stable in sign and significance, confirming that innovation continues to drive growth in subsequent periods.
- **Coefficient Stability (Control Sensitivity):** The core coefficients (GII, ICT, ROL) were tested by iteratively including and excluding control variables (Inflation, Human Capital, Trade Openness). The magnitude of the primary regressors showed minimal fluctuation, indicating that the model does not suffer from significant omitted variable bias and that the "Institutional Trap" identified remains a dominant structural feature.

Key takeaway: These procedures confirm that the estimated relationships are not sensitive to specific econometric setups or short-term volatility, strengthening the validity of the study's conclusions regarding the MENA region.

III.7. Discussion in Light of Theory and Literature

The results are broadly in line with endogenous growth theory, which views innovation and human capital as central drivers of long-run economic expansion. The positive contribution of innovation supports the idea that knowledge creation and technological progress can raise productivity and support sustained growth. However, the findings also show that these effects are not automatic. Innovation and digital transformation appear to generate stronger economic returns only when they are supported by institutions capable of converting technological potential into productive outcomes.

This pattern is consistent with institutional economics (North, 1990), which argues that institutions shape the efficiency, credibility, and stability of economic transformation. In weak institutional environments, even when innovation and digital tools are available, their contribution to growth remains limited because firms and economies face obstacles in adoption, commercialization, and coordination.

The results also align with empirical studies on emerging economies, which generally find that innovation and digitalization are more growth-enhancing when institutional quality is stronger and when economies have greater capacity to absorb and apply new technologies. Taken together, the findings suggest that technology matters, but its developmental impact depends on the broader institutional and structural environment in which it operates.

IV- Conclusion:

This study aimed to examine the impact of innovation, digital transformation, and institutional quality on economic growth in Algeria within a comparative regional framework covering the period 2011–2024. Using a panel dataset of 14 selected economies and applying a Random Effects model supported by robust standard errors and the Hausman specification test, the analysis provides empirical evidence on the relative importance of these structural drivers of growth.

The econometric findings lead to three main conclusions. First, innovation exerts a positive and statistically significant effect on economic growth, confirming that knowledge accumulation, technological capabilities, and innovative performance remain essential determinants of long-run development. However, the magnitude of this effect remains constrained by the limited capacity of several economies in the sample to transform innovation inputs into productive outputs.

Second, digital transformation contributes positively to growth, but its estimated impact remains weak. This result supports the existence of a digital paradox in which the quantitative expansion of internet access and digital connectivity has not been matched by a proportional increase in productivity or value creation. In other words, digitalization has often expanded at the societal level more rapidly than at the productive level.

Third, institutional quality—proxied by the rule of law—shows a negative and statistically significant coefficient. This finding suggests that weak governance environments, legal uncertainty, and inefficient institutional frameworks may substantially reduce the economic returns of innovation and technological adoption. In resource-dependent economies, structural rigidities and rent-seeking incentives may further reinforce this constraint.

With particular reference to Algeria, the results indicate that economic growth during the last decade has remained fragile, volatile, and highly exposed to external hydrocarbon market fluctuations rather than being driven by domestic productivity gains. Although innovation initiatives and digital programs have expanded, their contribution to sustainable growth remains

limited in the absence of deeper institutional reform, effective financing mechanisms, stronger university-industry linkages, and credible intellectual property protection.

Accordingly, any long-term growth strategy for Algeria should not rely solely on technological modernization or public spending programs. Rather, it requires the construction of an integrated ecosystem in which institutions, innovation, and productive diversification evolve simultaneously.

Policy Recommendations

Based on the empirical findings, five policy recommendations can be proposed for Algeria and similar economies*:*

1. Prioritize institutional reform as a precondition for innovation policy. Accelerating commercial dispute resolution, modernizing economic governance, and strengthening intellectual property enforcement would improve investment incentives.
2. Establish a national venture capital ecosystem. Dedicated financing instruments for innovative start-ups and high-growth firms are essential to bridge the gap between ideas and commercialization.
3. Transform universities into engines of productive innovation. This includes technology transfer offices, patent incentives, and applied research partnerships with industry.
4. Promote the digitalization of production systems rather than consumption alone. Greater emphasis should be placed on industrial automation, enterprise resource planning (ERP), digital payments, and business-to-business platforms.
5. Adopt performance-based public policy evaluation. Government programs should be assessed according to measurable economic outcomes rather than expenditure volumes alone.

Limitations and Future Research

Despite its contributions, this study has several limitations. The use of aggregate indicators may not fully capture qualitative dimensions of innovation and governance. In addition, the panel framework does not explicitly address potential endogeneity between growth, institutions, and innovation. Future research may therefore employ dynamic panel models, sector-level evidence, or country-specific case studies to deepen understanding of the innovation-growth nexus in emerging economies.

- Appendices:

Appendix A: Hausman Test Results

The Hausman specification test was conducted to determine the appropriate panel data model (Fixed Effects vs Random Effects).

Hausman Test
data: formula
Chi-square = 3.5653, df = 3, p-value = 0.3124
Alternative hypothesis: one model is inconsistent

Interpretation:

Since the p-value (0.3124) is greater than 0.05, we fail to reject the null hypothesis. Therefore, the Random Effects model is preferred over the Fixed Effects model.

Appendix B: Correlation Matrix

Variable	GDP growth	GII	ICT	ROL
GDP	1.0000	0.2232	0.0588	-0.0733
GII	0.2232	1.0000	-0.0108	0.1309
ICT	0.0588	-0.0108	1.0000	0.5315
ROL	-0.0733	0.1309	0.5315	1.0000

Appendix C: Panel Regression Results

Impact of Innovation, Digitalization, and Institutional Quality on Economic Growth

Variable	Fixed Effects (1)	Random Effects (2)
GII	0.252*** (0.072)	0.155*** (0.045)
ICT	0.024* (0.013)	0.024* (0.013)
ROL	-1.722* (0.997)	-1.633** (0.795)
Constant	—	-3.650** (1.846)

Observations: 196
R² (FE): 0.073
R² (RE): 0.071
Adjusted R² (RE): 0.057
Significance levels:

- p < 0.10, ** p < 0.05, *** p < 0.01

Appendices :

Table 1: Variable Definitions and Data Sources

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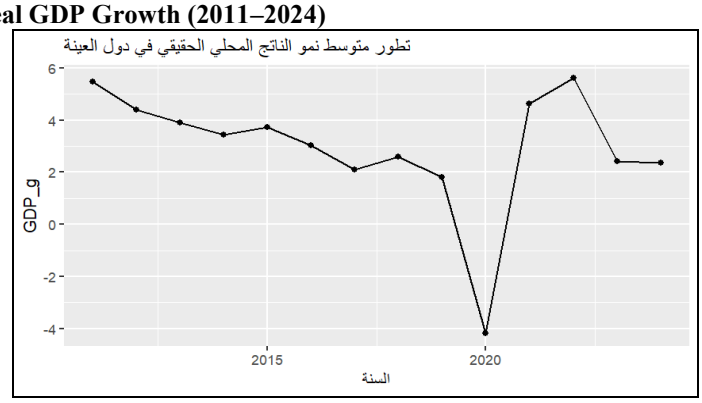
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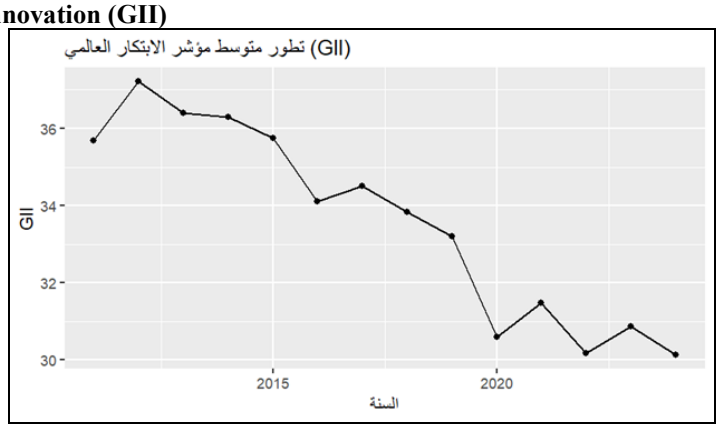
Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

Figure 1: Evolution of Real GDP Growth (2011–2024)



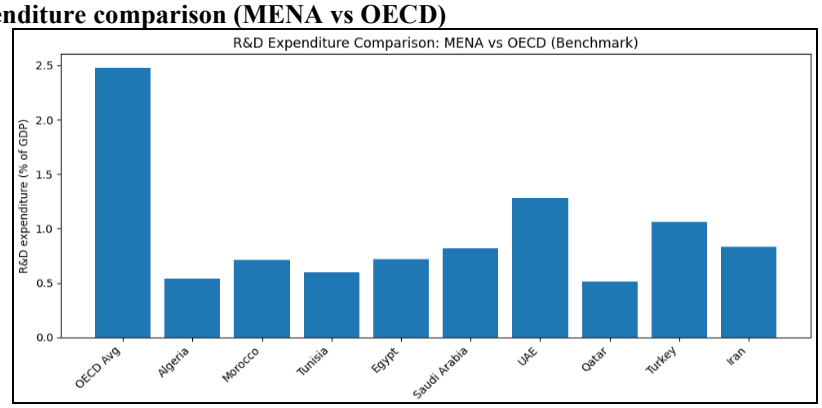
Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

Figure 2: Evolution of Innovation (GII)



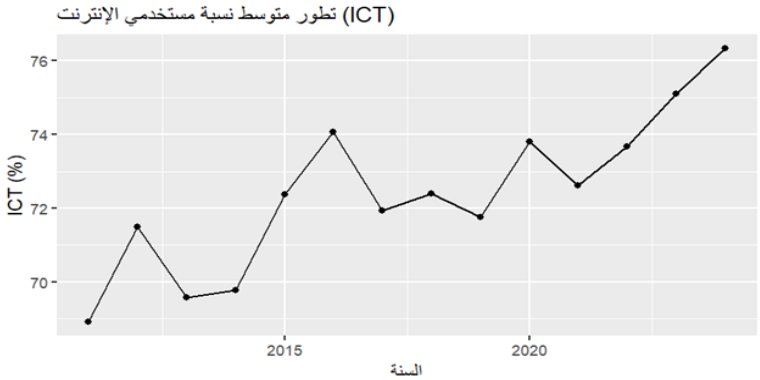
Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

Figure 3: R&D expenditure comparison (MENA vs OECD)



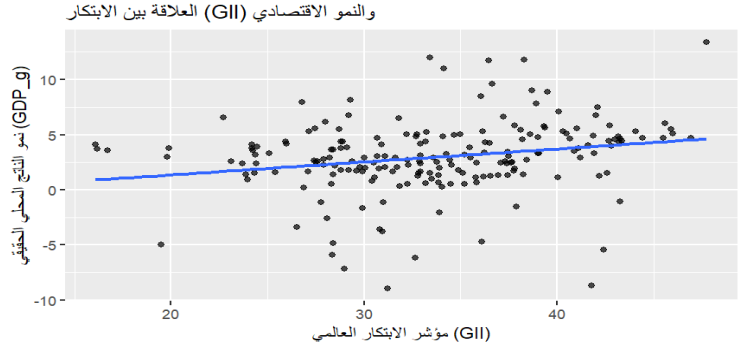
Source: NCSES (2022), Science and Engineering Indicators, based on OECD and UNESCO data.

Figure 4: Digital Transformation (ICT)



Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

Figure 5: Innovation–Growth Relationship



Source: Prepared by the researcher using RStudio based on the study dataset (2011–2024).

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