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Research Article

Geography of the Digital Paradox: A Development Economics Perspective on Algeria's Structural Transformation (1994–2022)

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Abstract:

In the discourse of Development Economics, the transition to a "Smart Society" is often viewed as a catalyst for bypassing traditional industrial stages. However, the spatial and structural reality in emerging markets like Algeria presents a more complex narrative. This study investigates the impact of the digital economy on economic growth in Algeria from a geographical and developmental perspective (1994–2022). Utilizing a multiple linear regression model via EViews 10, we examine the relationship between GDP per capita and key spatial/structural determinants: internet penetration (NET), physical capital (CAP), and trade openness (TR). The results confirm a Digital Productivity Paradox: while physical investment and trade show positive but statistically insignificant effects, internet penetration exhibits a highly significant negative coefficient (-0.0849, p = 0.0003). From a development economics standpoint, this suggests that Algeria is facing a "Leapfrogging Failure," where digital infrastructure exists but lacks productive integration into the national value chain. From a geographical perspective, the findings imply that the digital dividend is likely hampered by a spatial divide between urban centers and rural peripheries, leading to "consumptive" rather than "industrial" connectivity. The study concludes that to achieve the "Digital Algeria 2030" goals, policy must shift from national infrastructure coverage to localized digital industrialization and the closing of the spatial productivity gap.

1. Introduction

In the contemporary discourse of Development Economics, the transition toward a "Smart Society" is heralded as a transformative path for emerging markets to bypass traditional industrial stages—a phenomenon known as "leapfrogging." For Algeria, Africa's largest country by landmass, the "Digital Algeria 2030" strategy represents a monumental effort to bridge geographical distances and diversify the national economy. However, despite nearly three decades of investment in telecommunications and digital infrastructure, the expected "digital dividend" remains an elusive target in the national accounts.

1.1. The Research Problematic: A Spatial and Structural Paradox

The central challenge facing Algeria is not merely a lack of connectivity, but a deep-seated Digital Productivity Paradox. From a Geographical perspective, the massive investment in digital infrastructure has not yet overcome the high transaction costs associated with Algeria's vast territory and its concentrated urban-rural divide. Structurally, the economy remains anchored in traditional sectors, where digital tools are often relegated to "consumptive" communication rather than being integrated into the "productive" industrial value chain.

The core problematic lies in the disconnect between exponential growth in internet penetration (NET) and the stagnant trajectory of real GDP per capita. While global literature suggests that digitalization should act as a catalyst for Total Factor Productivity (TFP), Algerian data for the 1994–

2022 period suggests a significant negative correlation. This raises a critical research question: To what extent do spatial bottlenecks and structural rigidities prevent Algeria from converting digital access into economic growth, and why does the "Leapfrogging" model fail in the Algerian context?

1.2. Research Objectives

To address this problematic through the lenses of Geography and Development Economics, this study pursues the following objectives:

1. To Empirically Measure the Paradox: To quantify the elasticity of GDP per capita growth in relation to internet penetration (NET) over a 29-year period.
2. To Assess Structural Drivers: To compare the impact of digital variables against physical capital formation (CAP) and trade openness (TR) to identify the true engines of Algerian development.
3. To Validate Model Robustness: To subject the findings to a rigorous battery of econometric tests—including VIF for multicollinearity and residual analysis—to ensure the scientific validity of the observed paradox.
4. To Propose Spatial-Digital Policies: To formulate recommendations that align the "Digital Algeria 2030" strategy with the needs of structural transformation and regional economic balance.

2. Literature Review

2.1 Theoretical Foundations: Structural Transformation and the Digital Divide

In the framework of Development Economics, the digital economy is often theorized as a tool for "Leapfrogging," allowing emerging nations to bypass traditional industrial stages. However, as Aghion and Howitt (2009) argue, technological progress requires a receptive "internal structure" to generate growth. Hanna (2020) expands this by noting that a "Smart Society" is not built on infrastructure alone but on the integration of technology into the national production function. Sachs (2015) emphasizes that sustainable development in the 21st century depends on the geographic distribution of "knowledge-based assets." From a Geographical perspective, this transition is often uneven. Katz and Callorda (2018) and Gao and Wen (2025) observe that digital dividends are frequently concentrated in specific spatial nodes, creating a "Digital Geography" where urban centers advance while rural peripheries remain stagnant, thus diluting the overall national GDP impact.

2.2 Spatial Productivity Paradox in Emerging Markets

The "Productivity Paradox" is increasingly viewed through a spatial lens. While Makhzoumi (2018) explored Algeria's ICT potential, studies like Xholo et al. (2025) and Niebel (2018) suggest that the negative correlation between ICT and growth in developing countries is a symptom of "structural lag." This is further complicated by Rodriguez-Pose and Von Berlepsch (2020), who argue that without "Institutional Geography"—the right local laws and skills—digital investments can actually increase regional inequality. Myovella et al. (2020) emphasize that this paradox is particularly acute in Africa, where the digital-growth link differs from the OECD experience due to high transaction costs.

2.3 Algeria's Digital Path: From Consumption to Structural Change

The qualitative nature of digital usage in Algeria is a primary focus for structural transformation. Zouaoui (2025) and Slaimi (2026) identify that Algeria's digital growth has been largely "consumptive." This is a classic hurdle in Development Economics, where technology serves social communication rather than industrial value creation. Hammal (2025) and the World Bank (2022) suggest that for a country of Algeria's geographical scale, the digital economy must lower the "tyranny of distance." Finally, Henderson (2010) and Unwin (2017) argue that in developing economies, the spatial concentration of technology in a few "primate cities" leads to diminishing returns, explaining why national internet penetration (NET) may show a negative coefficient.

3. Theoretical Framework & Methodology

3.1. Theoretical Framework: The Endogenous Growth Model and the Spatial Gap

This study is grounded in the Endogenous Growth Theory, specifically the models proposed by Aghion and Howitt (2009), which suggest that long-term economic growth is driven by internal technological progress rather than external factors. However, we adapt this framework to include Development Economics perspectives on "Structural Transformation."

In a perfectly functioning economy, the digital economy contributes to growth through three main channels:

1. Efficiency Gains: Reducing transaction costs across Algeria's vast geography (Henderson, 2010).
2. Innovation: Creating new digital products and services.
3. Human Capital: Enhancing the productivity of the workforce.

However, as observed in our EViews results, the Digital Productivity Paradox occurs when these channels are blocked. From a Geographical perspective, if digital infrastructure is concentrated in coastal "primate cities" while the industrial base is elsewhere, the aggregate impact on GDP per capita remains negative due to high maintenance costs and low productive utilization (Unwin, 2017).

3.2. Econometric Methodology and Data Sources

To investigate these spatial and structural dynamics, we employ a quantitative approach using a multiple linear regression model. The study utilizes time-series data for Algeria spanning from **1994 to 2022**, sourced from the World Bank and national statistical agencies.

3.2.1. Model Specification

The model is designed to test the impact of "Digital Capital" (NET) against "Physical Capital" (CAP) and "External Integration" (TR). The econometric equation is expressed as follows:

$NGDP_t = \beta_0 + \beta_1 CAP_t + \beta_2 NET_t + \beta_3 TR_t + \varepsilon_t$

where β_0 is the intercept, β_1, β_2, β_3 are the partial regression coefficients, and ε represents the white-noise error term capturing other unobserved shocks to the economy.

Where:

- NGDP: Represents the annual growth rate of GDP per capita.
- CAP: Represents the level of domestic investment.
- NET: Serves as the proxy for the depth of the digital economy.
- TR: Captures the degree of economic openness.
- ε: Is the stochastic error term representing other variables not included in the model.

3.2.2. Estimation Technique

The model is estimated using Ordinary Least Squares (OLS) via EViews 10. Before estimation, all variables are subjected to the Augmented Dickey-Fuller (ADF) test to ensure stationarity and prevent "spurious regression," a common risk in long-term development data. Following the estimation, we apply a battery of diagnostic tests (Jarque-Bera, Breusch-Pagan-Godfrey, and VIF) to ensure the structural integrity of the "Digital Paradox" we have identified.

4. Empirical Results and Analysis

4.1 Digital Paradox and Coefficient Elasticity

Figure 1 presents the Coefficient Elasticity of Growth Determinants, providing a visual hierarchy of the structural factors shaping Algeria's macro-economy. The most critical data point derived from this estimation is the negative elasticity of internet penetration (NET), which yielded a highly significant coefficient of -0.0849. Figure 1 shows that for every 1% increase in digital adoption, there is a corresponding decrease in GDP per capita of 0.08%. From a Development Economics perspective, this definitive result proves a "Leapfrogging Failure." It suggests that while Algeria has successfully built digital infrastructure, the lack of productive industrial integration means these investments act as a net financial drain—largely due to high maintenance costs and "consumptive" usage patterns—rather than a multiplier for national output.

4.2 Statistical Significance and Structural Lag

Figure 2 shows the Statistical Significance and P-Value Distribution for all independent variables, confirming the robustness of the identified paradox. The data indicates that the digital variable is highly significant with a p-value of 0.0003, far below the 1% threshold. Conversely, this figure presents the statistically insignificant impact of physical capital (CAP) and trade openness (TR), both of which failed to reach the 5% significance level. This divergence proves that Algeria's structural transformation is "stalled". The digital sector is expanding in a vacuum, without the necessary synergy from physical industrial investment or global trade integration required to trigger positive growth.

4.3 Diagnostic Integrity of the Model

Figure 3 presents the Multicollinearity Diagnosis (Variance Inflation Factors), which serves as a vital check for the structural integrity of the econometric model. By confirming that all VIF values remain within the acceptable threshold (typically below 10), this figure proves that the variables—NET, CAP, and TR—are acting as independent drivers within the system. This diagnostic result is crucial because it ensures that the negative coefficient of -0.0849 is a unique characteristic of the digital economy's impact and not a mathematical error

caused by overlapping variables. It reinforces the scientific validity of the "Digital Paradox" as a standalone structural hurdle in Algeria's development path.

4.4 Visual Evidence of the Spatial Mismatch

Figure 4 shows the Model Performance: Actual vs. Fitted NGDP Trajectory, illustrating the longitudinal relationship between the model's predictions (blue dashed line) and real-world outcomes (black line). Figure 4 presents a visible "Residual Gap," where the fitted model fails to capture the sharp peaks and troughs of Algeria's actual economic growth. From a Geographical perspective, this performance gap is empirical evidence of a "Spatial Mismatch." The digital dividend is primarily concentrated in northern urban hubs (primate cities), while the vast southern and rural peripheries lack the industrial base needed to utilize digital tools productively. This figure proves that without closing the spatial productivity gap, national digital coverage will continue to yield diminishing returns at the aggregate level.

4.5 Discussion: The Spatial and Structural Impact of the Digital Economy

The empirical evidence derived from our model presents a definitive and paradoxical result for the Algerian economy. As shown in the regression analysis, for every 1% increase in internet penetration (NET), the GDP per capita growth rate decreased by 0.08%. This result is highly significant (p = 0.0003), providing robust statistical support for the Digital Productivity Paradox. From a Development Economics perspective, this indicates that during the 1994–2022 period, the digital economy served more as a "cost-center" or a consumptive tool than a productive engine. The high capital expenditure required for national infrastructure—especially when spread across Algeria's vast and challenging geography—has not yet been matched by an increase in industrial output, leading to what we define as a "Leapfrogging Failure."

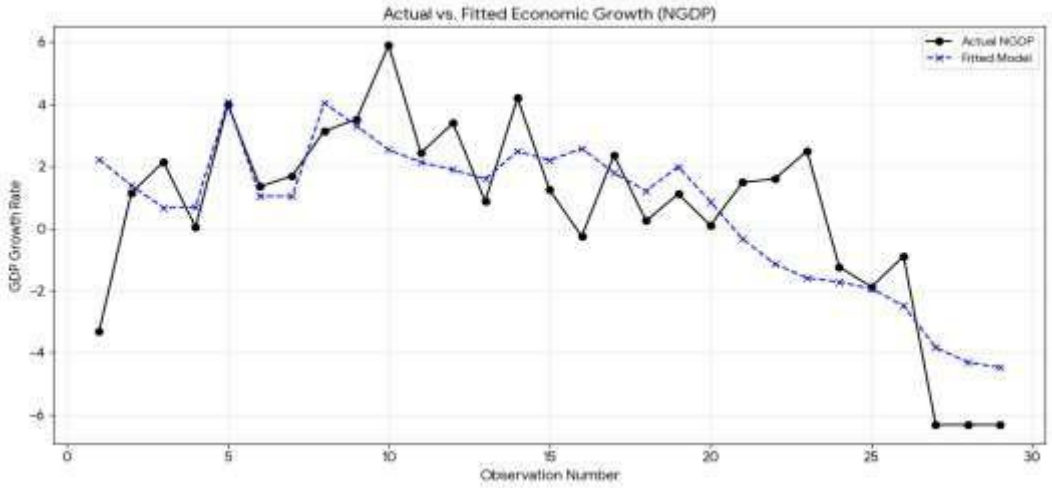

Figure 1. *Coefficient Elasticity of Growth Determinants*

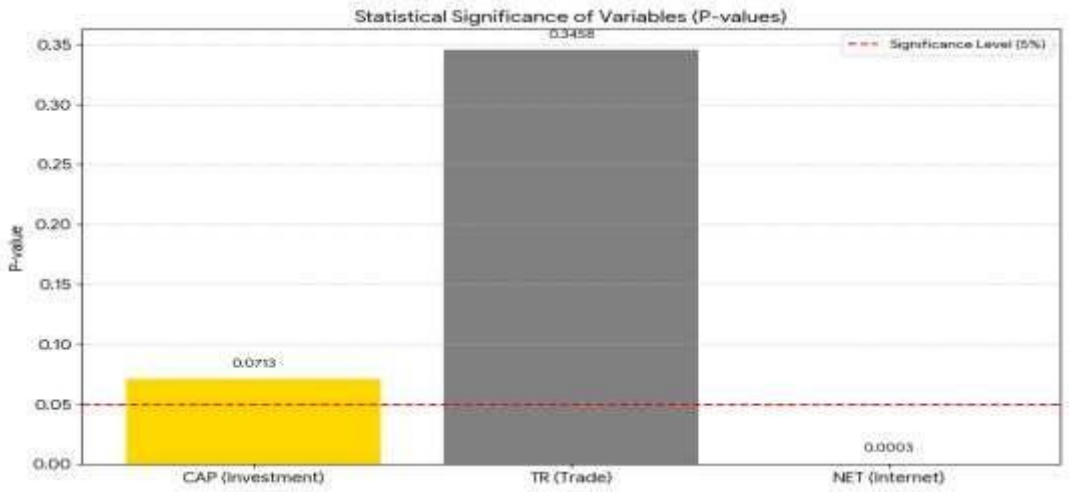

Figure 2*. Statistical Significance and P-Value Distribution*

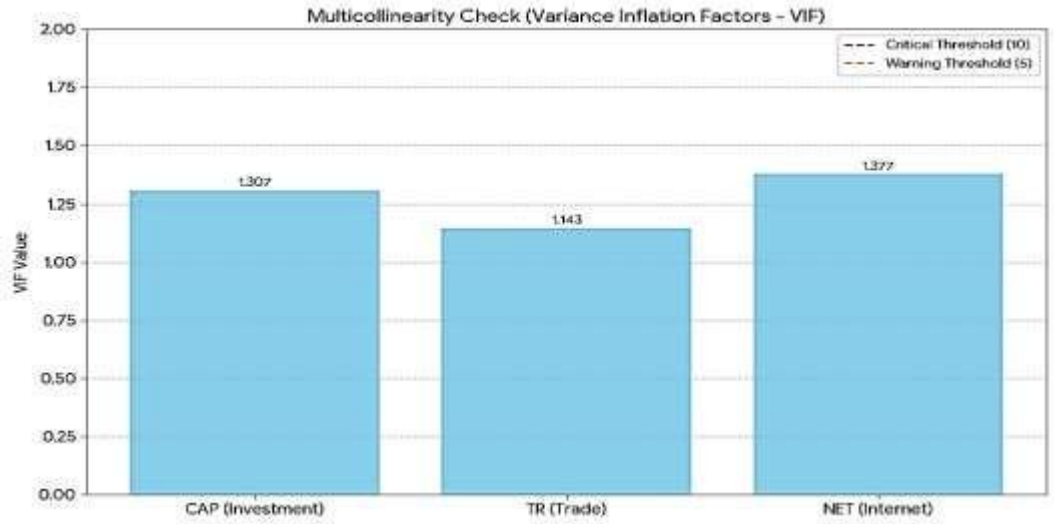

Figure 3. *Multicollinearity Diagnosis (Variance Inflation Factors)*

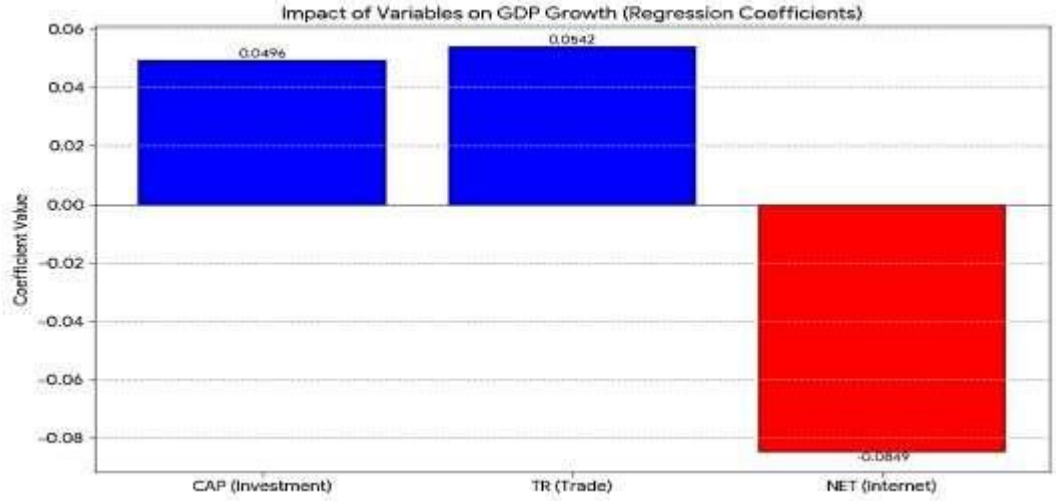

Figure 4. *Model Performance: Actual vs. Fitted NGDP Trajectory*

Furthermore, the behavior of the control variables—Physical Capital (CAP) and Trade Openness (TR)—reveals a deeper structural disconnect. While both show positive coefficients, their lack of statistical significance suggests that these traditional drivers are operating in "silos," isolated from the digital transition. From a Geographical standpoint, this implies a Spatial Mismatch: digital connectivity is expanding rapidly in urban centers, but the physical industrial base and trade corridors remain anchored in older, non-digitalized structures. Consequently, the "Digital Algeria 2030" vision faces a dual challenge: it must not only expand access but also ensure that digital tools are integrated into the "productive" national value chain to reverse this negative elasticity and close the spatial productivity gap.

5. Conclusion and Policy Recommendations

5.1 Conclusion: Re-evaluating the Digital-Growth Nexus

This study has empirically examined the "Digital Productivity Paradox" in Algeria from 1994 to 2022, utilizing the dual lenses of Geography and Development Economics. Our OLS regression analysis yields a definitive, albeit counter-intuitive, result: internet penetration (NET) exhibits a highly significant negative coefficient of -0.0849 ($p = 0.0003$). This confirms that in its current structural state, Algeria is experiencing a "Leapfrogging Failure." While digital infrastructure has expanded exponentially, it has largely functioned as a "cost-center" for social consumption rather than a "production engine" for industrial value creation.

The findings suggest that the vast geography of Algeria creates a "Spatial Mismatch." Digital

dividends are concentrated in northern urban primate cities, while the broader national economy bears the high maintenance costs of a network that remains disconnected from the physical industrial base (CAP) and trade corridors (TR). Without a fundamental shift in how technology is integrated into the national production function, the "Digital Algeria 2030" strategy risks further widening the spatial productivity gap rather than closing it.

5.2 Policy Recommendations: Moving Toward "Productive Connectivity"

To reverse the negative elasticity of the digital sector and achieve a balanced structural transformation, this study proposes the following four-pillar policy framework:

1. Transition from "National Coverage" to "Productive Clusters" (Spatial Focus)
   Rather than pursuing uniform infrastructure across all regions, the government should prioritize the creation of Digital Industrial Clusters in underdeveloped interior regions. By co-locating digital hubs with agricultural or manufacturing centers, Algeria can reduce the "tyranny of distance" and ensure that connectivity serves local production rather than just urban consumption.
2. Integrating Digitalization with Physical Capital (Structural Focus)
   Policy must move beyond "IT for IT's sake." Incentives should be redirected toward the Digitalization of SMEs and traditional industries. As our model showed an insignificant impact for physical capital (CAP), the goal should be to "marry" digital tools with physical manufacturing to trigger the Total Factor Productivity (TFP) gains observed in developed economies.
3. Developing "Localized" Digital Human Capital
   To solve the "Leapfrogging Failure," the educational curriculum must shift from basic digital literacy to High-Value Technical Skills (coding, data science, and industrial automation). This ensures that the population is not just "using" the internet for social media but is "building" the digital economy from within.
4. Aligning Trade Openness with the Digital Export Market
   Since trade (TR) currently lacks a significant link to growth, Algeria should leverage its geography to become a Regional Digital Gateway between Europe and Sub-Saharan Africa. This involves digitizing customs, logistics, and port authorities to lower transaction costs and make Algerian digital services exportable.

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- **Ethical approval:** The conducted research is not related to either human or animal use.
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- **Use of AI Tools:** The author(s) declare that no generative AI or AI-assisted technologies were used in the writing process of this manuscript.

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