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THE INFLUENCE OF DIGITAL SECTOR DEVELOPMENT ON ALGERIA'S ECONOMIC TRAJECTORY

The impact of digital economy indicators, in particular, the ICT index and the Internet usage index, on economic growth in Algeria is studied. Using the STAR model, it is determined whether these effects are symmetric. It is shown that the optimal model is non-linear, in particular the LSTAR model, and GDP estimation involves two stages. The results show that positive and negative shocks in the Internet usage index have asymmetric effects on economic growth in Algeria.

Keywords: ICT index; Internet usage; Economic Growth; STAR model.

The global digital economy has emerged as a fundamental driver of economic transformation, reshaping production, consumption, and governance paradigms worldwide. For resource-rich nations like Algeria, which is actively pursuing economic diversification and modernization under its new economic model and the

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“Algeria 2030” strategic vision, harnessing this digital transformation is not just an option but a critical imperative for sustainable development and reducing hydrocarbon dependency. The relevance of this study is anchored in this urgent need to align national strategy with the realities of the 21st century digital landscape.

Algeria has made significant, measurable progress in building its digital foundation. The internet penetration rate reached approximately 60% by 2020, accompanied by sustained government and private investment in communication infrastructure¹. This rapid digitization creates a pressing need to evaluate its true macroeconomic impact, moving beyond anecdotal evidence to rigorous empirical analysis. Conventional economic models often presuppose a simple, linear relationship between digital adoption and economic output. However, this assumption is increasingly challenged by the complex, multi-faceted nature of digitalization, which may involve critical thresholds, saturation points, and asymmetric effects that linear models fail to capture.

This research, therefore, specifically investigates the linkage between the digital sector and economic growth in Algeria, proposing that this relationship is inherently complex. The central proposition is that the influence of key digital indicators, such as internet penetration and a composite ICT index, on economic expansion is not straightforward. Instead, it may exhibit non-linear dynamics, such as threshold effects, and asymmetric responses to positive versus negative shocks.

To empirically test this proposition, the study employs the Smooth Transition Autoregressive (STAR) model. This advanced econometric technique is uniquely suited to identify and characterize regime-dependent behaviors and asymmetries that traditional linear models would overlook.

So, **the purpose of this article** is to provide a nuanced and robust empirical analysis that accurately maps how Algeria’s digital economy influences its macroeconomic trajectory.

By determining whether this relationship is linear or non-linear and symmetric or asymmetric, the findings aim to offer critical, evidence-based insights for policymakers. The results are intended to inform more effective economic strategy and policy design, ensuring that future investments in digital infrastructure, competency development, and regulatory frameworks are strategically aligned with the complex realities of the nation’s economic transition. This alignment is crucial for maximizing the digital economy’s contribution to resilient and sustainable growth, a challenge of paramount relevance for many developing economies navigating their own digital transitions.

A variety of authors have pointed out the crucial role that the digital economy, as reflected by ICT and internet usage, plays in the economic development of nations. As a result, this research has analyzed relevant articles and categorized the literature into two main sections.

¹ Individuals using the internet (% of population) in Algeria from 2005 to 2020. *World Bank Group*. 2021. URL: <https://data.worldbank.org/indicator/IT.NET.USER.ZS?locations=DZ> (assessed on: 05.08.2024).

A substantial body of research employs linear econometric models to establish a direct, positive relationship between digitalization and economic growth. These studies primarily focus on correlation and contribution analysis. K. Vu (2011) utilized a conventional cross-country regression approach to establish a robust correlation between ICT adoption and economic growth, later demonstrating a causal relationship. Another study by C. Choi & M. Hoon Yi (2009), which analyzed panel data from 207 countries using a growth model, found that the Internet significantly contributes to economic growth after controlling for investment, government consumption, and inflation. At a sectoral level, K. Vu (2013) demonstrated a strong positive relationship between ICT usage intensity and the growth of value-added and labor productivity in Singapore, quantifying that ICT investments contributed nearly one percentage point to GDP growth. Focusing on specific country groups, Z. Latif et al. (2018) employed advanced linear estimators (FMOLS, DOLS) for BRICS economies, confirming significant long-term elasticities between ICT and economic growth. Similarly, A. Portillo et al. (2020), using Partial Least Squares Structural Equation Modeling (PLS-SEM) for EU OECD countries, found that advancements in ICT implementation significantly contribute to growth. Collectively, these studies provide foundational evidence that digital infrastructure and usage are key components of modern economic development. However, their reliance on linear methodologies implicitly assumes a constant, uniform effect of digitalization across all contexts, an assumption that subsequent research has challenged.

Further investigation revealed that the digital-growth nexus is not uniform and is significantly moderated by a country's income level, region, and existing economic structure. The methodology here often involves grouping countries or using estimators that account for panel heterogeneity. A. Yousefi (2011), analyzing time-series data from 62 countries, found that ICT is a crucial growth factor for high and upper-middle-income nations but does not facilitate growth in lower-middle-income countries. This finding is echoed in regional studies. G. Harb (2017), in a study of the Arab and Middle East (AME) region, concluded that internet penetration is a vital growth driver in wealthier nations but falls short in middle-income AME countries. In a study by R. Bahrini et al. (2019), applying a panel Generalized Method of Moments (GMM) model, found that mobile phones, internet access, and broadband are pivotal for growth in selected MENA and Sub-Saharan Africa (SSA) countries, with a distinct advantage for MENA nations. Another research conducted by S. Asongu & N. Odhiambo (2020), also using GMM, found that internet penetration in SSA significantly enhances the positive effects of Foreign Direct Investment (FDI) on growth. Supporting the broader relevance of ICT, I. Otoo & N. Song (2021) and M. Kurniawati (2021) found positive impacts of internet and mobile technology on growth across income groups in global and Asian samples, though the benefits for middle-income countries are often described as emerging or beginning. This strand of literature critically establishes that the digital dividend is not automatic. It highlights the importance of contextual factors, suggesting the existence of potential threshold effects and complementary factors that determine the efficacy of digitalization. The use of models

like GMM represents a step forward in addressing endogeneity, yet the core relationship is often still modeled as linear within these contexts.

The most recent and methodologically advanced frontier of this literature directly tests for and identifies complex, non-linear dynamics, moving beyond the linear paradigm. M. Salahuddin & J. Gow (2016) applied ARDL cointegration tests to South African data, finding a significant long-run relationship between internet usage and growth, with Granger causality tests confirming that internet usage drives economic growth. In a study by M. Albiman & Z. Sulong (2017) explicitly tested for non-linear effects in Sub-Saharan Africa using a Pooled Mean Group (PMG) model. Their findings revealed that the linear influence of internet penetration is positive for lower-middle-income nations, implicitly acknowledging varying effects across regimes. Most critically, H. Becha et al. (2023) directly investigated the symmetry of the relationship for 45 African nations. By employing both linear (PMG-ARDL) and non-linear asymmetric (PMG-NARDL) models, they provided compelling evidence of complexity. Their key finding was that positive shocks in ICT imports boost growth, but the effect is asymmetric, with negative shocks having a different impact, a phenomenon observed in several countries within the sample. The studies by M. Albiman & Z. Sulong (2017) and particularly H. Becha et al. (2023) represent a significant methodological and conceptual evolution. They move beyond asking if digitalization affects growth to interrogate how it does so. Their findings confirm that the relationship can be non-linear, being subject to threshold effects, and asymmetric, where positive changes such as growth in the digital sector and negative changes like contractions or setbacks have unequal impacts on economic output.

A growing number of studies have specifically investigated the digital economy in Algeria and the North African region, providing a crucial foundation for this research while also revealing significant methodological and conceptual gaps. A recent study by A. Arbia & K. Sobhi (2024) on North Africa, including Algeria, used quantile regression and found that the internet penetration has varying effects, positive at low quantiles and negative at high quantiles. This directly suggests a non-linear and context-dependent relationship in the region. Similarly, H. Souria (2024) for the MENA region and BINUYO (2015) in a pan-African study that included Algeria, confirmed a positive association between ICT and growth, with the latter emphasizing the role of fixed wireless infrastructure. Research focused solely on Algeria has begun to outline its digital trajectory. N. Zghidi & R. Trabelsi (2025) in a comparative analysis, highlighted that digital transformation in developing countries like Algeria must be supported by adequate infrastructure and institutional quality to be effective. These studies affirm that digitalization is relevant to Algeria's economy. The existing literature on Algeria and its region has successfully established that a relationship between digitalization and growth exists.

The literature conclusively affirms the importance of the digital sector. The progression is clear from establishing correlation, to understanding contextual moderators, and finally to modeling inherent non-linearity and asymmetry. However, a significant gap remains in the context of Algeria. While the country has achieved notable digital progress, no existing study has explicitly modeled the po-

tential for both non-linear (threshold) and asymmetric dynamics in its digital economy-growth relationship. Therefore, this study fills this critical gap by investigating whether the relationship between Algeria's digital development and economic growth is best characterized by a simple linear model or by the complex, regime-dependent behaviors.

THEORETICAL FRAMEWORK FOR THE DIGITAL ECONOMY

The digital economy is characterized by the execution or facilitation of economic activities using electronic methods, which depend on the electronic processing, storage, and transmission of information. It also encompasses the activities that deliver the fundamental physical infrastructure and software essential for these electronic economic functions (Hashim, Nadia, 2008). Defined as a field within the social sciences, economics investigates the distribution of scarce resources to fulfill the various and often conflicting needs of people. The core of economics revolves around the production, distribution, and consumption of goods, as well as the institutions, regulatory frameworks, and environmental aspects that enable these economic processes (Alexandre, Mbo, 2012). To clarify, the digital economy is an economic system fundamentally based on digital information, characterized primarily by the information industry.

This system transforms traditional economic elements into digital formats, leading to the emergence of digital currencies, e-commerce, digital marketplaces, and new forms of digital products and services. At its core, the digital economy is facilitated by interconnected electronic institutions. Communication channels like email and corporate websites promote economic integration, enabling e-commerce — defined as the online trading of goods, services, and financial assets (Farid, 2007).

To move beyond a generic definition, it is essential to adopt a structured model that deconstructs the digital economy into its core, interdependent layers. This systematization allows for a clearer understanding of its components and their relationships. This research proposes a layered framework, synthesizing existing concepts, as illustrated in Fig. 1.

Layer 1: *The Core Digital Sector and its Foundational Infrastructure.* This base layer represents the direct production of digital goods and services and the essential infrastructure that enables it. It includes:

- *The ICT Sector:* Industries that produce core digital goods and services, including telecommunications, software publishing, computer programming, and IT services. The value-added of this sector is a direct contributor to a nation's GDP;
- *Digital Infrastructure:* The physical and software assets required for digital activities, such as telecommunication networks (fibre optic cables, 4G/5G towers), hardware (computers, servers), and core software platforms. This infrastructure is the necessary capital base for the entire digital economy.

Layer 2: *Platform-Enabled E-Commerce & Digital Services.* Building on the core sector, this tier encompasses economic activities mediated by digital plat-

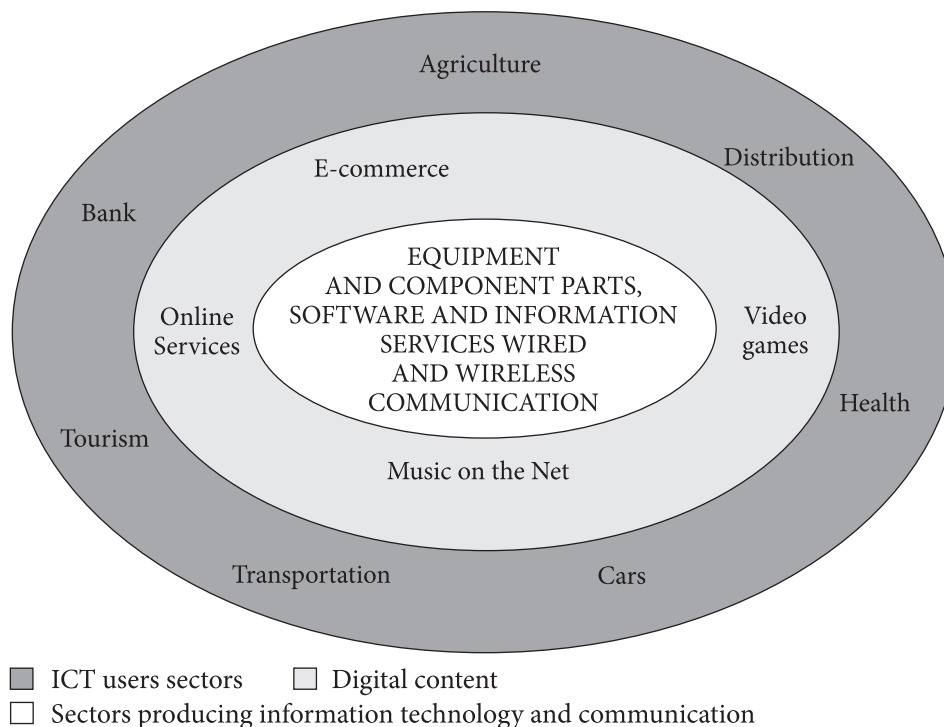


Fig. 1. The structure of Digital Economy

Source: compiled by the authors based on: bsi-economics. 2018. URL: <https://bsi-economics.org/wp-content/uploads/2015/11/Econumerique.pdf>

forms. This includes e-commerce (B2B, B2C), digital finance (online banking, fintech), and the sharing economy.

Layer 3: The Digitized Traditional Economy. This outermost layer captures the productivity gains and transformation of traditional sectors (e.g., agriculture, manufacturing, government services) through the adoption of digital tools and processes, a phenomenon often referred to as “digitalization”.

The model posits that the total macroeconomic impact of the digital economy is the aggregate of the direct value added from the foundational core sector and the indirect productivity enhancements and novel value generated within the platform enabled and digitized Layers.

Evaluating the development of a digital economy requires a multi-faceted approach using specific, quantifiable indicators. The most critical metrics include:

- **Internet Penetration Rate:** This measure evaluates the fraction of the population that has access to the internet. A higher penetration rate demonstrates improved connectivity and establishes a solid foundation for the advancement of the digital economy;
- **The Information and Communications Technology (ICT):** The foundation for analyzing a nation’s digital economy lies in its infrastructure. This analysis covers the physical components of ICT infrastructure, including computer hardware, telephone lines, transformers, fiber optic cables, satellite systems, and both

wired and wireless networks. It is also important to evaluate software investments and gather critical data on internet and network coverage, along with the extent of congestion in these systems. Additionally, understanding the level of obsolescence and depreciation within the digital infrastructure is equally significant. To summarize, the ICT infrastructure is a critical framework for assessing the development of a country's digital economy. This assessment involves quantifying both physical assets, including computing hardware and communication networks, as well as intangible assets like software and data related to internet and network activity. Evaluating the current status, accessibility, and robustness of this ICT infrastructure is vital for understanding the maturity and potential growth of a nation's digital economy (Hocin, 2013);

- **Electronic Commerce (*e-commerce*):** *e-commerce* involves the trading of goods and services for monetary value through networks mediated by computers. These transactions are finalized online when there is mutual agreement between buyers and sellers regarding the transfer of ownership or usage rights. Only those transactions that are paid for are included in the statistics, while free downloads, like software, are not counted. Examples of *e-commerce* include the online sale of books or CDs, transactions on electronic marketplaces, and business-to-business sales conducted through EDI networks (Mohamed nour, Sanae, 2008).

Algeria has undertaken significant efforts to integrate into the global digital economy, recognizing its potential for economic diversification beyond hydrocarbons. The country's "Algeria 2030" strategic vision underscores the importance of digital transformation.

- **Infrastructure and the Core Digital Sector:** Progress is evident in the expansion of communication infrastructure. The internet penetration rate has seen substantial growth, reaching approximately 60% by 2020, driven largely by mobile internet adoption. The government and private operators continue to invest in expanding fibre-optic networks and upgrading mobile telecommunications systems. However, the domestic ICT production sector (e.g., software development, hardware manufacturing) remains relatively small, with the economy still reliant on technology imports;

- ***e-Commerce and Digital Services:*** The ecosystem for platform-enabled services is in a nascent but developing stage. *E-commerce* is gaining traction, particularly in urban centres, though it faces challenges related to digital payment adoption, logistics, and consumer trust;

- ***Digitization of the Traditional Economy:*** The integration of digital technologies into traditional sectors like government services (*e-governance*), agriculture, and manufacturing is an ongoing process, with numerous public and private initiatives aimed at enhancing productivity through digital tools.

Algeria finds itself in a transitional phase having built a foundational digital infrastructure that supports basic connectivity, but still working to fully leverage this infrastructure to foster a robust core digital sector and achieve widespread digital transformation across its traditional economy.

THEORETICAL IMPACTS OF THE DIGITAL ECONOMY ON GROWTH

In theory, the digital economy supports economic growth in two significant ways. Firstly, it directly increases economic output by elevating digital capital as a key production element. Secondly, it indirectly contributes to growth by boosting overall productivity levels across the economy as digital capital expands, (Economics, 2016).

The digital economy has a direct influence on macroeconomic performance, primarily through heightened productive investments made by companies. These investments encompass both physical assets, such as digital tools and materials, and intangible assets like software, which are essential for production activities. Consequently, this leads to a volume effect on economic growth, as the increase in productive capital enhances overall gross fixed capital formation (GFCF), resulting in a rise in GDP. This illustrates a direct volume effect.

The indirect effects of the digital economy are reflected in the rise of overall factor productivity, which is fueled by the broad integration of digital technologies. Factor productivity, an indicator of how technological advancements influence economic growth, poses measurement challenges, as it cannot be evaluated solely by increasing inputs like capital and labor. Enhancements in factor productivity are partially driven by sectors that manufacture digital goods and those that embrace digital innovations. The notable increases in productivity within producer sectors have contributed to lower prices for digital goods and services, affecting inflation and price trends. This decline in prices motivates user sectors to invest in digital products, thereby further enhancing their productivity. Additionally, the extensive integration of digital innovations across the economy influences overall factor productivity. These innovations produce 'network' externalities: the broader their adoption, the more significant the benefits, such as improved learning and economies of scale. Thus, the proliferation of digital innovations facilitates innovation and productivity gains across all economic sectors.

Methodology. To examine the relationship between digital economy indicators and Algeria's economic growth, the research utilized data on ICT and internet usage as proxies for the country's digital economy. It also incorporated data on the evolution of Algeria's economic growth, focusing on the period from 2005 to 2022 as our study timeframe. The definitions of the key variables used in this study are summarized in Table 1. All data were sourced from the World Bank website².

To analyze the linear structure of time series, the research employs a series of tests specifically designed to uncover the linear properties of each dataset. Key tests include those developed by H. White (1989), T. Terasvirta & C. Granger (1993) and A. McLeod & W. Li (1983). The general hypothesis underlying these tests is as follows:

H_0 : there is linearity structure;

H_1 : nonlinearity structure.

² World bank open data. *World Bank Group*. 2021. URL: <https://data.worldbank.org/> (assessed on: 05.09.2024).

A consistent rejection of the null hypothesis across these tests provides robust evidence in favor of a nonlinear specification, justifying the subsequent application of the STAR methodology.

Upon establishing nonlinearity, we employ the STAR model, which allows for smooth transitions between different regimes or states of the economy.

The smooth transition autoregressive (STAR) model, comprising $(m = p + k + 1)$ independent variables, where p corresponds to lags of the dependent variable and k to exogenous variables can be formulated as follows (Terasvirta et al., 1993):

$$y_t = \beta x_t + (\theta x_t)F(z_t) + u_t, \quad (1)$$

where

$$u_t \sim iid(0, \sigma^2), \beta = (\beta_0, \beta_1, \dots, \beta_m), \theta = (\theta_0, \theta_1, \dots, \theta_m), \quad (2)$$

$$x_t = (1, y_{t-1}, \dots, y_{t-p}, x_{1t}, \dots, x_{kt}).$$

And Z_t is the transition variable. The function $F(Z_t)$ is continuous and might be even or odd.

The odd function:

$$F(z_t) = (1 + \exp\{-\gamma(z_t - c)\})^{-1}. \quad (3)$$

It yields the logistic STAR model (LSTAR).

The even function:

$$F(z_t) = (1 - \exp\{-\gamma(z_t - c)^2\}). \quad (4)$$

It defines the exponential STAR model (ESTAR).

When comparing the two transition functions, the logistic function varies monotonically with Z_{t-d} , whereas the exponential function varies symmetrically around c with Z_t . As γ increases, both functions grow steeper, reflecting an accelerated transition speed. Refer to Fig. 2 (Zhou, 2010).

The specification of STAR models involves the following steps, as described by T. Terasvirta (1994):

- Formulate a linear autoregressive model;
- Conduct linearity tests for various values of the delay parameter d and identify the appropriate value of d if linearity is rejected;
- Select between Logistic Smooth Transition Autoregressive (LSTAR) and Exponential Smooth Transition Autoregressive (ESTAR) models through a series of nested hypothesis tests.

Table 1. Data definition

Internet	Individuals using the Internet (% of population)
ICT	Computer, communications, and other services (% of commercial service imports)
GDP_Evaluation	GDP Growth rate

Source: authors' description.

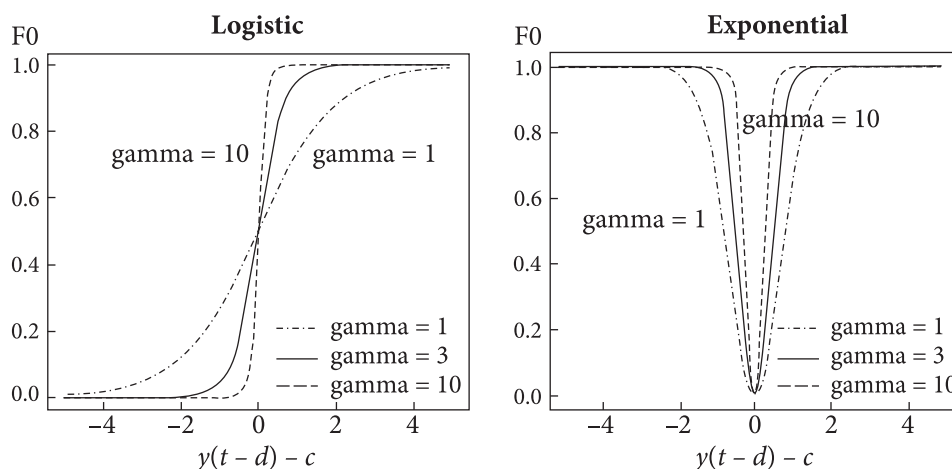


Fig. 2. Logistic and exponential transition functions of varying values of gamma
Source: Zhou, 2010, p. 4.

This test is used to distinguish between LSTAR and ESTAR structures and relies on the sequence of nested tests presented below (Terasvirta, 1994):

$$H_1 : \beta_{4j} = 0, \\ j = 1, \dots, P. \quad (5)$$

$$H_2 : \beta_{3j} = 0 \mid \beta_{4j} = 0, \\ j = 1, \dots, P. \quad (6)$$

$$H_3 : \beta_{2j} = 0 \mid \beta_{4j} = \beta_{3j} = 0, \\ j = 1, \dots, P. \quad (7)$$

According to the selection rule, the ESTAR model is chosen if H_2 yields the smallest p -value; otherwise, the LSTAR family is selected. Notably, the test's outcome is contingent on the selected transition variable.

An ESTAR model may be approximated by an LSTAR model when the transition variable's data predominantly exceeds the transition parameter c . Conversely, an LSTAR model can be approximated by an ESTAR model if its transition function grows slowly around c (i.e., for small γ). Nevertheless, an ESTAR model is unsuitable for approximating rapid transitions between regimes, such as those in a TAR model.

Empirical findings and discussion. This analysis presents an 18-year overview of Algeria's performance in technological integration and economic growth. The data reveals a trajectory of significant transformation and volatility.

The summary statistics for the main variables used in this study are presented in Table 2.

ICT Index, shows a substantial mean of 14.63%, indicating a considerable reliance on foreign technology. However, the high standard deviation (13.27) and a dramatic increase from a minimum of 0.005% to a maximum of 34.08% point to a major, non-linear expansion in ICT imports over the period.

Concurrently, Internet Usage among the population saw remarkable growth, rising from a base of 5.84% to 74.89%. Despite this progress, the median value of 26.00% being lower than the mean suggests that for half of the years, internet penetration remained below one-quarter of the population, highlighting a period of accelerated but initially delayed digital adoption.

Algeria's GDP Growth averaged a positive 2.41%, with the median (3.00%) indicating generally stable expansion. However, the range, which includes a severe contraction of -5.10%, underscores the economy's high vulnerability to external shocks, likely linked to hydrocarbon price volatility.

Linearity test: Prior to specifying a nonlinear model, it is essential to test the null hypothesis of linearity against the alternative of nonlinearity in the structure of ICT, Internet usage and Economic growth evaluation.

Table 2. Descriptive statistics

Statistic	ICT	Internet	GDP evaluation
count	18.000000	18.000000	18.000000
mean	14.631611	32.674652	2.405556
std	13.271195	23.569500	2.221148
min	0.005200	5.843942	-5.100000
25%	0.230500	11.547500	1.625000
50%	12.825000	26.000000	3.000000
75%	27.387500	48.701615	3.400000
max	34.080000	74.890000	5.900000

Source: The data analysis was conducted using Python software by the authors.

Table 3. Linearity tests of ICT

ICT		
TEST	STAT-value	p-value
Terasvirta test	9.9239	0.0069
McLeod-Li test	—	$9.388 \cdot 10^{-5}$
White neural network test	10.567	0.005

Source: The data analysis was conducted using R-Studio software by the authors.

Table 4. Linearity tests of Internet usage

Internet		
TEST	STAT-value	p-value
Terasvirta test	6.4752	0.0392
McLeod-Li test	—	0.000204
White neural network test	6.5382	0.03803

Source: The data analysis was conducted using R-Studio software by the authors.

Table 5. Linearity tests of GDP evaluation

GDP evaluation		
TEST	STAT-value	p-value
Terasvirta test	8.0076	0.018
McLeod-Li test	—	0.9672
White neural network test	7.659	0.021

Source: The data analysis was conducted using R-Studio software by the authors.

Table 6. Linearity tests of the relationship between GDP evaluation and digital economy

Testing linearity against STR					
Variables in AR part	CONST GDP_EVALUATION($t - 1$) ict(t) INTERNET(t)				
Param. not under test					
Sample range	[2006, 2022], T = 17				
<i>p-values of F-tests (NaN — matrix inversion problem)</i>					
Transition variable	<i>F</i>	<i>F4</i>	<i>F3</i>	<i>F2</i>	Suggested model
GDP_EVALUATION($t - 1$)	8.30E-02	8.07E-01	2.08E-01	1.04E-03	Linear
ict(t)	7.54E-01	5.07E-01	8.49E-01	4.92E-01	Linear
INTERNET (t) *	1.63E-02	1.58E-02	2.31E-01	3.36E-01	LSTR1
TREND	5.32E-01	4.98E-01	4.18E-01	5.34E-01	Linear

* indicates the selected transition variable (Internet) based on the lowest p -value for the F -statistic and the LSTR1 suggestion.

Source: based on JMulti output.

Table 7. Table of starting values

STR GRID SEARCH		
Variables in AR part	CONST GDP_EVALUATION ($t - 1$) ict(t) INTERNET(t)	
Restriction theta = 0		
Transition variable	INTERNET(t)	
Sample range	[2006, 2022], T = 17	
Transition function	LSTR1	
Grid c	{7.38, 74.89, 30}	
Grid gamma	{0.50, 10.00, 30}	
SSR	gamma	$c1$
2.7934	10.0000	53.9374

Source: based on JMulti output.

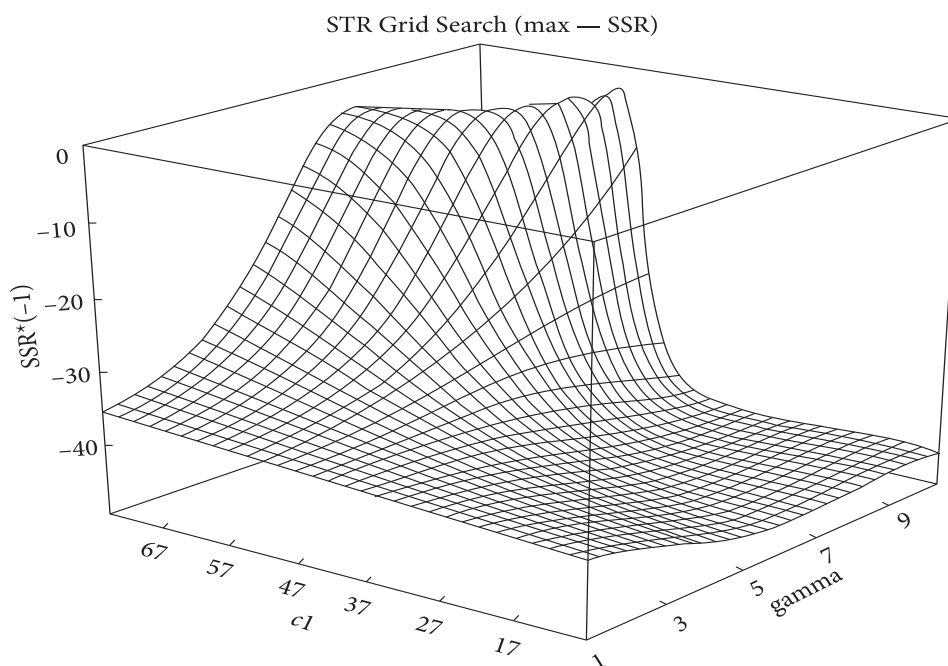


Fig. 3. Graph of initial
Source: based on JMulti output.

The ICT index: Table 3 presents the results of the linearity tests for the ICT index time series.

As shown in the table, the test results reveal that the ICT index time series displays nonlinearity. The null hypothesis was rejected, as all p -values for the Terasvirta test, the McLeod-Li test, and the White neural network test fell below the 5% significance threshold.

Internet usage index: Research presents the results of the linearity tests for this time series as follows.

Based on the results shown in Table 4, the null hypothesis of linearity for the internet usage index time series is rejected, as all p -values for the Terasvirta test, the McLeod-Li test, and the White neural network test were below the 5% significance level. This indicates that the internet usage index time series exhibits nonlinearity.

Economic growth evolution: The results of the linearity tests for the economic growth time series are shown in the following Table 5.

As shown in Table 5, the Terasvirta test and the White neural network test both suggest that the economic growth time series displays nonlinear characteristics, with p -values below the 5% significance threshold. In contrast, the McLeod-Li test yields a p -value above 0.05, indicating that the null hypothesis of linearity cannot be rejected for this series.

The findings from the Terasvirta test and the White neural network test, consistently indicate that the economic growth time series is nonlinear. Thus, it can be concluded that the economic growth time series exhibits nonlinear characteristics.

Following the confirmation that the study variables exhibit nonlinearity, this paper will investigate the linearity of the relationship between economic growth (the dependent variable) and the independent variables, which include the internet usage index and the ICT index. The Terasvirta test is employed for this purpose, and the results are as follows (Table 6).

The results demonstrate that the internet usage index variable has the lowest F -statistic, leading to its selection as the transition variable. This implies that Algeria's economic growth follows a nonlinear LSTAR process, shaped by annual changes in internet usage. As a result, economic growth in Algeria transitions between regimes based on internet usage. Furthermore, positive and negative shocks to the internet usage index exert asymmetric effects on economic growth. Thus, this study will proceed to estimate an LSTAR model. Before doing so, however, the initial values for the estimated parameters must be established via a grid search on the following data.

Table 8. Estimation of LSTAR model

Variables in AR part	STR ESTIMATION				
	CONST GDP_EVALUATION($t-1$) ict(t) INTERNET(t)				
Restriction theta = 0					
Restriction phi = 0					
Restriction phi = -theta					
Transition variable	INTERNET(t)				
Sample range	[2006, 2022], T = 17				
Transition function	LSTR1				
Number of iterations	9				
Variable	Start	Estimate	SD	t -stat	p -value
<i>Linear part</i>					
CONST	2.94711	3.60828	0.7122	5.0665	0.0015
GDP_EVALUATION($t-1$)	-0.25762	-0.36167	0.1581	-2.2879	0.0560
ict(t)	0.00474	0.06898	0.0755	0.9132	0.3915
INTERNET(t)	0.0436	0.00102	0.0458	0.0224	0.9828
<i>Nonlinear part</i>					
CONST	-157.58467	-159.61957	14.3139	-11.1514	0.0000
GDP_EVALUATION($t-1$)	-0.89039	-0.80001	0.2041	-3.9205	0.0057
ict(t)	4.04877	4.09902	0.4295	9.5432	0.0000
INTERNET(t)	0.27044	0.27961	0.0646	4.3289	0.0034
gamma	10.0000	17.89117	5.5427	3.2279	0.0145
c1	53.93737	51.44421	0.9546	53.8925	0.0000

Source: based on JMulti output.

The Table 7 indicates that the initial value for the threshold parameter c is 53.9374, and the initial value for the transition speed parameter γ is 10. Figure 3 plots the transition function based on the starting values from Table 7. As expected, the graph confirms the smooth transition between regimes identified by the grid search.

With these initial values, the LSTAR model was estimated to evaluate economic growth, using the internet usage index as the transition variable. The results are as follows (Table 8).

The empirical results from the STAR model provide nuanced insights into the non-linear relationship between digitalization and economic growth in Algeria.

The analysis reveals that in the linear regime, lagged economic growth exerts a negative influence on its current value. While both the ICT index and internet usage show positive coefficients, aligning with prior research H. Becha et al. (2023), A. Portillo et al. (2020), K. Vu (2011; 2013) for ICT; I. Otoo & N. Song (2021), M. Kurniawati (2021), S. Asongu & N. Odhiambo (2020), M. Albiman & Z. Sulong (2017), M. Salahuddin & J. Gow (2016) and C. Choi & M. Hoon Yi (2009) for internet, these effects are not statistically significant. This initial finding underscores the limitation of linear models in capturing the true dynamics at play.

In contrast, all coefficients in the non-linear part of the model are statistically significant, confirming the presence of a robust regime-dependent relationship. The estimation identifies two distinct economic regimes, with the transition between them triggered at an internet usage index threshold of $c1 = 51.444$. The high transition speed of 17.891 indicates that the Algerian economy shifts relatively quickly between these states, underscoring the dynamic nature of the digital economy's impact.

A pivotal finding is the divergent influence of digital indicators: internet penetration is the dominant trigger for economic regime shifts, while the composite ICT index shows a weaker effect. This stems from their conceptual differences. Internet penetration is a *diffusion-oriented* metric; its rapid adoption creates immediate network effects, lowering transaction costs and catalyzing broad-based economic activity, hence its role as a potent, fast-acting threshold variable. Conversely, the ICT index is an *infrastructure-oriented* metric reflecting capital stock; its benefits materialize more gradually as they depend on complementary investments. Therefore, internet usage acts as a leading indicator of digital-economic activation, while the ICT index represents a slower-moving foundational capacity, explaining its lesser role in triggering immediate non-linear growth transitions.

The results demonstrate an asymmetric adjustment process where the Algerian economy's growth path is highly sensitive to changes in internet usage. Positive shocks that push penetration past the critical threshold can rapidly propel the economy into a higher-growth regime, while negative shocks below this threshold can have a disproportionately negative effect, locking it into a lower-growth state. This underscores the strategic imperative for policymakers to focus specifically on accelerating internet adoption and accessibility, as it is the most potent and responsive lever for triggering positive structural change in the digital era.

CONCLUSION

This research empirically investigated the influence of digital economy indicators on Algeria's economic growth and assessed whether these effects are symmetric. The analysis spanned the period from 2005 to 2022 and applied the nonlinear STAR model, which allows for smooth transitions between regimes instead of abrupt changes. This research relied on time series data for the ICT index and the internet usage index in Algeria, which reflect the digital economy, as well as time series data for economic growth.

Following a series of linearity tests on the study variables, the results confirmed that the ICT index, the internet usage index, and economic growth are nonlinear time series. A linearity test on the model further revealed that the LSTAR model is the optimal choice. Upon estimating the model, the research determined that economic growth shifts between two regimes, and with fast speed in the transition. The LSTAR model's estimation indicates that positive and negative shocks to the internet usage index asymmetrically impact economic growth in Algeria. These findings highlight the internet's more pronounced role in shaping economic growth compared to the ICT index, as both are pivotal indicators for measuring Algeria's digital economy.

This study makes a substantive contribution by addressing a critical gap in the scholarly discourse, namely the empirical examination of how ICT indices and internet penetration influence economic development. The resulting insights possess significant practical utility, providing a framework for policymakers in Algeria and other developing nations to foster sustainable economic growth. Distinguished by its innovative approach, timely focus on the digital economy, and explicit policy relevance, this research enriches the ongoing international debate concerning the role of macroeconomic instruments in advancing core economic goals.

The relevance of this research extends beyond Algeria. The methodological approach and findings offer valuable insights for other developing economies undergoing digital transformation, such as Ukraine. Both nations share a strategic imperative to diversify their economies (Algeria from hydrocarbons, and Ukraine from traditional heavy industry and agriculture). A comparison reveals a shared challenge: ensuring that digital infrastructure investments translate into broad-based, resilient economic growth. For Ukraine, which possesses a strong IT services sector, this research underscores the importance of fostering robust domestic internet penetration and digital adoption to ensure that the benefits of its tech sector diffuse throughout the entire economy. The demonstrated non-linear and asymmetric effects suggest that policymakers in both countries should anticipate critical thresholds and design policies that are resilient to digital shocks.

To achieve its digital and economic transformation, Algeria must implement a comprehensive strategy. This necessitates cultivating digital literacy through education, incentivizing e-commerce, and modernizing core ICT infrastructure. The implementation of integrated, cross-sectoral information systems is vital for enhancing efficiency and transparency. Furthermore, modernizing financial admi-

nistration is critical to bridge the technological divide. The resultant financial surpluses must then be strategically leveraged to diversify the economy and ensure sustainable, long-term growth.

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ВПЛИВ РОЗВИТКУ ЦИФРОВОГО СЕКТОРУ НА ЕКОНОМІЧНУ ТРАЄКТОРІЮ АЛЖИРУ

Проведено емпіричне дослідження асиметричного впливу показників цифрової економіки на економічне зростання в Алжирі в період між 2005 і 2022 р. Ґрунтуючись на використанні вдосконаленої нелінійної авторегресійної методології плавного переходу (STAR), як оптимальний інструментарій дослідження вибрано логістичну модель STAR (LSTAR), що дало змогу вийти за межі традиційного лінійного аналізу. Завдяки плавному переходу між двома різними режимами модель успішно фіксує динаміку економічного зростання з оцінками, які засвідчують, що ці переходи відбуваються швидко. Головним результатом є виявлення неоднорідного зв'язку: шоки в індексі використання Інтернету мають асиметричний вплив на економічне зростання, за якого позитивні й негативні зміни справляють непропорційний вплив. Крім того, аналіз показує, що використання Інтернету є більш потужним і вагомим фактором зростання порівняно з ширшим індексом ІКТ, що підкреслює першорядну важливість підключення до Інтернету в цифровому економічному ландшафті Алжиру.

Здійснене емпіричне дослідження цих нелінійних зв'язків допомагає заповнити прогалину в науковому дискурсі. Істотне значення роботи полягає в інноваційному методологічному підході, зосередженості на актуальній темі цифрової трансформації та очевидній важливості для розроблення політики. Отримані результати базуються на фактах і вирізняються великою практичною корисністю, надаючи цінну інформацію для розробників політики в Алжирі та інших подібних країнах, що розвиваються. Отже, ці результати стратегічно орієнтовані на обґрунтування і формування ефективних стратегій і політик, спрямованих на використання цифрових інструментів з особливим акцентом на поліпшення доступу й підвищення рівня охоплення Інтернетом, що в кінцевому підсумку сприятиме сталому і стійкому економічному розвитку.

Ключові слова: *індекс ІКТ; використання Інтернету; економічне зростання; модель STAR.*

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