

**World Bank's KAM and Economic Growth in Algeria: An ARDL Analysis
(1990–2023)****نموذج KAM للبنك الدولي والنمو الاقتصادي في الجزائر: تحليل ARDL (1990-2023)****Ahmane Abdelouahab¹, Boudiaf Hafid²**¹ University of Algiers 3, Laboratory of Human Capital and Performance, (Algeria),

ahmaneabdelouahab@gmail.com

² University of Algiers 3 (Algeria), boudiafhf@gmail.com**Received:** 01/10/2025**Accepted:** 12/12/2025**Published:** 31/12/2025**Abstract:**

This study aims to measure the impact of various indicators of the knowledge economy on economic growth in Algeria during the period from (1990-2023), using and employing all the main indicators that are consistent with the World Bank's KAM methodology, where the autoregressive distributed lag model "ARDL" was used. The results of the standard study concluded that: There is a long-term relationship between the study variables, and that both the variable of mobile phone subscriptions (per 100 people) and the variable of patents for residents and non-residents have an inverse relationship with the economic growth rate, while both the variable of school enrollment, higher education (% of total) and the variable of trade openness have a direct relationship with the economic growth rate in Algeria.

Keywords: Knowledge economy, KAM methodology, economic growth, ARDL model, Algeria.**JEL Classification Codes:** O3, O4, C32**ملخص:**

تهدف هذه الدراسة إلى قياس تأثير مختلف مؤشرات الاقتصاد المعرفي على النمو الاقتصادي في الجزائر خلال الفترة الممتدة من (1990-2023)، وذلك باستخدام وتوظيف كل المؤشرات الرئيسية الموافقة لمنهجية البنك الدولي kam، حيث تم استخدام نموذج الانحدار الذاتي للفجوات الزمنية المبطنة ARDL، ولقد خلصت نتائج الدراسة القياسية إلى: وجود علاقة طويلة المدى بين متغيرات الدراسة، وأن كل من متغير اشتراكات الهاتف النقال (لكل 100 شخص) ومتغير براءات الاختراع للمقيمين وغير المقيمين لهما علاقة عكسية مع معدل النمو الاقتصادي، في حين أن كل من متغير الالتحاق بالمدارس، التعليم العالي (% من الإجمالي) ومتغير الانفتاح التجاري لهما علاقة طردية مع معدل النمو الاقتصادي في الجزائر.

كلمات مفتاحية: اقتصاد المعرفة، منهجية KAM، النمو الاقتصادي، نموذج ARDL، الجزائر.

تصنيفات JEL: O3، O4، C32

INTRODUCTION:

The term “knowledge economy” has emerged as a new and influential factor in major global economies at the dawn of the current millennium. The prevailing economic paradigm has shifted from the industrial economy, which relies on machinery, to the knowledge economy, which is based on intellect and knowledge (Fale, et al. 2021, World Bank 2003) . This transformation has been clearly reflected in the tremendous technological progress, where technology has become a central component of production (Vărzaru et Bocean 2024). The latest breakthrough of this technology is artificial intelligence, which has triggered a profound revolution across various fields and sectors (Moch 2023, P 1). As a result, the strength and productivity of economies are increasingly measured by the robustness of their knowledge economy (Shahabadi, Kimiaei et Afzali 2016). All of this has prompted many countries, including Algeria, to compete in catching up with these rapid and dynamic changes.

In this research paper, we aim to address different aspects of the knowledge economy in Algeria and the future challenges associated with achieving economic diversification that would free us from dependence on hydrocarbon rents—a dependency that has long constrained public revenues and made the national economy vulnerable to fluctuations, particularly in light of recent global crises and geopolitical conflicts, such as the Russia–Ukraine war and the conflict in the Middle East. Moreover, the paper highlights the role of the knowledge economy through several sub-indicators and its impact on the process of economic growth.

Research Problem:

Based on the above, the following research problem can be raised:
To what extent do knowledge economy indicators affect economic growth in Algeria?

In light of this main problem, the following sub-questions can be formulated:

- What is the current state of knowledge economy indicators in Algeria?
- What is the magnitude of the impact of each indicator on economic growth?

Research Hypotheses:

- There is a mutual integration between knowledge economy variables and economic growth in Algeria.
- The knowledge economy indicators adopted in this study follow a positive trend and contribute to supporting economic growth in Algeria.

Research Objectives:

Through this study, we aim to highlight the impact of the knowledge economy on economic growth, and to show how knowledge has become the essential and indispensable alternative for the growth of world economies. For resource-dependent economies in particular, or those relying on a single resource, the knowledge economy represents a lifeline for supporting economic diversification and preserving natural resources for future generations. We argue that meaningful progress in various fields—especially in the economic sphere—can only be achieved through knowledge. Furthermore, we seek to examine Algeria’s position in

this field, identify the strengths and weaknesses of the different sub-indicators of the knowledge economy in Algeria, and outline the future challenges ahead.

Research Methodology:

The study relied on the descriptive method by presenting theoretical definitions related to the indicators, describing the knowledge economy, its measurement approaches, and its main indicators. We also employed analytical methods by examining the reality of the knowledge economy in Algeria according to the World Bank's KAM methodology. In addition, the econometric analysis was carried out using the Autoregressive Distributed Lag (ARDL) model, in an attempt to measure the impact of knowledge economy indicators on economic growth in Algeria during the period 1990–2023.

Previous Studies:

Several previous studies have addressed the topic of the knowledge economy and its impact on economic growth. Among them:

- The study by *Kherbouche Mohamed and Laouaj Ben Omar* (2019), entitled “*The Reality of the Knowledge Economy and Its Impact on Economic Growth in Algeria: An Econometric Study (1980–2017)*”. This study used several indicators representing the main pillars of the knowledge economy, employing the cointegration methodology, the Vector Autoregression (VAR) model, and Granger causality tests. The findings revealed mixed positive and negative results between the dependent variable (economic growth rate) and the independent variables (knowledge economy indicators) in both the short and long run. Furthermore, the variance decomposition analysis showed a weak impact of knowledge economy indicators on economic growth in Algeria, while the Granger causality test indicated no causal relationship between knowledge economy indicators and the economic growth rate.
- Study by *Asmaa Mohamed Hafed Abdel Hamid* (2023): Entitled “*The Impact of the Knowledge Economy on Economic Growth in Egypt during the Period (1990–2020): An Econometric Study.*” The study employed the Augmented ARDL model. The findings indicated that the student–teacher ratio in primary education had no significant effect on economic growth. However, the number of resident patent applications had a significant positive effect on economic growth, while both mobile phone subscriptions per 100 inhabitants and political instability had a significant negative effect on economic growth.

1-The Conceptual Framework of the Knowledge Economy

In the latter half of the last century, the world has witnessed rapid and multifaceted developments in the economies of many countries, which began to gradually transition toward the new economy—known as the post-industrial economy, the information economy, and the digital and internet economy—until it reached the knowledge economy. The latter is considered a more advanced and comprehensive model, relying on knowledge in all its components as a foundation for creating wealth and added value.

1-1 Definition of the Knowledge Economy

- **The World Bank** defines the knowledge economy as: “an economy that uses knowledge in all its components in order to achieve comprehensive economic and social development.” (Chen et Dahlman 2006)
- **The Organization for Economic Cooperation and Development (OECD)** defines it as: “an economy based on the uses of knowledge to produce and disseminate information.” (OECD 1996, P. 3)
- It has also been defined as: “a set of strategic changes in the nature of the economic environment and the efforts to organize it so that it becomes more responsive and consistent with the challenges of globalization, information and communication technology, the universality of knowledge, and sustainable development in its integrated and holistic sense. A society that possesses knowledge, controls it, and contributes to creating, deepening, and developing its various branches is more qualified than others to keep pace with progress and enter globalization through its widest gates, across economic, scientific, cultural, social, and political dimensions.” (عليان 2012)

Thus, the knowledge economy is the integrated whole of knowledge, technology, and the enabling environment, where knowledge plays the primary driver and leading role in the production process and wealth creation, in order to achieve comprehensive economic development, improve quality of life, enhance institutional competitiveness, increase productivity, and develop human capital.

1-2 Characteristics of the Knowledge Economy

The knowledge economy is characterized by several key features, the most important of which are:

- **Exceptional flexibility and adaptability** to rapid changes and the increasing life dynamics whose pace and impacts continue to accelerate.
- **A remarkable capacity for renewal** and full interaction with other economies that now seek integration into it, to the extent that it has become difficult to separate it from them, to discuss it in isolation, or to refer to them without its explicit involvement.
- **The ability to innovate and generate new intellectual, knowledge-based, and even non-knowledge-based products** that were previously unavailable and unknown in markets. It also contributes to the development of such unprecedented products that meet consumer and distributor needs in a more satisfactory and persuasive way, while reinforcing the systematic and continuous creation of such products.
- **Multiple and diverse sources of value creation**, characterized by being expansive, renewable, and simultaneously flowing. Despite their internal coherence and consistency, these sources are rich and abundant to the point of being nearly unlimited, which amplifies their influence across all areas of this economy.
- **No barriers to entry.** The knowledge economy has no closed doors; it is fully open. Thus, there are no temporal or spatial obstacles for those wishing to engage with it. All that an individual requires is intellectual knowledge, operational will, a comprehensive

understanding of its dimensions and aspects, along with a natural commitment to its requirements and a precise respect for the rights of all stakeholders.

- **Self-reliance combined with interconnectedness.** The knowledge economy depends on itself as well as on its relationships with other economies. It is in a state of continuous motion and constant search for talents, bold ideas, and creative minds. Therefore, competition over these resources depends on the ability of enterprises and information systems to attract and employ such intellectual capacities. (أبو عزام 2020، 58)

1-3 The Importance of the Knowledge Economy

The significance of the knowledge economy emerges from its pivotal role as a cornerstone of contemporary economic, social, and technological transformation (Kefela 2010). In this context, scientific and practical knowledge has become the fundamental driver of wealth creation, accumulation, and growth, replacing the traditional dependence on scarce natural resources. Economically, the knowledge economy provides a pathway for generating high added value through systematic investment in innovation, technology, and research, thereby enhancing productivity, diversifying sources of national income, and strengthening competitiveness in global markets by expanding exports of knowledge-intensive products. Socially, it serves as a catalyst for the creation of diverse, high-quality, and renewable employment opportunities, particularly in information technology, communication, and software industries, which in turn contributes to reducing unemployment, improving standards of living, and fostering inclusive growth. Technologically, the knowledge economy underpins the advancement of digital transformation and artificial intelligence, creating an environment that fosters innovation, accelerates organizational renewal, and facilitates the continuous development of new products and services tailored to dynamic consumer and market needs (الكعص و هتهات 2025).

Moreover, its importance is reflected in reducing reliance on finite natural resources by harnessing and expanding knowledge-based assets, thereby ensuring the sustainability of economic activities and aligning with global environmental and climate imperatives. It also provides a conducive framework for attracting both domestic and foreign investment by leveraging human capital and scientific research, which reinforces investor confidence and supports long-term economic resilience. Ultimately, the knowledge economy is not only instrumental in enhancing organizational creativity and competitiveness but also represents a strategic imperative for nations aspiring to achieve comprehensive, sustainable, and innovation-driven development (Rezny, White et Maresova 2019).

2- Indicators of the Knowledge Economy

The measurement of the knowledge economy across different regions of the world relies on a wide range of indicators and variables, reflecting the multidimensional nature of this concept. These indicators are constructed using diverse methodological approaches and typically encompass a mix of factors such as educational attainment, innovation capacity, economic competitiveness, and the quality of infrastructure. They are designed to capture the extent to which knowledge is produced, disseminated, and utilized as a key driver of economic growth and social development. Data sources for these indicators are equally diverse,

combining quantitative datasets collected by national and international statistical institutions with qualitative information derived from perception surveys and expert assessments.

At the country level, the progress of the knowledge economy is often assessed through indicators that emphasize the degree of reliance on information and communication technologies (ICTs), the promotion of research and development (R&D) activities, and the enhancement of human capital development. These dimensions serve as critical proxies for gauging the ability of economies to generate, absorb, and apply knowledge effectively. However, despite growing international interest in refining and expanding such indicators, no single standardized global measure has yet been universally adopted. Instead, a number of methodological frameworks are currently employed, each with its own scope and specificities. Among the most widely recognized are:

- The World Bank's Knowledge Assessment Methodology (KAM)
- The OECD methodology
- The European Union framework
- The OECD–APEC methodology for the Asia-Pacific region
- The Arab Knowledge Index

In this research paper, we adopt the World Bank's Knowledge Assessment Methodology (KAM) as the principal framework for evaluating the state and progress of the knowledge economy in Algeria. This choice is motivated by its comprehensive nature, its broad international recognition, and its ability to provide a comparative assessment of a country's knowledge economy in relation to both regional peers and global benchmarks.

World Bank Knowledge Assessment Methodology (KAM):

The World Bank's Knowledge Assessment Methodology (*KAM*) is one of the most widely recognized approaches for measuring the knowledge economy. It was designed to assist countries seeking to build and leverage knowledge as a means of enhancing their competitiveness, fostering growth, and achieving prosperity.

KAM is structured around four key pillars, supported by more than 80 variables, to evaluate the Knowledge Economy Index (KEI) across a wide range of countries and regions. The assessment is expressed on a scale ranging from 0 (lowest) to 10 (highest). It relies on two composite indices: the Knowledge Index (KI) and the Knowledge Economy Index (KEI). The four pillars are:

1. **Economic Incentive and Institutional Regime (EIR):** the framework of policies and institutions that promote efficient allocation of resources and stimulate knowledge-based activities.
2. **Education and Human Resources (EHR):** the capacity of a society to develop, train, and continuously upgrade a skilled and educated workforce.
3. **Innovation System (IS):** the network of firms, research centers, universities, and other organizations that generate, adopt, and disseminate new knowledge.
4. **Information and Communication Technology (ICT):** the availability and effective use of modern information and communication infrastructure.

3- Algeria's Status According to the Knowledge Economy Index under the KAM Methodology

3-1 Information and Communication Technology (ICT) Index:

According to the *DIGITAL 2023* report issued by the leading global agency specializing in fixed and mobile internet statistics worldwide, data specific to Algeria have been recorded and are presented in the following table. A simple comparative analysis is also provided to highlight the changes observed between 2022 and 2023.

Table (1): ICT Indicators for Algeria, 2022–2023

Indicator	2022	2023	Change
Internet penetration	60.6%	70.9%	+10.3
Number of Internet users	27.28 million	32.09 million	+4.81
Average fixed Internet speed	9.78 Mbps	11.01 Mbs	+1.23
Average mobile Internet speed	11.44 Mbps	13.40 Mps	+1.96

Source: Authors' elaboration based on the *DIGITAL 2023* report (DataReportal 2023)

Algeria has achieved remarkable progress, advancing 14 positions in the ICT Development Index (IDI), according to the latest report published by the International Telecommunication Union (ITU). Previously ranked 102nd, Algeria has now ascended to the 88th position out of 169 ITU member states, attaining an overall score of 77.8 points. This performance places the country well above the African average (47.4 points), the Arab states' average (74.5 points), and the middle-income countries' average (62 points).

It is worth emphasizing that the ICT Development Index (IDI) stands as the most authoritative global benchmark for measuring and assessing the level of information and communication technology development across nations. Since its inception in 2009, this index has been annually issued by the International Telecommunication Union to provide a comprehensive and comparative evaluation of ICT progress worldwide.

3-2 Innovation Index

Algeria has experienced a setback in the most recent *Global Innovation Index (2023)*, following a trajectory that, although upward over the past years, has remained somewhat gradual. Nevertheless, projections suggest that in the coming years Algeria's ranking will increasingly reflect the broader economic dynamism currently underway.

Table (2): Algeria's Ranking in the Global Innovation Index

Year	2020	2021	2022	2023
Global Rank	121	120/132	115/132	119/132
Rank Change	-	+1	+5	-4

Source: Authors' elaboration based on the Global Knowledge Index, (WIPO 2023)

Although the results presented above may appear insufficient, they nonetheless remain encouraging. Algeria possesses significant potential to improve its position in the future, supported by sustained economic activity, the gradual removal of structural obstacles, and the implementation of a series of laws designed to foster investment.

The Global Innovation Index (GII) aims to rank both the innovation capacities and outcomes of economies worldwide. It is regarded as a key measurement tool that assists policymakers in identifying the most effective pathways to stimulate innovation activities, thereby reinforcing economic and human development.

3-3 Education and Human Resources Index

In the academic year 2023/2024, Algeria's education system encompassed over 11 million enrolled students across all levels of schooling. At the primary level, the number of pupils reached 5.8 million, while the middle cycle accounted for 3.6 million students, and the secondary cycle included approximately 1.6 million. This broad student population is supported by a substantial workforce of more than 820,000 employees, of whom 529,000 are teachers and around 291,000 serve in administrative and technical roles. To accommodate this scale, Algeria operates a vast educational infrastructure of 29,138 institutions, comprising 20,473 primary schools, 5,974 middle schools, and 2,691 secondary schools.

At the level of higher education and research, the system hosted 1,496,821 university students during 2023/2024, alongside 5,120 international students. Gender distribution shows a significant female majority, with 901,165 female students (60%) compared to 600,776 male students (40%). Instruction and supervision are provided by an academic body of nearly 70,000 professors across diverse disciplines. The higher education network itself is composed of 115 pedagogical institutions, including 39 national higher schools, 13 regular higher schools, 54 universities, and 9 university centers.

Despite this extensive human and institutional capital, Algeria's performance in international rankings remains modest. According to the 2023 Education Quality Index published by the World Economic Forum, Algeria was ranked 119th worldwide and 11th within the Arab region, placing it among the lower tiers, slightly ahead of Mauritania and Egypt. In the domain of higher education and scientific research, the Times Higher Education World University Rankings included 23 Algerian universities, signaling incremental progress but also underscoring the challenges that remain in aligning national educational outcomes with global standards.

3-4 Economic Incentives and Institutional Frameworks

Algeria's economic performance in recent years reveals a dynamic yet fluctuating trajectory in its external sector. In 2022, the country registered a notable trade surplus of 3,588.5 billion Algerian dinars (approximately USD 29.66 billion), reflecting the strength of its export sector, which reached USD 65.53 billion, compared with imports totaling USD 38.87 billion. However, by 2023, the surplus had declined considerably to 1,711.1 billion Algerian dinars (around USD 12.71 billion). This contraction was mainly due to a decrease in export revenues, which fell to USD 55.55 billion, coupled with an increase in imports that rose to USD 42.84 billion. Such developments underscore Algeria's structural dependence on global commodity markets, as well as the persistent need for economic diversification and resilience-building in the face of external shocks.

From an institutional perspective, Algeria's standing in the Rule of Law Index (2023), published by the World Justice Project (WJP), offers insights into the quality of governance

and institutional performance. The country was ranked 84th globally out of 142 countries, with an overall score of 0.49 (on a scale from 0 to 1), positioning it 5th in the Arab world and 7th in Africa. While this result highlights progress in certain areas, it also reveals systemic challenges that continue to constrain institutional efficiency.

A closer examination of the sub-indicators paints a nuanced picture. Algeria scored relatively well in order and security, ranking 61st worldwide with a score of 0.75, and in civil justice, where it achieved 62nd place with 0.55. However, weaknesses are evident in domains such as open government (123rd globally, 0.36) and the protection of fundamental rights (113th globally, 0.43). The country also struggles with constraints on government powers (97th, 0.47) and absence of corruption (74th, 0.45). Meanwhile, scores in regulatory enforcement (70th, 0.49) and criminal justice (79th, 0.41) suggest moderate progress, though substantial room for improvement remains.

Taken together, these findings reflect a dual reality: on the one hand, Algeria benefits from a relatively secure environment and an improving justice framework; on the other, it continues to face governance and transparency challenges that limit institutional effectiveness. Bridging this gap will be essential to strengthening investor confidence, fostering sustainable growth, and consolidating Algeria's position in both regional and global contexts.

4. Econometric Methodology and Empirical Analysis

In order to examine the impact of the knowledge economy on economic growth in Algeria, four sub-indicators were selected, each representing one of the main pillars of the knowledge economy. Their influence on economic growth was then assessed using data extracted from the World Bank database covering the period 1990–2023.

4-1 The Model Specification

This study employs the Knowledge Assessment Methodology (KAM) developed by the World Bank, where the selected knowledge economy indicators are treated as independent variables, while economic growth serves as the dependent variable. Economic growth is proxied by the growth rate of GDP per capita. The independent variables are operationalized as follows:

- **Education and Human Resources Index:** represented by the *Enrollment in Higher Education (% of total)* indicator (EHEI), a sub-component of the broader education and human capital pillar.
- **Information and Communication Technology Index:** proxied by *Mobile cellular subscriptions (per 100 people)* (CEL), capturing ICT penetration.
- **Innovation and Creativity Index:** measured through *Patent applications, residents and non-residents* (PAT), serving as a proxy for national innovative capacity.
- **Economic Incentives and Institutional Regime Index:** proxied by *Trade Openness* (TO), reflecting integration into global markets.

Accordingly, the growth model can be expressed as follows:

$$\Delta LGDP = \alpha_0 + \sum_{i=0}^{p-1} \beta_{1i} \Delta LGDP_{t-1} + \sum_{i=0}^{q_1-1} \beta_{2i} \Delta LEHEI_{t-1} + \sum_{i=0}^{q_2-1} \beta_{3i} \Delta LCEL_{t-1} + \sum_{i=0}^{q_3-1} \beta_{4i} \Delta LPAT_{t-1} + \sum_{i=0}^{q_4-1} \beta_{5i} \Delta LTO_{t-1} + \phi_1 LGDP + \phi_2 LEHEI + \phi_3 LCEL + \phi_4 LPAT + \phi_5 LTO + u_t$$

where:

- Δ denotes **first differences**;
- μ is the **error term** of the baseline model;
- α_0 represents the **constant term**;
- $\phi_i \forall i = 1, \dots, 4$ denote the **elasticities** of the explanatory variables, capturing the **long-run relationship** between economic growth and the knowledge economy indicators;
- $\beta_i \forall i = 1, \dots, 4$ The short-run dynamics are captured by the **error-correction representation**, linking deviations from the long-term equilibrium with short-term adjustments.

Variable definitions:

- **LGDP**: logarithm of GDP per capita growth;
- **LEHEI**: logarithm of higher education enrollment (% of total);
- **LCEL**: logarithm of mobile cellular subscriptions (per 100 people);
- **LPAT**: logarithm of patent applications (residents and non-residents);
- **LTO**: logarithm of trade openness.

4-2 Stationarity Analysis of Time Series

To ensure the validity of the econometric estimations, the stationarity of the time series was examined using the Augmented Dickey-Fuller (ADF) test at the 1%, 5%, and 10% significance levels. The results are summarized in Table (05).

Table (3): Augmented Dickey-Fuller Test Results

Variables		Trend & Intercept		Intercept		None	
		t-stat	Prob	t-stat	Prob	t-stat	Prob
LGDP	Level	-1.9462	0.6080	-0.4502	0.8886	0.9757	0.9091
	1st Diff	-5.2437	0.0009***	-5.3898	0.0001***	-5.1300	0.0000***
LEHEI	Level	-3.2835	0.0872	-0.1148	0.9396	2.4962	0.9960
	1st Diff	-3.7028	0.0367**	-3.7590	0.0077***	-2.4242	0.0170**
LCEL	Level	-3.5562	0.0548	-1.9601	0.3014	-0.7131	0.3993
	1st Diff	-2.8245	0.2027	-1.9855	0.2907	-1.9740	0.0481*
LPAT	Level	-2.3787	0.3831	-0.5619	0.8659	1.1301	0.9297
	1st Diff	-4.8954	0.0022***	-4.9881	0.0003***	-4.7626	0.0000***
LTO	Level	-2.1523	0.4991	-2.2269	0.2010	0.0226	0.6829
	1st Diff	-6.8082	0.0000***	-6.1635	0.0000***	-6.2769	0.0000***

Notes: Stationarity at the 10% level (*), 5% level (**), and 1% level (***).

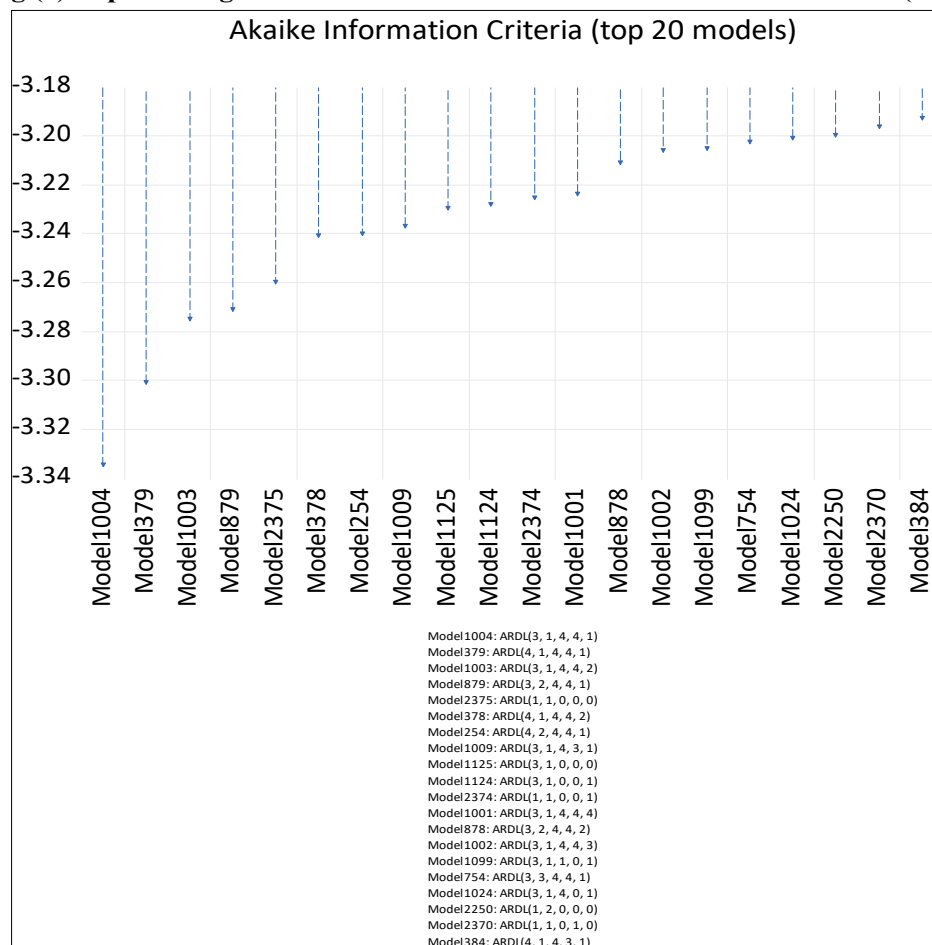
Source: Authors' elaboration based on E-Views 12 outputs

The results clearly indicate that all the series under investigation exhibit non-stationarity at their levels, thereby confirming the presence of unit roots. However, when tested at their first differences, the null hypothesis of a unit root is consistently rejected across all variables, implying that the series achieve stationarity after first differencing.

This finding highlights that the studied variables are integrated of order one, $I(1)$, which is consistent with the requirements for conducting cointegration analysis in the subsequent stages of the econometric modeling.

Accordingly, the stationarity of the time series satisfies the necessary condition for employing the Autoregressive Distributed Lag (ARDL) model. Prior to estimating the model, it is essential to determine the optimal lag structure, which was identified based on the Akaike Information Criterion (AIC). The results indicate that the most appropriate specification corresponds to the ARDL (3,1,4,4,1) model, as illustrated in the following figure.

Fig (1): Optimal lag selection based on the Akaike Information Criterion (AIC)



Source: Authors' elaboration based on E-Views 12 outputs

4-3 Cointegration Analysis

Cointegration refers to the possibility of the existence of a long-term equilibrium relationship among non-stationary time series. The overall significance of the model under study is tested using the Wald test (F-statistic) with a non-standard distribution, and the result is compared with the critical tabulated values. The test results can be summarized as shown in the following table:

Table (4): F-Bounds Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic k	4.567076 4	Asymptotic: n=1000		
		10%	2.2	3.09
		5%	2.56	3.49
		2.5%	2.88	3.87
Actual Sample Size	29	1%	3.29	4.37
		Finite Sample: n=35		
		10%	2.46	3.46
		5%	2.947	4.088
		1%	4.093	5.532
		Finite Sample: n=30		
		10%	2.525	3.56
		5%	3.058	4.223
		1%	4.28	5.84

Source: Authors' elaboration based on E-Views 12 outputs

Based on the results presented in the table above, the computed F-Statistic value of 4.567076 for the Wald test exceeds the critical bounds at all significance levels. Accordingly, the null hypothesis (H_0) is rejected, and the alternative hypothesis (H_1) is accepted, confirming the existence of a long-run relationship among the study variables.

Table (5): Diagnostic Tests for Assessing the Robustness of the ARDL Model

Statistic	Estimated Value	Prob
ARCH Heteroskedasticity Test	0.190281	0.6663
Breusch-Godfrey Serial Correlation LM Test	0.342317	0.7190
Jarque-Bera Test for Normality	4.918243	0.0855

Source: Authors' elaboration based on E-Views 12 outputs

The diagnostic tests confirm the reliability and adequacy of the estimated ARDL model. Specifically, the ARCH test yielded a statistic of 0.190281 with $P = 0.6663$, supporting the null hypothesis of homoscedastic residuals, which indicates that the model's error variance is stable. The Breusch-Godfrey LM test, with an F-statistic of 0.342317 and $P = 0.719$, suggests the absence of serial correlation in the residuals, ensuring the independence of successive errors. Additionally, the Jarque-Bera test for normality, with $J-B = 4.918243$ and $P = 0.0855$, indicates that the residuals approximately follow a normal distribution, satisfying a key assumption for valid inference in the ARDL framework. Overall, these results provide strong evidence of the model's robustness and reliability for capturing the long- and short-run dynamics of the study variables.

4-4 Model Estimation

After determining the optimal lag length according to the Akaike Information Criterion (AIC), the results indicated that the best-fitting model is ARDL(3,1,4,4,1). This model is deemed appropriate for examining the impact of selected independent variables on economic growth in Algeria. The analysis proceeds by assessing these effects over the long run, followed by the short run. The results are presented as follows:

Table (6): Long-Run Parameter Estimates

Levels Equation Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
DLCEL	-0.180079	0.281835	-0.638952	0.5359
DLEHEI	1.085380	2.306740	0.470525	0.6472
DLPAT	-0.431753	1.267293	-0.340689	0.7398
DLTO	4.051868	4.804817	0.843293	0.4170
C	0.033099	0.093144	0.355350	0.7290
EC = DLGDP - (-0.1801*DLCEL + 1.0854*DLEHEI - 0.4318*DLPAT + 4.0519*DLTO + 0.0331)				

Source: Authors' elaboration based on E-Views 12 outputs

Based on the above table, the results indicate that both mobile phone subscriptions and patent variables are negatively associated with Algeria's economic growth rate. Although the Student's t-statistics are not significant at the 5% level, the coefficients suggest that a one-unit increase in mobile phone subscriptions per 100 people is associated with a reduction in the economic growth rate by 0.180079 units. Similarly, a one-unit increase in patents is associated with a decline of 0.431753 units in economic growth. These findings may reflect a limited or transitional impact of technological diffusion on short-term growth dynamics.

Conversely, higher education enrollment and trade openness exhibit a positive relationship with economic growth, albeit with Student's t-statistics also not significant at the 5% level. Specifically, a 1% increase in higher education enrollment corresponds to a 1.08% increase in economic growth, while a 1% increase in trade openness is associated with a 4.05% growth increment. This underscores the potential role of human capital accumulation and external sector integration in fostering growth in Algeria.

Following the estimation of the Error Correction Model (ECM) within the ARDL framework, the short-run dynamics and adjustment process toward long-run equilibrium are presented as follows:

Table (7): Short-Run Coefficient Estimates and ARDL-UECM Results

ECM Regression Case 2: Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(DLGDP(-1))	-0.622950	0.115574	-5.390043	0.0002
D(DLGDP(-2))	-0.434815	0.119387	-3.642055	0.0039
D(DLCEL)	-0.146763	0.030450	-4.819868	0.0005
D(DLEHEI)	-0.046274	0.303869	-0.152281	0.8817
D(DLEHEI(-1))	0.029638	0.314457	0.094251	0.9266
D(DLEHEI(-2))	-0.175816	0.316772	-0.555023	0.5900
D(DLEHEI(-3))	0.991927	0.303738	3.265732	0.0075
D(DLPAT)	0.275950	0.066564	4.145663	0.0016
D(DLPAT(-1))	0.376147	0.085987	4.374442	0.0011
D(DLPAT(-2))	0.375117	0.074843	5.012019	0.0004
D(DLPAT(-3))	0.152091	0.066711	2.279853	0.0435
D(DLTO)	1.094169	0.165293	6.619564	0.0000
CointEq(-1)*	-0.407365	0.064525	-6.313329	0.0001

Source: Authors' elaboration based on E-Views 12 outputs

Based on the table above, the error correction coefficient is negative (-0.407365) and statistically significant at both the 5% and 1% levels. This indicates that the long-run adjustment speed toward equilibrium is approximately 40.73%. These results confirm that the ARDL model is stable and that a long-run equilibrium relationship exists among all the variables included in the model.

The short-run coefficient estimates reveal that mobile phone subscriptions have a negative relationship with Algeria's economic growth rate, with Student's t-statistic significant at the 5% level. Specifically, a one-unit increase in mobile phone subscriptions per 100 people is associated with a reduction of 0.146763 units in the economic growth rate. This can be largely attributed to the fact that mobile phone usage in Algeria is primarily limited to voice communications and social media, unlike in developed countries where smartphones are extensively integrated into various financial transactions such as electronic payments, bank transfers, and online banking accounts. Furthermore, the limited domestic production of mobile phones imposes additional burdens on the national treasury due to import costs. According to the 2022 report of the National Statistics Office, Algeria's imports of mobile phones and related components amounted to approximately USD 1.2 billion, representing nearly 3% of total non-oil imports.

Conversely, an increase of one unit in patents leads to a rise in economic growth during the first, second, and third lag periods by 0.376147, 0.375117, and 0.152091 units, respectively. This can be primarily attributed to the emergence of new enterprises that promote domestic investment and increase locally manufactured output. Such developments enhance commercial productivity, serving as an indicator of the competitiveness of domestic products relative to more expensive imported goods, thereby helping reduce imports. This trend is further reinforced by the establishment of university-affiliated startups and research-friendly environments in Algerian universities, which have stimulated patent activity and the creation of numerous innovative enterprises. These initiatives contribute to job creation and mitigate unemployment, explaining the observed short-run positive impact on economic growth.

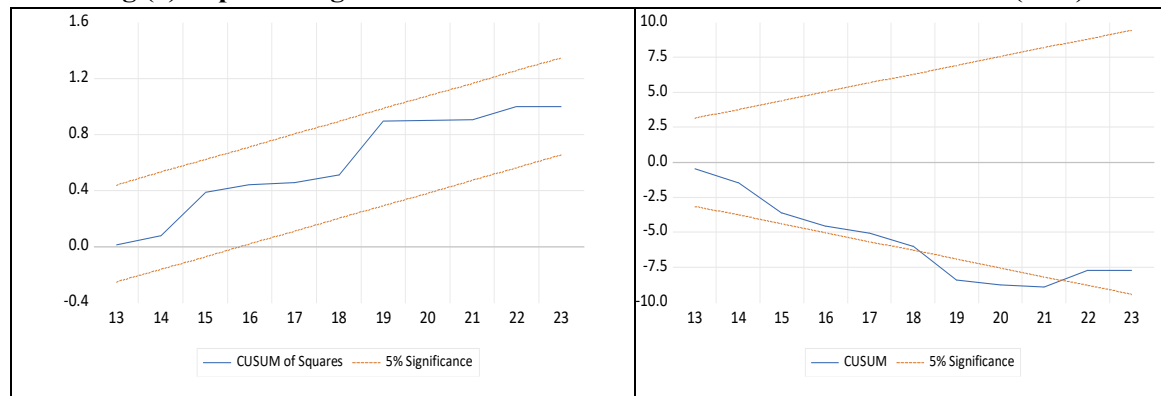
Moreover, both higher education enrollment and trade openness exhibit a positive relationship with Algeria's economic growth. Student's t-statistics are significant at the 5% level during the first and third lag periods, respectively. The positive effect of higher education enrollment can be explained by its direct impact on the supply of skilled labor, which receives specialized training aligned with the demands of the national labor market. This underscores the crucial role of higher education in fostering a qualified workforce, which is essential for achieving sustainable economic take-off and development. Similarly, the positive association between trade openness and economic growth can be interpreted through the expansion of external trade. Increased openness, achieved via liberalization and integration into global markets, along with the expansion of exports, stimulates economic growth by enhancing competitiveness and efficiency in the domestic economy.

Overall, these results highlight the dual importance of human capital accumulation and technological innovation, alongside strategic trade integration, in driving both short- and long-term economic growth in Algeria.

To ensure the stability of the estimated model, the cumulative sum of residuals (CUSUM) and the cumulative sum of squares (CUSUMSQ) tests were employed to detect any structural

changes in the data and to assess the consistency of long-run parameters with short-run dynamics. The results are presented as follows:

Fig (2): Optimal lag selection based on the Akaike Information Criterion (AIC)



Source: Authors' elaboration based on E-Views 12 outputs

Based on the figure above, it is observed that both the cumulative sum of residuals (CUSUM) and the cumulative sum of squared residuals (CUSUMSQ) lines remain entirely within the critical boundaries at the 5% significance level. This indicates that there is no evidence to reject the null hypothesis of parameter stability or structural change. Consequently, it can be concluded that the estimated model exhibits overall stability and consistency, with a harmonious alignment between short-run and long-run results.

These findings confirm the robustness of the ARDL model, ensuring that the dynamic relationships captured among the variables are reliable over the sample period. The stability in both the residuals and their squared values suggests that shocks or temporary fluctuations in the data do not significantly affect the integrity of the model, thereby reinforcing confidence in both the short-term and long-term inferences drawn from the analysis.

Conclusion

This study explored the influence of knowledge economy indicators on economic growth in Algeria over the period 1990–2023, employing the ARDL modeling framework to capture both short-term fluctuations and long-term dynamics.

The analysis revealed a significant cointegration relationship between key knowledge economy indicators—including school enrollment and higher education as a percentage of the total population (EHEI), mobile phone subscriptions per 100 people (CEL), patent applications for residents and non-residents (PAT), and trade openness (TO)—and the country's economic growth. This finding confirms the existence of a long-run equilibrium relationship, underscoring the intertwined nature of knowledge-based factors and economic performance in Algeria.

The results indicate that school enrollment and higher education (EHEI), along with trade openness (TO), are positively associated with economic growth. These positive relationships align with established economic theory, highlighting the pivotal role of human capital accumulation and integration into global markets in promoting sustainable economic development. Higher education, by enhancing the quality and skills of the labor force, ensures alignment with the evolving requirements of the national labor market, thereby fostering productivity and innovation. Trade openness, by facilitating access to international markets,

promoting competition, and expanding exports, further stimulates domestic growth and efficiency.

Conversely, mobile phone subscriptions (CEL) and patent applications (PAT) exhibited a negative relationship with economic growth. Although this contradicts conventional economic theory, it accurately reflects the Algerian context, where mobile technologies are predominantly used for communications and social media rather than integrated into productive and financial applications. Furthermore, domestic patent activity remains at an early stage, with limited immediate contribution to economic output, and the high costs associated with importing mobile technologies place additional burdens on the national treasury. These structural realities help explain the observed inverse effects of these indicators on growth.

The estimated error correction term demonstrated a significant speed of adjustment toward long-run equilibrium, reinforcing the stability and robustness of the ARDL model. This indicates that, despite short-term deviations, the Algerian economy's growth trajectory tends to realign with its long-term equilibrium path, validating the reliability of the model's short- and long-term inferences.

Overall, the study highlights that the impact of knowledge economy indicators on Algeria's economic growth remains relatively limited. This aligns with the country's lagging position in global knowledge economy rankings, emphasizing the need for strategic policy interventions. To enhance the contribution of knowledge-based factors, policymakers should prioritize the expansion and modernization of the higher education system, strengthen research and innovation ecosystems, promote the local development and productive application of mobile technologies, and implement policies that enhance technological diffusion and entrepreneurship. Additionally, further integration into global trade networks can leverage comparative advantages and stimulate economic diversification, thereby maximizing the potential of knowledge economy assets to drive sustainable and inclusive economic growth in Algeria.

Bibliography List:

- Chen, Derek H. C., et Carl C. Dahlman. *The Knowledge Economy, The KAM Methodology And World Bank Operations*. Vol. 35867. Édité par World Bank Institute. Washington D. C., 2006.
- DataReportal. «Digital 2023: Algeria.» 2023, <https://datareportal.com/reports/digital-2023-algeria>.
- DATAREPORTAL. «Digital 2023: Algeria.» 2023.
- Fale, Koketso, Fanglin Li, Isaac Adjei Mensah, Akoto Yaw Omari-Sasu, et Mohammed Musah. «Knowledge-Based Economy Capacity Building for Developing Countries: A Panel Analysis in Southern African Development Community.» *Sustainability* 13, n° 5 (2021): 1-28, <https://doi.org/10.3390/su13052890>.
- Kefela, Ghirmai T. «Knowledge-based economy and society has become a vital commodity to countries.» *International NGO Journal Vol. 5*(7), pp. 160-166 5, n° 7 (2010): pp. 160-166.
- Moch, Enrico. «The Industrial Revolution of Artificial Intelligence: A New Era of Automation and Innovation.» *International Journal of Public Administration Management and Economic Development* 8, n° 2, p1 (2023): 1-12.
- OECD. *The Knowledge-Based Economy*. Vol. 34988. Édité par OECD. Paris, 1996, P. 3.
- Rezny, Lukas, James Buchanan White, et Petra Maresova. «The Knowledge Economy: Key to Sustainable Development?» *Structural Change and Economic Dynamics* 51, n° 1 (2019): 10.1016/j.strueco.2019.02.003.
- Shahabadi, Abolfazl, Fatemeh Kimiaei, et Mohammad Arbab Afzali. «The Evaluation of Impacts of Knowledge-Based Economy Factors on the Improvement of Total Factor Productivity (a Comparative Study of Emerging and G7 Economies).» *Journal of the Knowledge Economy* 9 (2016): 896-907.
- Vărzaru, Anca Antoaneta, et Claudiu George Bocean. «Digital Transformation and Innovation: The Influence of Digital Technologies on Turnover from Innovation Activities and Types of Innovation.» *Systems* 12, n° 359 (2024): 1-25.
- WIPO. *Global Innovation Index 2023*. 2023.
- World Bank. *Lifelong Learning in the Global Knowledge Economy: Challenges for Developing Countries*. Washington, D. C.: World Bank, 2003, 2.
- ربحي مصطفى عليان. *اقتصاد المعرفة*. عمان: دار صفاء للطباعة والنشر والتوزيع، 2012.
- لطيفة لكعص، و المهدي هتهات. "التكامل بين الذكاء الاقتصادي واقتصاد المعرفة كركيزة استراتيجية لتحقيق الابداع والابتكار." *مجلة التكامل الاقتصادي* 13، رقم 1 (2025): 346-332.
- محمد خالد أبو عزام. *ادارة المعرفة والاقتصاد المعرفي*. عمان: دار زهدي للنشر والتوزيع، 2020.