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IMPACT OF INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT) AND THE KNOWLEDGE ECONOMY ON ECONOMIC GROWTH: AN ANALYTICAL APPROACH BASED ON THE ARDL MODEL

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ABSTRACT

This article delved into the profound impact of emerging Information and Communication Technologies (ICT) and the knowledge economy on economic growth, with a primary focus on the unique dynamics within the Moroccan context. Leveraging the ARDL model and World Bank datasets, our survey systematically analyzed various variables, revealing a significant association between several factors and economic growth. Surprisingly, internet access showed no substantial correlation in the Moroccan context. The core objective of this study was to elucidate the intricate relationship among ICT, the knowledge economy, and economic performance, contextualized within the distinctive features of the Moroccan economic landscape. In this era which is defined by a rapid technological evolution, our research provided valuable insights, advocating for innovation and knowledge creation as pivotal strategies in the Moroccan context. Additionally, the study uncovered a crucial link between investments in research, development, higher education, and overall economic growth. It is imperative to note that while this article focuses specifically on aspects related to ICT and the knowledge economy in Morocco, it does not encompass all contributing factors to economic growth. Nonetheless, it serves as a substantive contribution, shedding light on trends that intertwine ICT, the knowledge economy, and economic growth in the Moroccan context. The implications extend beyond national boundaries, underlining the global significance of this research field. Despite the valuable insights provided, we acknowledge inherent limitations within the scope of this study.
Keywords: *Knowledge Economy, ICT, Economic Growth, GDP, ARDL.*

1. INTRODUCTION

The current global economic dynamics witness a profound transformation characterized by the emergence of the knowledge economy (KE, henceforth) and the prevalence of Information and Communication Technologies (ICT). Often termed the digital revolution, this era redefines the foundations of global economic growth, building upon prior studies highlighting the substantial impact of the KE and ICT. Rapid advancements in ICT, data proliferation, artificial intelligence, and process automation have disrupted traditional business models, as evidenced by previous surveys and analyses (Brynjolfsson and McAfee, 2017[1]; Arntz, Gregory, and Zierahn, 2016) [2]. These developments raise questions about their impact on economic growth and how businesses must adapt to these transformations.

In this evolving context, governments, businesses, and researchers strive to understand the impact of the knowledge economy and ICT on economic growth. Substantial investments in research and development, along with policies encouraging innovation and technology diffusion, underscore the importance of these factors in stimulating economic growth, as supported by empirical studies (Brynjolfsson and Hitt, 2000[3]; Mairesse and Mohnen, 2010) [4]. However, questions persist regarding the complex nature of this relationship and the underlying mechanisms.

1.1 Research Aim:

The core objective of this study is to explore the intricate relationship between the knowledge economy, ICT, and economic growth with a particular emphasis on the distinctive features of the Moroccan economic landscape. In an era marked by

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rapid technological evolution, understanding the drivers of economic growth is imperative. Our research contributes to this understanding by investigating the impact of the KE and ICT on economic growth within the context of Morocco. The knowledge economy, characterized by knowledge, information, and innovation, plays a pivotal role in fostering economic growth. Countries investing in research and development, promoting high-quality higher education, and encouraging technological advancements are better positioned for sustainable progress.

Our study examines the relationships between ICT and the KE in the specific context of economic growth. We adopt an approach based on the ARDL model to model this complex relationship, allowing for the analysis of short and long-term interactions between the variables of interest while accounting for a non-stationarity data.

To address our research question, we formulate four research hypotheses:

H1. Internet access has a significant impact on economic growth (GDE).

H2. Information and Communication Technologies impact economic growth.

H3. Research and development expenditures influence economic growth.

H4. The number of teachers in higher education (NHET) significantly influences economic growth

1.2 Scope and Conceptualization:

Our research focuses on exploring the relationship between the knowledge economy, ICT, and economic growth, with a specific emphasis on the Moroccan context. The motivation behind this study lies in the recognition of the transformative potential of the KE and ICT in driving economic progress. By concentrating on these aspects, we aim to provide valuable insights into the dynamics that contribute to economic growth in the Moroccan landscape. However, it is important to note that our study does not claim to encompass all factors influencing economic growth; as matter fact, it aims at making a significant contribution within its defined scope.

1.3 Research Design and Steps:

This study employs an Auto Regressive Distributed Lag (ARDL) model-based approach to model the intricate relationship among KE, ICT, and economic growth comprehensively. This methodology facilitates a nuanced analysis of short- and long-term interactions between variables while accounting for data non-stationarity. The subsequent steps involve a rigorous literature review, a detailed methodology outlining our approach, a presentation of results, and finally, a conclusion summarizing key findings and suggesting avenues for future research.

The study will follow a four-section structure: literature review, methodology, results presentation, and conclusion, ensuring a thorough analysis of the impact of ICT and the KE on economic growth.

2. LITERATURE REVIEW

2.1 Economic Growth Theory:

The economic growth theory serves as a fundamental cornerstone of economics by exploring the underlying mechanisms that guide the expansion and development of economies over time. Various theoretical approaches have been developed to explain the sources and determinants of economic growth, including the Solow model, endogenous growth models, innovation theory, capital accumulation theory, sustainable endogenous growth theory, and balanced growth theory.

The Solow model, conceived by Robert Solow[5], emerges as one of the early theories of economic growth. It posits that economic growth is primarily exogenous, determined by external factors such as technological advances. According to this model, economies converge towards a long-term equilibrium characterized by constant technical growth. The endogenous growth theory, as an analytical framework, emphasizes the role of internal factors in driving long-term economic growth. Researchers such as Paul Romer[6], Robert J. Barro[7], Xavier Sala-i-Martin[8], Robert E. Lucas Jr[9], Gene M. Grossman[10], Elhanan Helpman, Philippe Aghion, and Peter Howitt (11)have all contributed to this theory. Romer (1990) [6] introduced an innovative model of an economic system where knowledge and innovation play a central role in growth. Barro and Sala-i-Martin (1995) [8] examined technological diffusion and economic convergence in relation to growth. Lucas Jr (1988) [12] delved into mechanisms of economic development, focusing on ideas and knowledge. Grossman and Helpman (1991)[10] studied the links between innovation and global-scale growth. Aghion and Howitt (1992) [11] advanced a growth model based on creative destruction, where continuous innovation is the driver of economic growth.

These researchers have significantly contributed to the endogenous growth theory by highlighting the importance of innovation, knowledge diffusion, and investment in human capital for long-term economic growth. Their work laid the foundation for analyzing endogenous determinants of growth and paved the way for subsequent studies on the intricate interactions between the knowledge economy, Information and Communication Technologies (ICT), and economic growth.

2.2 Innovation Theory:

Developed by economists such as Joseph Schumpeter and Robert Solow, innovation theory emphasizes the pivotal role of innovation in economic growth. Schumpeter highlighted the crucial role of innovative entrepreneurs in creating positive economic disruptions through technological innovation. Complementarily, Solow contributed to defining the concept of exogenous growth by acknowledging the significant impact of technological advancements on economic growth. This theory underscores that the introduction of new ideas, technologies, products, and processes can stimulate productivity, promote economic development, and influence the competitiveness of businesses and nations.

Innovation is thus considered a key driver of economic growth by enhancing productivity, reducing costs, improving product quality, and creating new market opportunities. It also fosters the competitiveness of businesses and nations, allowing those at the forefront of innovation to maintain an economic advantage. Public policies, investments in research and development, education, intellectual property protection, and access to financing play a crucial role in promoting innovation and economic growth. Innovation is often regarded as an essential driver of competitiveness and economic progress in the modern world.

2.3 Human Capital Theory:

The human capital theory, enriched by the eminent contributions of researchers such as Theodore W. Schultz, Gary S.(1961) [13] Becker, Jacob Mincer(1964)[14], Robert E. Lucas Jr., Eric A. Hanushek(1988)[12], and Ludger Woessmann, [15] provides an essential framework for understanding the relationship between Information and Communication Technologies (ICT) and economic growth. This theoretical perspective highlights the crucial importance of improving skills and individual productivity in economic development. For instance, Theodore W. Schultz (1961)[13] played a central role in introducing the concept of human capital, emphasizing that investments in higher education and training represent forms of capital that enhance individuals' productivity and income. Gary S. Becker (1964) [14] extended this approach by developing a robust economic perspective of human capital, demonstrating that higher education and training are investments that increase individuals' skills and production capacity. Also, Jacob Mincer (1958) [16] quantified human capital and highlighted its positive impact on income distribution, demonstrating how individuals investing in their own human capital can benefit from better career prospects and incomes. Robert E. Lucas Jr. (1988)(9) expanded the human capital theory by integrating it into the context of economic development, emphasizing that human capital, composed of the skills, knowledge, and abilities of workers, is a crucial factor in stimulating long-term economic growth. Furthermore, Eric A. Hanushek and Ludger Woessmann (2008) [17] highlighted the importance of cognitive skills, particularly acquired through quality higher education, in fostering a country's economic development. Their research showed that cognitive skills are an essential driver of productivity and economic growth.

Regarding ICT, previous research has analyzed their impact on higher education, training, and human capital. It is crucial to note that the growing role of ICT in improving individual skills and productivity has become predominant. ICT facilitates access to information, online learning, and educational resources, thereby enhancing human capital by allowing individuals to acquire new skills more efficiently. However, it is worth noting that the effect of human capital on economic growth can vary depending on economic opportunities and the quality of institutions in a country (Ali M.; Egbetokun, A.; Memon, M.H. 2018) [18]. Similarly, research may yield contrasting results, as studies in the Malaysian context revealed a non-significant correlation between human capital and economic growth (Salleh, N.M., Bujang, I., Andin, C., and Mazlan, M.N.A 2022) [19]. Nevertheless, some recent studies have corroborated the positive impact of human capital on economic growth. For example, a study conducted in the Shandong province revealed sustained growth in human capital and economic growth, highlighting the importance of factors such as R&D expenditures, higher education, medical resources, and other indicators of economic development (Wang, S., Lin, X., Xiao, H., Bu, N., and Li, Y. 2022) [20]. Furthermore, human capital theory provides a powerful conceptual framework for understanding how ICT can influence economic growth by improving individuals' skills and productivity. However, empirical results may vary based on national contexts and specific economic conditions.

In short, these authors have shown that human capital theory has much to say about the relationship between this theory and economic growth.

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2.4 Knowledge Economy:

The concept of the KE was first introduced by Peter Drucker in 1968[21], as outlined in his work. However, the foundations of this economy already exist, although it was not conceptualized in the same way at that time. Increased interest in KE intensified when the World Bank has established fundamental criteria for access, based on four essential indicators: higher education, research and development, information systems, as well as legal and legislative systems. Thus, KE is defined as an economy where processes of production and investment in knowledge play a central and sustainable role, contributing to the creation of national wealth and the improvement of efficiency in all economic sectors.

In the context of globalization, the competitiveness of national economies increasingly relies on their ability to generate and exploit knowledge, with key indicators of economic growth such as : knowledge, higher education, and innovation (Mohamed, M.M.A.; Liu, P.; Nie, G. 2022) [22], many countries have adopted policies focused on the production of knowledge and its transformation into wealth, thereby stimulating the growth and competitiveness of their economies. In a recent study covering a sample of 20 developing countries over the period 1996-2020, the authors measured various variables related to the knowledge economy. Using three models, namely the cumulative regression model, the fixed-effects model, and the random-effects model, they estimated that 93% of the variations in the economic growth of developing countries were attributable to their dependence on the knowledge economy. The use of cross-sectional time series models was emphasized for its role in increasing the accuracy of statistical forecasts by considering both the temporal and cross-sectional dimensions of the data.

According to research conducted by Mohamed, M.M.A., Liu, P., and Nie, G., [22] a positive correlation was established between the number of mobile phone users and economic growth. Each increase of one unit in the number of mobile phone users is associated with an increase of 0.0045 units in economic growth. This relationship is particularly notable in developing countries, where the increase in the number of mobile phone users is crucial, especially during major crises such as the COVID-19 pandemic.

3. METHODOLOGY

3.1 Data Collection and Selection:

The first phase of the methodology involves data collection from the World Bank, a reliable source providing economic indicators, Information and Communication Technologies (ICT) data, and statistics related to the KE for several countries, including Morocco. Simultaneously, the specification of the Autoregressive Distributed Lag (ARDL) model was undertaken. In this step, key variables were rigorously selected, including the KE index encompassing indicators such as the number of teachers in higher education, the number of teachers (% female), and Internet subscriptions. ICT indicators and economic growth variables, such as the Gross Domestic Product (GDP) growth rate, were also included.

3.2 ARDL Model Estimation:

The second phase focused on estimating the ARDL model, considering the lags of variables to capture short- and long-term effects on economic growth. This model, recognized for its ability to handle non-linear relationships and address potential non-stationarities in time series, proved suitable for our study. The obtained results underwent a thorough analysis. The estimated coefficients were examined in detail to assess the direction and magnitude of the impact of the KE and ICT on economic growth in Morocco. Appropriate statistical tests were conducted to ensure the robustness of the results and the validity of the formulated hypotheses.

In summary, the use of the ARDL model provided in-depth and robust results on the interrelation between the knowledge economy, ICT, and economic growth in Morocco. These findings could guide policymakers and economic stakeholders in identifying areas where strategic investments could have a positive impact on long-term economic growth. However, it is essential to note that any econometric study has limitations, and careful consideration of possible sources of uncertainty is integrated into the interpretation of the results.

3.3 Stationarity Test:

To conduct this assessment, we employed the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests. These tests aim to determine the presence of a unit root in a time series by comparing the coefficient of the lagged variable to a critical value. If the coefficient is less than the critical value, it suggests that the series is stationary; otherwise, it is considered non-stationary.

The ADF test (Table 1) was applied to each variable in our model. We specified an autoregressive model with optimal lags to account for any serial autocorrelation. Variables showing a unit root were differenced once to ensure stationarity. This approach allowed us to construct a robust ARDL model using stationary time series.

The generally followed procedure for estimating an ARDL model involves the following steps:

1. Estimation of the chosen model based on Akaike information criteria.
2. Conducting the test for the existence of the long-term relationship using the Bound test.
3. Estimation of the relationship with the error correction term.
4. Conducting necessary tests, such as serial correlation and CUSUM stability tests.
5. Rejecting or accepting the model and interpreting the results.

Table 1: Unit Root Test Results (ADF) - Generated by the Authors with Eviews 11

UNIT ROOT TEST TABLE (ADF)						
	At Level					
		GDP	INT	DRE	NHET	ICT
With Constant	t-Statistic	-43.027	2.4391	-18.447	-45.610	-42.977
	Prob.	0.0040	0.9999	0.3487	0.0022	0.0041
		***	n0	n0	***	***
With Constant & Trend	t-Statistic	-34.980	-11.993	-23.511	-45.180	-34.797
	Prob.	0.0739	0.8812	0.3882	0.0103	0.0762
		*	n0	n0	**	*
Without Constant & Trend	t-Statistic	0.6278	4.2563	-0.6072	-41.199	0.5329
	Prob.	0.8405	0.9999	0.4401	0.0003	0.8192
		n0	n0	n0	***	n0
	At First Difference					
		d(GDP)	d(INT)	d(DRE)	d(NHET)	d(ICT)
With Constant	t-Statistic	-36.759	-39.664	-21.364	-53.734	-36.753
	Prob.	0.0169	0.0080	0.2340	0.0005	0.0169
		**	***	n0	***	**
With Constant &Trend	t-Statistic	-33.576	-37.894	-21.442	-51.604	-33.602
	Prob.	0.0952	0.0455	0.4892	0.0038	0.0948
		*	**	n0	***	*
Without Constant & Trend	t-Statistic	-36.860	0.6110	-22.036	-55.500	-36.835
	Prob.	0.0012	0.8369	0.0301	0.0000	0.0012
		***	n0	**	***	***
Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant						
*MacKinnon (1996) one-sided p-values.						

Table 2 : Unit Root Test Results (PP) - Generated by the Authors with Eviews 11

UNIT ROOT TEST TABLE PP						
	At Level					
		GDP	INT	DRE	NHET	ICT
With Constant	t-Statistic	-52.061	2.7946	-13.788	-45.606	-51.810
	Prob.	0.0006	1.0000	0.5704	0.0022	0.0006
		***	n0	n0	***	***
With Constant & Trend	t-Statistic	-96.185	-10.019	-11.739	-45.180	-96.458
	Prob.	0.0000	0.9196	0.8869	0.0103	0.0000
		***	n0	n0	**	***
Without Constant & Trend	t-Statistic	-21.036	8.5201	-0.4016	-41.191	-27.502
	Prob.	0.0371	1.0000	0.5253	0.0003	0.0087
		**	n0	n0	***	***
	At First Difference	-	-	-	-	-
		d(GDP)	d(INT)	d(DRE)	d(NHET)	d(ICT)
With Constant	t-Statistic	-139.460	-39.875	-21.338	-196.238	-140.218
	Prob.	0.0000	0.0077	0.2349	0.0000	0.0000

		***	***	n0	***	***
With Constant & Trend	t-Statistic	-137.499	-120.419	-21.411	-202.454	-138.330
	Prob.	***0.0000***	***0.0000***	***0.4907***	***0.0001***	***0.0000***
		***	***	n0	***	***
Without Constant & Trend	t-Statistic	-143.150	-19.602	-22.011	-202.406	-143.135
	Prob.	***0.0001***	***0.0501***	***0.0303***	***0.0001***	***0.0001***
		***	*	**	***	***
Notes: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1%. and (no) Not Significant						
*MacKinnon (1996) one-sided p-values.						

For our estimations, we initially estimated the model by including all explanatory variables. The selected model, according to the SIC criterion, is the ARDL (4, 1, 1, 0, 1), as illustrated in Figure 1 below, with 4 lags for the dependent variable GDP. For the explanatory variables, one lag was retained for each, except for the variable NHET, which has no lag.

The use of the Akaike Information Criteria (AIC) was pivotal in selecting the optimal model for our analysis, guiding our choice towards the ARDL (4, 1, 1, 0, 1). The chosen ARDL model exhibited a upper AIC compared to other specifications, indicating it strikes the best balance between fitting the data and model complexity. This choice underscores the robustness of the ARDL (4, 1, 1, 0, 1) model in explaining temporal relationships in our data, enhancing the credibility of our results.

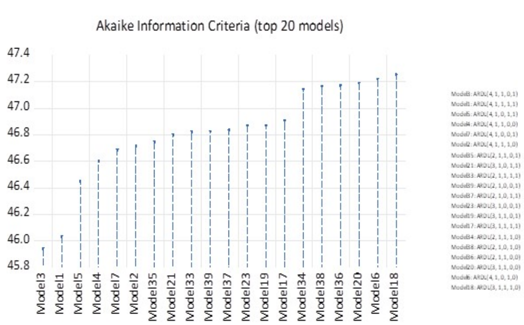


Figure 1 : Akaike Information Criteria, - Generated by the Authors with Eviews 11

Table 3 : Selected Model - ARDL(4, 1, 1, 0, 1) with AIC Value 18, - Generated by the Authors with Eviews 11

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
GDP(-1)	-0.295835	0.187706	-1.576055	0.1758
GDP(-2)	-0.979292	0.170513	-5.743195	0.0022
GDP(-3)	0.121695	0.182386	0.667235	0.5342
GDP(-4)	-0.473258	0.154773	-3.057754	0.0282
INT	4600.02	887.743	5.183859	0.0035
INT(-1)	37200.01	8396.424	4.429318	0.0068
DRE	20501.12	8281.006	2.476627	0.0561
DRE (-1)	2902.09	1098.184	2.638923	0.0460
NHET	673315.6	173264.4	3.886058	0.0116
ICT	9151.549	2013.981	4.544010	0.0061
ICT (-1)	-5856.620	2398.917	-2.441360	0.0586

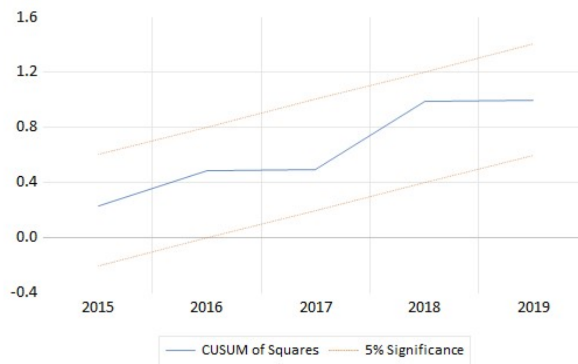
$$\mathrm{GDP} = (-0.295835 \times GDP_{(t-1)} - 0.979292 \times GDP_{(t-2)} 0.121695 \times GDP_{(t-3)} - 0.473258 \times GDP_{(t-4)}) + (4600.02 \times INT_{(t)} + 37200.01 \times INT_{(t-1)}) + (20501.12 \times DRD_{(t)} + 2902.09 \times DRE_{(t-1)}) + (673315.6 \times \mathrm{NHET}_{(t)}) + (9151.549 \times ICT_{(t)} - 5856.620 \times ICT_{(t-1)}) + \varepsilon_{(t)}$$

Where: The adjusted R^2, considering both the number of explanatory variables and observations, refines the raw R^2. In our case, the model exhibits an adjusted R^2 of 0.991126, indicating excellent goodness of fit.

For the Breusch-Godfrey Test, the F-statistic is 3.900346 with a probability 0.1464. This test assesses the autocorrelation of the model's residuals. If the associated probability is above a pre-established significance threshold, such as 0.05, it can be concluded that there is no autocorrelation in the residuals.

Table 4: Heteroskedasticity And Normality Tests, - Generated by the Authors with Eviews 11

	Breusch-Godfrey	Breusch-Pagan-Godfrey	Jarque-Bera
F statistic	3.900346	1.114928	2,460352



Probability	0.1464	0.5019	0,2922 41

Regarding the Breusch-Pagan-Godfrey Test, the F-statistic is 1.114928 with a probability 0.5019. This test aims to detect heteroskedasticity in the residuals. If the probability is above the chosen significance threshold, it can be concluded that there is no heteroskedasticity in the residuals.

As for the Jarque-Bera Test, the F-statistic is 2.460352 with a probability of 0.292241. This test assesses whether the model's residuals follow a normal distribution. If the probability is above the significance threshold, it can be concluded that the residuals follow a normal distribution.

In other words, if the CUSUM of squares test stays within the orange bounds, it indicates that the model's residuals do not show a systematic pattern of variance change. This observation enhances the credibility of the model results and confirms that the homoskedasticity assumptions are met. It is worth noting that the Cumulative Sum (CUSUM) test is typically employed to detect structural changes in a time series. In this specific context, the use of the CUSUM test suggests the absence of significant structural changes in the analyzed data.

*F*igure 2 : CUSUM of Squares Analysis , Generated by the Authors with Eviews 11

The calculated F-statistic has a value of 12.22562, determining the significance level at which the test is conducted; in this case, a significance level of 10% was used.

The columns I(0) and I(1) represent the critical values of the test statistic at the specified significance levels. For example, at a 10% significance level, the critical value is 1.9 for I(0) and 3.01 for I(1).

The test statistics 'k' are relevant when the number of levels of the categorical variable (k) is 4. At a 5% significance level, the critical value is 2.26 for k=4. For a 2.5% significance level, the critical value is 2.62 for k=4. Finally, at a 1% significance level, the critical value is 3.07 for k=4.

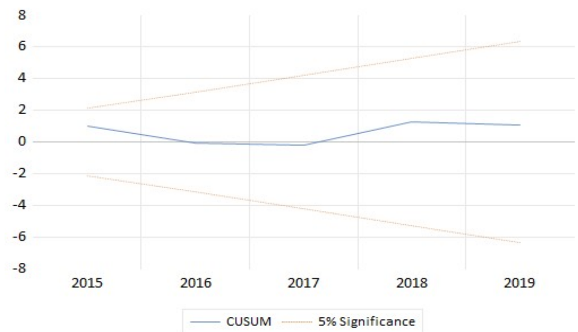


Figure 3 : *CUSUM Analysis, - Generated by the Authors with Eviews 11*

Table 5 : F-Bounds Test Results, - Generated by the Authors with Eviews 11

Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	12.22562	10%	1.9	3.01
K	4	5%	2.26	3.48
		2.5%	2.62	3.9
		1%	3.07	4.44

Table 6 : Short-Term Equation, - Generated by the Authors with Eviews 11

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP(-1)	1.330856	0.186867	7.121947	0.0008
GDP(-2)	0.351564	0.121420	2.895430	0.0340
GDP(-3)	0.473258	0.108304	4.369715	0.0072
INT	0.4335	0.196	2.216	0.027
DRE	54.4418	18.813	2.894	0.004
ICT	3.961089	1118.879	8.179212	0.0004
CointEq(-1)*	-0.632810	0.054066	-11.70438	0.0000

The short-term equation for the model is as follows:

$$GDP_{(t)} = (1.330856 \times GDP_{(t-1)}) + (0.351564 \times GDP_{(t-2)}) + (0.473258 \times GDP_{(t-3)}) + (0.4335 \times INT_{(t)}) + (54.4418 \times DRE_{t}) + (3.961089 \times ICT_{t}) - (0.632810 \times CointEqt_{(t-1)}) + \varepsilon_{(t)}$$

Explanation of coefficients: GDP(-1) (GDP lagged by one year): For each increase in GDP

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with a one-year lag increases by 1.330856. The t-statistic of 7.121947 indicates that this coefficient is significant, with an associated probability of 0.0008.

The positive coefficient means a positive lagged effect of GDP on current economic output. This suggests that the previous year's economic performance has a significant influence on current GDP. The high t-statistic of 7.121947 and the associated low probability of 0.0008 reinforce the significance of this coefficient, indicating that past economic activities play a crucial role in shaping the current economic landscape.

CointEq(-1)* (Cointegration variable lagged by one year): The cointegration variable lagged by one year has a coefficient of -0.632810. The t-statistic suggests that this coefficient is significant, with an associated probability of 0.0000. This indicates long-term error correction between the variables. The negative coefficient indicates an inverse relationship between the lagged cointegration variable and the current economic conditions. The significance, as reflected in the t-statistic of 0.0000, suggests a robust long-term error correction mechanism between variables. This implies that deviations from the long-term equilibrium between cointegrated variables are corrected in the subsequent year, contributing to the stability of the economic system. GDP Lags (GDP(-1), GDP(-2), GDP(-3)): Significant and positive coefficients for the GDP lags indicate temporal dependence of GDP. This suggests that past values of GDP have an impact on current GDP, which may be due to economic persistence effects, economic cycles, or long-term economic policies. The positive coefficients for lagged GDP values affirm the temporal persistence of economic conditions. This temporal dependence can be attributed to economic persistence effects, cyclical patterns, or the influence of long-term economic policies. The significance of these coefficients emphasizes the importance of considering historical economic performance when analyzing current GDP. INT (Internet Access): The positive and significant coefficient for INT (Internet Access) suggests that an increase in spending on internet access positively influences short-term GDP growth. This aligns with expectations, indicating that enhanced internet access contributes to economic growth through improved efficiency, resource management, and innovation facilitated by increased connectivity. DRE (Research and Development Expenditure): The positive and significant coefficient for DRE implies that higher spending on Research and Development positively impacts short-term GDP growth. This emphasizes the crucial role of R&D in driving innovation, productivity improvement, and the development of new technologies, thereby contributing to short-term economic growth. ICT (Information and Communication Technology): The positive coefficient indicates that increased investment in Information and Communication Technology positively affects short-term GDP growth. The statistical significance of this coefficient emphasizes the role of ICT in stimulating economic growth by introducing advancements in technology and communication.

These interpretations collectively highlight the importance of technology-related investments (INT, DRE , ICT) in influencing short-term economic growth. The positive coefficients, coupled with their statistical significance, reinforce the idea that these expenditures contribute meaningfully to economic outcomes in the short run. Improved connectivity, innovation, and technological advancements emerge as key drivers in shaping immediate economic dynamics. Innovative activities for immediate economic benefit.

Table 7 : Long-Term Equation, - Generated by the Authors with Eviews 11

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ICT	33309.2	1969.14	16.90873	0.0000
DRE	18889.9	1839.29	10.28031	0.0001
NHET	256336.1	77748.24	3.297002	0.0215
INT	1254.403	845.8365	1.483032	0.1982

The long-term equation for the model is as follows:

$$GDP_{(t)} = 33309.2 \times ICT_{(t)} + 18889.9 \times DRE_{(t)} + 256336.1 \times \mathrm{NHET}_{(t)} + 1254.403 \times INT_{(t)} + \varepsilon_{(t)}$$

The positive coefficient associated with ICT (Information Technology expenditure) in our analysis signifies a robust connection between increased spending on information technology and GDP, highlighting the substantial impact of IT investments on economic growth. This positive relationship is rationalized through various mechanisms, all contributing to the overall enhancement of economic dynamics. Firstly, heightened information technology spending results in improved efficiency in production processes. The integration of advanced IT solutions streamlines operational workflows, reduces redundancies, and optimizes resource utilization. This increased operational efficiency, in turn, leads to higher productivity within industries, ultimately contributing to the growth of the overall economy. Effective resource management is another mechanism justifying the positive coefficient for ICT. Information technology enables businesses to manage resources more efficiently, whether through automated inventory systems, data-driven decision-making, or optimized supply chain processes. By leveraging IT tools, businesses can minimize waste, allocate resources more strategically, and enhance overall resource utilization, thereby fostering economic growth. Facilitation of innovation is a crucial factor in understanding the positive impact of information technology spending on GDP. Investments in IT provide a fertile ground for innovation, enabling companies to adopt cutting-edge technologies, develop new products and services, and explore novel business models. The continuous integration of technological advancements encourages a culture of innovation within industries, contributing to economic growth by keeping businesses competitive in a rapidly evolving landscape. Additionally, investments in information technology contribute to increased access to new markets. Through digital platforms and online channels, businesses can reach a wider audience both domestically and internationally. This expanded market reach opens up new opportunities for trade and commerce, fostering economic growth by connecting businesses with a diverse array of consumers and partners. Increased labor productivity is a direct outcome of investments in information technology. Automation, digital tools, and advanced technologies contribute to more streamlined and efficient work processes, enabling workers to accomplish tasks with greater speed and accuracy. This boost in productivity not only benefits individual businesses but also collectively contributes to increased economic output, as a more productive workforce is a driving force behind economic growth. Furthermore, the positive coefficient for ICT reflects how investments in information technology stimulate competitiveness. Businesses that embrace and invest in IT are better positioned to adapt to market changes, respond to customer needs, and stay ahead of competitors. This heightened competitiveness contributes to a dynamic and thriving economic environment, further supporting overall economic growth. Concrete examples of companies benefiting from IT investments reinforce our argument. A case in point is Amazon, where advanced IT systems have improved the efficiency of logistics operations, increasing the company's competitiveness in the global marketplace. Similarly, Singapore's Smart Hospital illustrates the benefits in the healthcare sector, showing how the adoption of electronic medical records and advanced monitoring technologies has transformed the delivery of care, offering an enhanced patient experience. These examples underline how investment in IT boosts operational efficiency, improves competitiveness, opens up new markets, and fosters innovation, all of which contribute to economic growth. Incorporating more specific case evidence reinforces our assertion that IT investment is a key driver of economic prosperity.

DRE (Research and Development Expenditure):

The positive coefficient associated with DRE (Research and Development Expenditure) in our analysis signifies a constructive relationship between increased spending on research and development and GDP, revealing the pivotal role that research and development play as catalysts for economic growth. DRE stands out as a fundamental driver of innovation, as emphasized by the positive coefficient associated with it. The linkage between DRE spending and economic growth is rooted in the transformative impact that innovation has on various facets of the economy. Allocating resources to R&D enables economies to unlock new ideas, technologies, and methodologies, thereby enhancing overall productivity and efficiency. The positive impact of DRE on GDP extends beyond mere innovation, serving as a driving force behind the improved quality of products and processes. Sustained investment in research and development allows businesses and industries to optimize their operations, leading to the creation of high-quality goods and services and contributing to an elevation in overall economic output. Investment in DRE acts as a catalyst for the creation of new technologies. The positive coefficient for DRE underscores how such investments stimulate technological advancements, propelling industries forward and positioning countries at the forefront of global innovation. The resulting influx of new technologies has a cascading effect on business competitiveness, with companies actively engaged in DRE gaining a strategic edge in the market. Furthermore, the positive relationship between DRE spending and economic growth suggests that such investments create opportunities for overall economic development. As industries innovate, adapt, and embrace new technologies, they become better equipped to navigate the complexities of the global marketplace. This heightened competitiveness, stemming from a culture of research and development, contributes to sustained economic growth, leading to an increase in GDP. Investments in research and development play a crucial role in fostering innovation across various industries, resulting in tangible economic impacts. In the pharmaceutical sector, companies dedicating significant resources to DRE have revolutionized healthcare by developing groundbreaking medicines and vaccines. For instance, the rapid development of RNA-based COVID-19 vaccines showcases how DRE directly contributes to public health and, consequently, economic productivity. Automobile manufacturers focusing on research and development have transformed the industry through technological advancements, as seen with the introduction of electric vehicles (EVs) and autonomous driving capabilities. This not only enhances product quality but also positions companies at the forefront of a dynamic market, fostering economic growth.

In the technology industry, giants like Apple, Google, and Microsoft consistently allocate substantial funds to DRE, driving product innovation. The development of smartphones, artificial intelligence applications, and cloud computing services are direct outcomes of these investments, propelling economic growth and maintaining global competitiveness. Aerospace companies engaging in significant research and development efforts contribute to technological breakthroughs, leading to the production of more efficient and safer aircraft. This benefits both the aerospace industry and the broader economy. Within the renewable energy sector, investments in DRE lead to innovations such as more efficient solar panels and advanced wind turbines. These technologies contribute not only to a sustainable future but also stimulate economic activity by creating jobs and establishing new markets. In the biotechnology and healthcare sectors, companies investing in research and development drive significant breakthroughs. The development of gene therapies, personalized medicine, and innovative medical devices showcases the transformative impact of DRE on improving health outcomes and fostering economic growth in the healthcare industry. In summary, the positive coefficient for DRE reflects the multi-faceted impact of research and development on economic dynamics. It highlights DRE as a driver of innovation, a catalyst for improved productivity and product quality, and a key player in fostering technological advancements and business competitiveness, all of which collectively contribute to economic growth.

NHET (Number of Higher Education Teachers):

The positive coefficient associated with NHET (Number of Higher Education Teachers) in our analysis signifies a robust connection between the presence of higher education teachers and GDP, highlighting the indispensable role that higher education and educators play in shaping economic dynamics. Higher education emerges as a pivotal factor in fostering economic growth, acting as a key enabler in skill and knowledge development within the workforce. The positive relationship between the number of higher education teachers and GDP underscores the instrumental role well-qualified educators play in equipping individuals with the expertise required for the modern job market.

The significance of higher education extends beyond individual skill development, playing a critical role in enhancing overall workforce productivity and innovation capacity. By providing advanced knowledge and specialized training, higher education contributes to a workforce that is not only skilled but also adept at generating innovative solutions and adapting to evolving challenges. Moreover, the positive association between the number of higher education teachers and economic growth emphasizes that an educated and skilled workforce is a valuable asset for businesses, fostering a business environment conducive to knowledge creation and innovation. In essence, the positive coefficient for NHET reflects the synergy between higher education and economic growth, portraying investment in quality education facilitated by a robust presence of skilled higher education teachers as a catalyst for economic development. This relationship aligns with the broader understanding that an educated and skilled workforce is a cornerstone of competitiveness, driving economic growth and prosperity. Despite the substantial impact of innovation, its role in short-term economic growth may be somewhat overshadowed by other factors such as investment in information technology and research and development. The subtlety of innovation's contribution in the short term highlights the multifaceted nature of the economic landscape. While innovation, characterized by the introduction of new ideas, technologies, and practices, has inherent qualities that can potentially boost productivity and competitiveness, short-term economic growth may be more immediately influenced by factors like investment in information technology and research and development. For example, in Finland, the high number of qualified higher education teachers has been a driving force behind the country's success in education and innovation. Emphasis on teacher training and

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expertise has contributed to a well-educated population, directly influencing Finland's economic growth through a well-informed and adaptable workforce. Similarly, in South Korea, the positive association between NHET and GDP is illustrated by the country's emphasis on higher education and the presence of qualified educators. Institutions such as Seoul National University and KAIST have played a key role in the advancement of research and technology, contributing significantly to South Korea's economic progress and technological competitiveness. The positive relationship between the number of higher education teachers and economic growth is observable in emerging economies like Brazil, where the presence of qualified teachers in institutions such as the University of São Paulo has enabled advances in various fields, fostering innovation and contributing to Brazil's economic development. However, this does not diminish the importance of innovation in a broader economic context. In the long term, innovation retains its transformative potential, creating a ripple effect by introducing new ideas, technological advances, and innovative practices. This capacity positively influences productivity and competitiveness over an extended period, contributing to continuous economic improvement.

4. ANALYSIS OF RESULTS IN THE CONTEXT OF THEORY

4.1 SOLOW MODEL AND ENDOGENOUS GROWTH THEORY:

The outcomes of our study, highlighting the positive impact of Information Technology Investments (ICT), Research and Development (DRE), the Number of Higher Education Teachers (NHET), and Internet access (INT) on GDP, align with the principles of Endogenous Growth Theory. This affirms the substantial role played by internal factors in driving economic growth. The Solow Model, which emphasizes exogenous factors such as technological advancements, finds support in our results, showcasing the significant contribution of these internal elements to sustained economic expansion

4.2 INNOVATION THEORY:

Our discussion on the positive effects of innovation on productivity, cost reduction, product quality, and the creation of new market opportunities is consistent with the tenets of Innovation Theory. The results underscore how innovation serves as a key driver of economic growth, aligning with the theory's emphasis on the transformative impact of new ideas, technologies, and practices.

4.3 HUMAN CAPITAL THEORY:

The findings regarding the positive impact of human capital (NHET) on economic growth align with Human Capital Theory. This underscores the importance of education and training in fostering individual skills and productivity. Our results affirm the theory's premise that investments in human capital, represented by well-qualified higher education teachers, contribute significantly to long-term economic growth.

4.4 KNOWLEDGE ECONOMY:

The discussion on the knowledge economy, particularly emphasizing indicators such as higher education, research and development, and information systems, resonates with the concept of the knowledge economy. Our results, illustrating a positive correlation between the number of mobile phone users and economic growth, further align with this perspective. This underscores that in a globalized context, factors like higher education, research, and technology infrastructure play a central and sustainable role, supporting the creation of national wealth and efficiency improvement across economic sectors.

In summary, our study's outcomes are in harmony with established economic growth theories, providing empirical evidence that strengthens the foundation of these theoretical frameworks. The positive relationships identified emphasize the critical role of internal factors, innovation, human capital, and knowledge-driven elements in shaping economic dynamics and fostering sustainable growth.

5. CONCLUSION

In conclusion, our comprehensive analysis illuminates robust positive correlations between key factors—Information Technology (INT), Research and Development Expenditure (DRE), Number of Higher Education Teachers (NHET), and Innovation (ICT)—and Gross Domestic Product (GDP). The positive coefficients associated with each variable underscore their substantial contributions to economic growth, supported by well-established mechanisms. Notably, investments in Information Technology (INT) exhibit a significant positive impact on GDP, driven by enhanced efficiency, improved resource management, and the facilitation of innovation. Similarly, the positive coefficient for Research and Development Expenditure (DRE) underscores its pivotal role in fostering innovation, improving productivity, and contributing to economic growth. The positive relationship between the Number of Higher Education Teachers (NHET) and GDP highlights the critical role of education in enhancing workforce skills and knowledge, vital elements that bolster productivity and innovation. While the positive coefficient for Innovation (ICT) suggests its favorable impact on GDP, it appears less pronounced compared to INT, DRE , and NHET. However, our study raises intriguing questions that extend beyond the scope of this analysis, warranting further exploration to understand the nuanced interplay between innovation and long-term economic growth. Additionally, our research does not delve into potential moderating or mediating effects of external factors, leaving room for future investigations to uncover the intricacies of these relationships. As we conclude, this study offers valuable insights into the factors influencing economic growth, intentionally refraining from addressing all possible questions. Future research endeavors could explore the dynamics of innovation in greater detail, examining its specific pathways and interactions within the broader context of technological investments and educational enhancements. While acknowledging the limitations inherent in our study, including the focus on specific variables, the absence of exploration into moderating or mediating effects, the temporal scope, and the context specificity of the research, our study provides valuable insights and lays the groundwork for future research to explore the complexities of economic growth further.

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