Article

Measuring and Analyzing the Impact of ICT Applications on GDP using ARDL Methodology: Iraq Case Study

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Abstract: The fourth digital revolution is one of the most prominent events of the current century. One of the most prominent manifestations of this revolution is the progress made in ICT applications. ICT has a direct impact on human life, and the current study aims to clarify what ICT is by studying and analyzing some applications directly related to ICT and its impact on the composition of Iraq's GDP during the period. (2010-2022), as the study relied on a time-series analysis of ICT components (Number of personal computers used per 100 people, Internet usage density per 100 people, and finally number of mobile and wireless telephone lines activated). The study examined the time series of GDP at constant prices for the period in question. The study used the methodology of slowing down time gaps. (ARDL) to analyze the effects of ICT applications on the composition of GDP. The study showed a long-term moral impact relationship between the number of mobile and wireless lines and GDP. Between the Internet intensity index per 100 people and GDP. In the short term, measurement and analysis results showed that the independent variable (GDP) was only affected by the variable number of personal computers per 100 people and the effect was negative according to the results.

1. Introduction

Increased interest in Information and Communication Technology (ICT), especially after the launch of the fourth technology revolution associated with artificial intelligence and its applications, perhaps one of the most important reasons for interest in this field of science is the positive effects that ICT has had in improving the efficiency of production and performance in projects [1], [2]. Creating positive opportunities, especially for developing countries, to provide adequate land for sustainable development plans. It is worth noting that the tremendous development in the information and technical aspect has created a kind of competition at the international level both at the level of developing and developed countries [3], [4], [5]. Especially because AI-related applications changed a lot of economic and social concepts on the one hand, On the other hand, the accelerated development of ICT has created a competitive race between countries to possess modern technologies in the field of ICT or telecommunications, creating a kind of technological inequality between these countries that is reflected in GDP growth rates and creating what is called in the technological literature the digital divide between countries. To achieve the objectives of this study and verify the hypothesis of the study, the study was divided into three main investigators. The first examined the methodology of the study. The second examined the concept of ICT, the economic implications, and the explanatory theories of

ICT's relationship to economic growth. The third and final research examined the measurement of the ICT relationship through some relevant applications and changes in GDP using the "ARDL" methodology, to reach conclusions and recommendations [6].

2. Materials and Methods

2.1. Objective of the study

The current study aims to clarify the concept of ICT to study the expected effects of the use of ICT applications and to study and analyze their impact on economic activity by influencing GDP levels. Disclosure of whether there is a correlation between the significant development of information, technical, and communication applications and Iraq's GDP levels through the use of the econometrics methodology.

2.2. The importance of study

Due to the lack of studies showing the relationship between the prevalence of ICT applications and the composition of Iraq's gross domestic product (GDP), the current study attempts to link the use of ICT applications to the reflection in GDP composition rates, especially since ICT-related applications have shown an imperative in the present era as AI systems develop (AIS). The evolution of global economic systems in both developing and advanced countries has become partly or partly linked to the expansion of ICT applications, the one hand. On the other hand, the development of these applications and their contribution to the formation of GDP at least time, cost, and effort.

2.3. Study problem

Because of the significant development of the technical information and communication aspect at the international level, and through field observation and access to official government data, the researcher found that there are several problems related to the current study which can be summarized by the following questions:

1) What is the reality of Iraq's ICT infrastructure?
2) Does Iraq have an effective national strategy to develop the ICT sector?
3) How does the prevalence of ICT applications affect GDP?

2.4. Study hypothesis

The study begins with the following hypothesis: There is no moral correlation between the widespread use of ICT applications and Iraq's GDP composition rates.

2.5. Spatial and temporal scope of the study

1) Spatial scope: Republic of Iraq
2) Time range: The study will rely on time series data (2010-2022)

2.6. Previous studies

1) Study "Ahmad Mustafa Radwan" and "Issam Ahmad al-Badri", published in the Scientific Journal of Research for Commercial Research, Issue III, Part I, 2023, entitled (The impact of digital transformation on macroeconomic variables), The study aimed to investigate the application of digital transformation to macroeconomic variables. Digital transformation has many positive effects on macroeconomic variables provided that education and learning systems are changed. Providing new skills, and future human cadres capable of achieving excellence in digital work and social well-being.

2) The study "Zubair Belhouchat" and "Mohammed Rekhaili", published in the Journal of Humanities and Social Sciences, vol. 7, No. 3, 2021, where the two researchers addressed in their tagged study (The Information Society, Arab Knowledge, and the digital divide) highlighted the challenges facing Arab countries' societies in an era of globalization and economic, cultural and social openness, especially those related to the development and use of ICT systems. The two researchers concluded that the widening digital divide between Arab countries and the developed world had adversely affected the development of Arab countries' economies. The study recommended the need to consolidate Arab countries' efforts to overcome that digital divide, especially since Arab countries have a competitive advantage in human, material, and financial resources [7].

3) Study "Basim Ghadir" and "Qusay Ali", published in the Journal of the University of Tishrin Research and Scientific Studies - Economic and Legal Sciences Series, vol. 40, No. 5, 2018, entitled (Impact of ICT on Syria's economic growth, statistical analysis for 1995-2012) In this study, time chains were used from 1995 to 2012, and the study found a short-term negative moral correlation between economic growth and the technology index. (Info density) (representing the country's ICT and human capital balance) While the relationship was positive and moral in the long run.

4) Study "Rajah Rasiah", published in the International Journal of Internet and Enterprise Management, Vol. 4, No.3, 2006, entitled " (Information and Communication technology and GDP per capita), The study addressed three key hypotheses regarding the link between GDP per capita growth and ICT. The first assumption is that GDP growth predates ICT growth, The second assumption is that the relationship between GDP growth and ICT will be strong and positive. The third assumption is that ICT's economic impact on GDP per capita will rise over time. After analyzing the data between 1995 and 2000, the study found results supporting the three assumptions. The study also recommended increased government support for the ICT sector to increase ICT's positive impact on GDP per capita [8].

5) The study "Jae-pyo Hong", published in Technical Forecasting and Social Change, Vol 116, 2017, as the study used a methodology Granger Causality tests the relationship between investment in research and development and the economic growth of the ICT industry, it found results in this regard, most notably, the existence of a two-way causal link between ICT investment and economic growth. The results also showed that private investment in ICT-related R&D has a stronger relationship with economic Nu than with public investment.

3. Results and Discussion

3.1. ICT sector in Iraq realistic look

Technological advances in the field of information and communications certainly have economic, social, cultural, and political implications. These effects vary depending on the adoption of each country's ICT concepts. Before entering into a conception of the reality of ICT in Iraq during the study period, some concepts related to ICTs must initially be clarified.

3.1.1. ICT concept

There are many ICT concepts, known by "Kathleen Knoll" from the University of Texas. The set of technical tools that facilitate the methods of communication between customers within the single system and that give greater flexibility to functioning [9], another

IT concept is knowledge and application of products, processes, methods, tools, and systems that contribute to the production of goods and services by investing in people's knowledge accumulation [10], and can be defined as use of technical applications and data in productive processes to contribute to improving the performance efficiency and productivity of workers in different sectors [11].

3.1.2. Analysis of the structure of Iraq's ICT sector

The fourth digital revolution has affected social, economic, cultural, and even political life. The tremendous development in the field of ICT and related applications has affected in one way or another the welfare levels of individuals and countries. By influencing different economic sectors, especially those that directly affect human life, one of the most significant results of progress in the field of ICT is that the sprawling world has become a small village. Progress in the field of telecommunications and the Internet, the emergence of tablets, the development of software applications, and the development of knowledge, especially in the field of ICT, have had a significant impact on the development of economic, social, human, and cultural development rates. This is because ICT applications have the advantage of distinguishing them from traditional means of communication, being transnational in political, cultural, and economic terms for all States.

In Iraq, successive governments since the political regime's change in 2003 have tried to pay attention to this pivotal and important sector. The Ministry of Planning of Iraq through the Central Statistical Agency Powell conducted an ICT survey in 2008. In 2019, the Ministry also conducted a survey in which it attempted to identify indicators of ICT activity for families and individuals. The last activity carried out by the Ministry was in 2022 through an electronic form approved for the first time in cooperation with the Directorate of Transport and Communications Statistics, which included all individuals who are older than 5 years male and female and all Iraqi governorates in addition to the governorates of the Kurdistan Region. It is worth mentioning that all the surveys mentioned relied on key indicators as well as sub-indicators of ICT activity. One of the main indicators is the internet intensity index per 100 people, miscellaneous computer intensity indicator per 100 people, number of mobile and wireless telephone lines ICT applications ", which are the same indicators that the current study will adopt to measure the relationship between ICT applications and changes in GDP.

The table shows the main ICT indicators at the national level:

Table 1. Key indicators of ICT activity in Iraq for the period 2010-2022

Years	Set up mobile and wireless telephone lines	Usage intensity of personal computers per 100 people	Number of Internet users per 100 people
2010	33772908	5.6	2.8
2011	34330211	5	3.4
2012	37896772	5.1	4.2
2013	35510331	5.3	5.3
2014	35846824	5.8	5.9
2015	33470916	4.3	6
2016	34957526	5.2	6.2

2017	40001723	6.2	6.6
2018	39150741	6.7	7.4
2019	39671125	5.8	7.7
2020	39963490	6.9	8.1
2021	40727153	8.6	8.4
2022	44146973	8.0	9.2

Preparation of researcher based on data:

- Communications and Mail Report 2019, n.d.

- (Ministry of Planning, n.d.) and (Statistics, n.d.)

The following figure (Figure 1, Figure 2) illustrates the development of ICT indicators in Iraq during the study period:
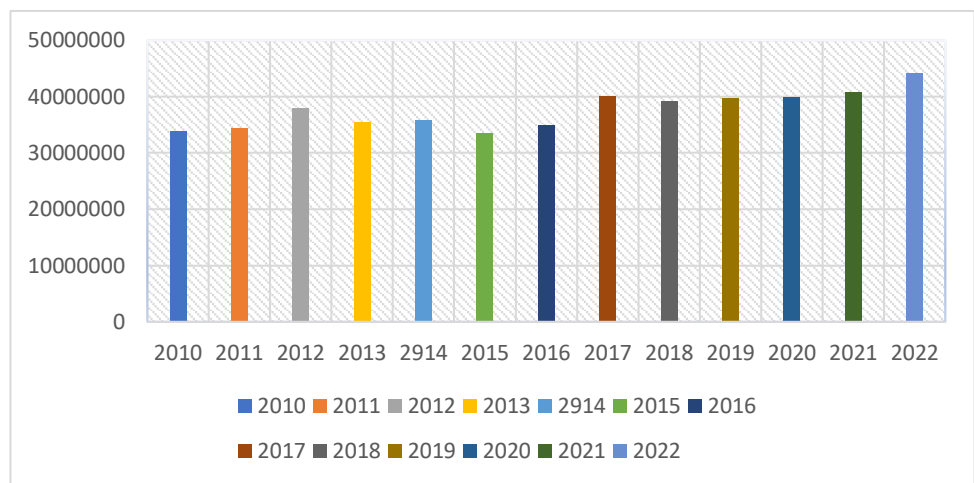

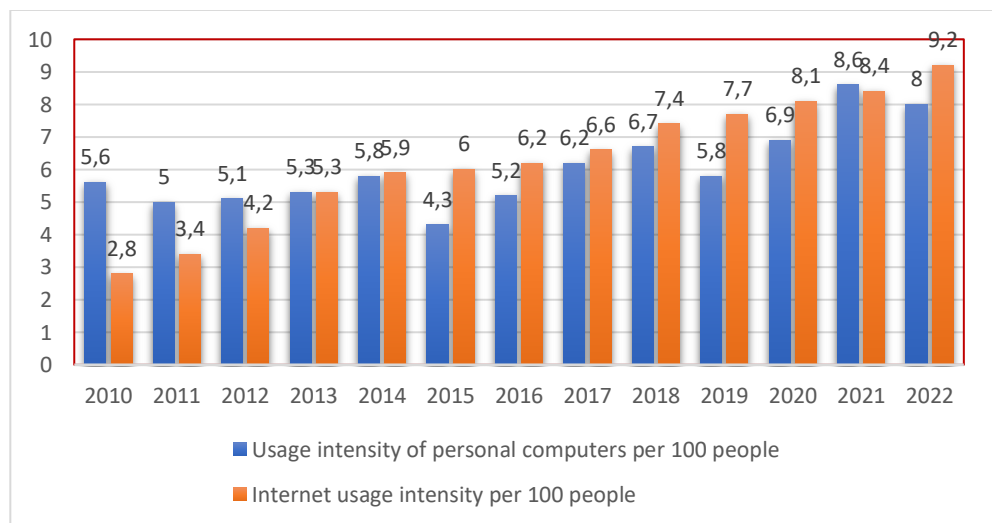**Figure 1**. Preparation of mobile and wireless telephone lines for the period (2010-2022)

Figure 2. Intensity of use of personal computers and internet per 100 persons for the period (2010-2022)

From Table 1 and Figure (1, 2) that ICT application indicators have evolved during the period (2010-2022), this confirms the Iraqi citizen's interest in acquiring and using ICT-

related applications, noting that the number of mobile and wireless phone users has increased from (33772908) million lines in 2010 to (44146973) one million lines in 2022, and the intensity of Internet usage per 100 people has increased from (2.8) in 2010 to (9.2), this is due to the intensity of the use of personal computers per 100 people as it increases from 5.6 In 2010 to 8.0 in 2022, the Iraqi Government recognized the importance of the ICT sector in achieving economic, social and cultural sustainability through its implications for the composition of GDP.

3.2. Econometrics application and data analysis

3.2.1. Model classification

To prove or negate the study's hypothesis, the study will use the self-degradation methodology for distributed slowing (ARDL). The es on official data obtained from official Iraqi government sources. Before starting with the estimate, the model to be adored by the study will have to be characterized as follows:

$$ln\ GDP = \alpha_0 + \alpha_1\ lnX1 + \alpha_2\ lnX2 + \alpha_3\ lnX3 + ln\epsilon i$$

Where:

GDP = GDP at constant prices (ID)

$\alpha 0$ = Fixed limit

X1 = Number of mobile and wireless telephone lines

X2 = The intensity of using personal computers per 100 people

X3 = Internet usage density per 100 people

ϵi = Random error

It is expected that increasing population activity in their use of ICT applications will leave a positive impact on GDP, so the positive signal for all model variables is shown.

3.2.2. Model descriptive statistics (natural distribution test)

Normal tests have been tested for the natural distribution of model data. The results are as follows:

Table 2. Natural distribution of model variables

	LOGGDP	LNX1	LNX2	LNX3
Mean	8.266603	7.574277	0.773095	0.772260
Median	8.290930	7.578602	0.763428	0.792392
Maximum	8.346629	7.644901	0.934498	0.963788
Minimum	8.122828	7.524668	0.633468	0.447158
Std. Dev.	0.068836	0.037276	0.084748	0.155899
Skewness	-0.894235	0.224962	0.443352	-0.827643
Kurtosis	2.710106	1.969502	2.513771	2.677282
Jarque-Bera	1.778109	0.684860	0.553942	1.540563
Probability	0.411044	0.710043	0.758076	0.462883
Sum	107.4658	98.46560	10.05024	10.03938
Sum Sq. Dev.	0.056860	0.016674	0.086186	0.291653
Observations	13	13	13	13

Preparation of the researcher based on the results of the Eviews12.

Table 2 notes that all model variables track natural distribution because the Probability value is greater than 5%. The following graphic shows the normal distribution of model variables:
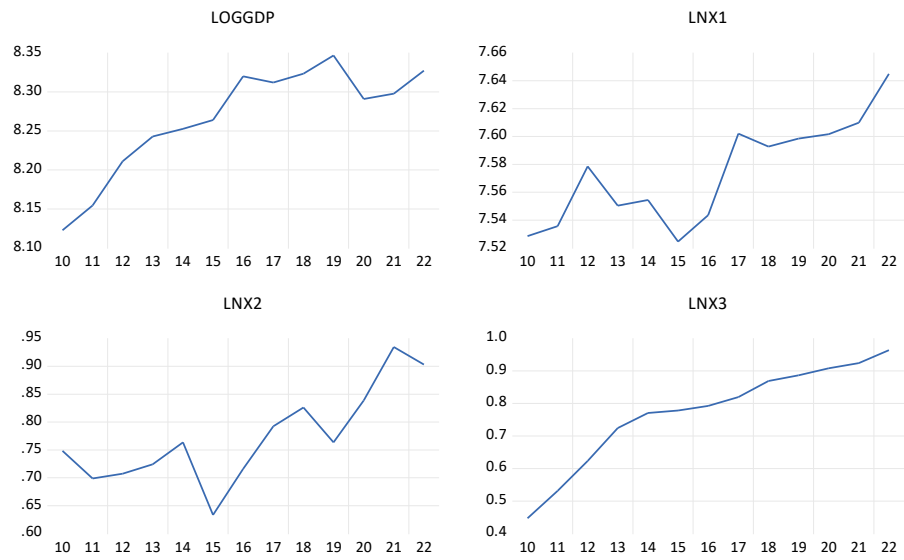

Figure 3. Natural distribution of model variables

3.2.3. Stable template series test for model variables

There are many statistical methods to test the stability of time series including the Autocorrelation Function, Q Statistical Method, Box-Pierce Method, and Dickie-Fuller Expanded Test (ADF) and Philips-Perron test, the study will depend on the test (Philips-Perron) to detect the stability of the time chains used in the proposed model and the reason for resorting to this test is the shortness of the time chain, which included (13) views only.

Table 3. Stable test results time series

	Philips-Perron Test			
Variables	**Level**		**First difference**	
	Trend & Constant	**Constant**	**Trend & Constant**	**Constant**
Log GDP **Prob.**	- 2.011512 (0.5376)	5.730702 (0.0008)	----	----
Ln X1 **Prob.**	- 2.206206 (0.4451)	0.665882 (0.8193)	- 4.842401 (0.0146)	----

Ln X2 **Prob.**	- 3.589867 (0.0755)	0.875289 (0.7588)	- 7.009828 (0.0010)	----
Ln X3 **Prob.**	-5.891955 (0.0030)	----	----	----

Note from the previous table that variable (ln GDP) is Stable at the level and with the clip, the two variables (ln X1, ln X2) settled after taking the first discrepancies, and with the clip and the time direction, either the variable (ln X3) has stabilized at the level with the clip and time direction, and since the model variables have stabilized at the (I_0) and (I_1) ARDL methodology can be used to estimate the model.

3.2.4. Test slowing periods using the standard (Akaike)

To ascertain that the variables are not self-related and fixed, the AIC Information Criteria Akaike rule has been used, with a maximum of two slowdowns for the dependent variable and one slowdown for the autonomous variables.
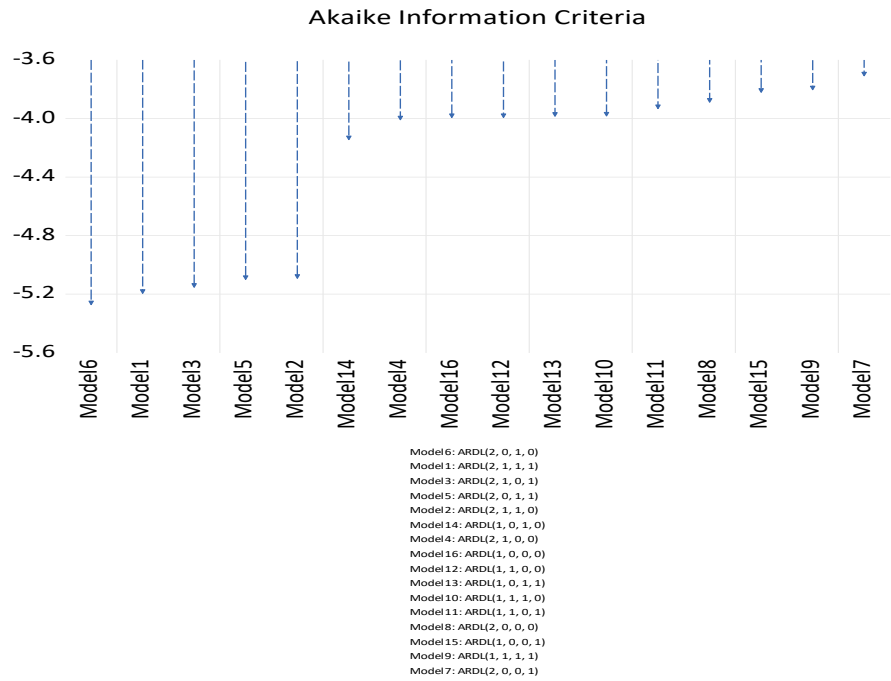
Figure 4. Slowing periods for study variables

From the comparison of the corresponding AIC values the ARDL (2,0,0,1) model was selected as shown in the above figure.

To test for a long-term balance between model variables and GDP variables, the study will use the Bounds Test method. This test is based on the nihilistic hypothesis that "there is no long-term balance between model variables" and the table that shows the results reached:

Table 4. Border test results

F-Bounds Test		Null Hypothesis: No levels of relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	5.571413	10%	3.47	4.45
k	3	5%	4.01	5.07
		2.5%	4.52	5.62
		1%	5.17	6.36

The previous table shows that the value of the statistic (F) exceeded the upper and lower limits established by Pesaran et al. (2001) [12], reaching (5.571413) and at morale levels of 10%, 5%), thus rejecting the imposition of nowhere and accepting the alternative imposition of (long-term balance between model variables).

3.2.5. Diagnostic tests to detect the quality of the estimated model

According to the ARDL methodology, it is assumed that all OLS method assumptions are valued, including that the model errors follow natural distribution, are not biased, have less variation, and are consistent. To reveal the extent to which these assumptions are achieved, the study follows a set of diagnostic tests:

a) Normality test

There are a range of tests that reveal the natural distribution of random errors such as the Kurtosis test, the Skewness test, and the Jarque-Berra test. Perhaps the last is the most famous test, which the study will rely on to test the (H_0) hypothesis that the protector of the estimated regression equation is naturally distributed.

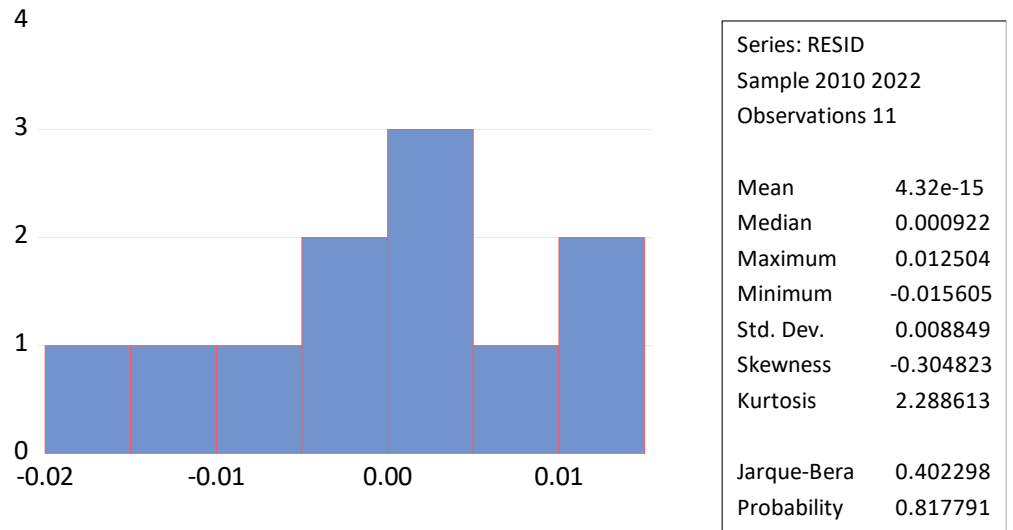| Series: RESID	
Sample 2010 2022	
Observations 11	
Mean	4.32e-15
Median	0.000922
Maximum	0.012504
Minimum	-0.015605
Std. Dev.	0.008849
Skewness	-0.304823
Kurtosis	2.288613
Jarque-Bera	0.402298
Probability	0.817791

Figure 5. Natural distribution test for estimated model protector

From the Figure 5, it is observed that the probability is greater than 5%, and therefore the retention follows the normal distribution.

b) Autocorrelation test

The Durbin-Watson (D.W) test is one of the most famous tests to detect serial association, and also a test (Durbin-h Test) H-Statistic, Test (LM-Test) Breusch Goldfrey Serial Correlation, In most standard studies the test is relied upon (D.W) is famous for detecting the existence of a self-correlation problem but in the current study model is considered invalid as the affiliate variable added its slowed values as an independent variable in the regression model, so the LM test proposed by Breusch Goldfrey, which provides for the imposition of nowhere in it (the absence of a serial self-association between the values of the retention), and the judge's alternative imposition (the existence of a serial link to the discretion protector).

Table 5. Breusch-Godfrey serial correlation LM test

Breusch-Godfrey Serial Correlation LM Test:			
Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	4.323171	Prob. F (2,1)	0.3220
Obs*R-squared	9.859671	Prob. Chi-Square (2)	0.0072

From the results of the previous test, we refuse to impose nowhere, i.e. no subjective correlation between the protector of the regression model being the probability value of the F test greater than 5%.

c) Homoscedasticity test

Many tests reveal the problem of asymmetry, and the current study will rely on the ARCH-Test test to test the imposition of inequality (constant indiscriminate error limit variation in the estimated regression model), versus the alternative imposition of variability.

Table 6. Heteroskedasticity test: ARCH

Heteroskedasticity Test: ARCH			
F-statistic	0.616529	Prob. F (1,8)	0.4550
Obs*R-squared	0.715518	Prob. Chi-Square (1)	0.3976

From the test results the imposition of nowhere is accepted, that the probability value of a staple (F) is greater than (5%) i.e. the contrast is constant.

The results of previous diagnostic tests show that the proposed model of the study has a standard high quality, so the joint integration model will be estimated for both long and short generations.

3.2.6. Estimate the Co-integration model in the short and long term

The error correction model is based on the assumption that there are two forms of relationships between changes in GDP as a subordinate variable and changes in ICT indicators as separate variables as long-term relationships are measured by the level of model variables. While short-term relationships are measured by changes between them during each period, to ascertain a long-term balance between the proposed model variables, the study resorted to a joint integration test.

Table 7. Estimate error correction model according to ARDL methodology

ECM Regression				
Case 5: Unrestricted Constant and Unrestricted Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-11.26547	1.697251	-6.637481	0.0070
@TREND	-0.044900	0.005978	-7.511001	0.0049
D(LOGGDP(-1))	-1.136103	0.183515	-6.190791	0.0085
D(LNX2)	-0.996037	0.147899	-6.734559	0.0067
CointEq(-1)*	-1.535824	0.230045	-6.676174	0.0069

Levels Equation				
Case 5: Unrestricted Constant and Unrestricted Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNX1	2.044578	0.483706	4.226904	0.0242
LNX2	-1.146710	0.202239	-5.670073	0.0109
LNX3	1.483127	0.278036	5.334292	0.0129

3.2.7. Structural stability test for model transactions

To ensure that the estimated model is free of any structural changes, the structural stability of the model's transactions is tested through two tests in which the structural stability of the estimated model's short- and long-term transactions is tested. The first test is the cumulative total of the protectors. (CUSUM) The second test is the total test of cumulative retention boxes (CUSUM of Squares)*, these tests are based on two hypotheses, imposing nowhere (H_0) structural instability of estimated parameters and alternative imposition (H_1) that structurally estimated parameters are stable, so that the graph of tests within critical boundaries falls at a 5% morale level, zero imposition is rejected and the estimated parameters are structurally stable.
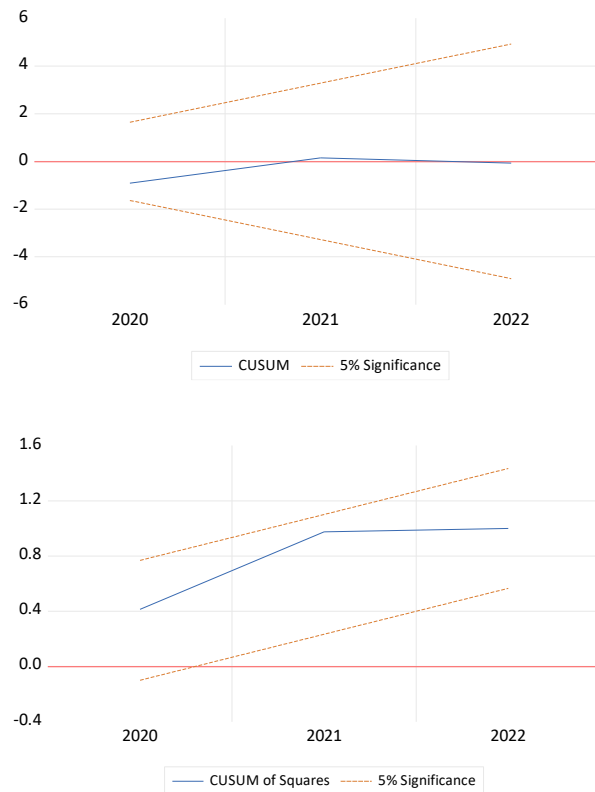

Figure 6. Cumulative total test for parcels and bouquet boxes

From Figure 6, it is clear that the cumulative total of the protectors and the oblique squares lies within the boundaries of the critical area, confirming the stability of the estimated model at a morale level of 5%, so it can be said that there is consistency and stability between the short- and long-term results of the estimated model [13].

After confirmation of long-term balance as shown in Table 4, Table 7 shows the results of the joint integration, as the top of the table represents the estimation of the short-term relationship. The bottom of the table is the form of the long-term relationship. The results of the estimation of the long-term relationship show that the variable of mobile and wireless lines is statistically moral at a moral level. (5%), and has a positive impact on the GDP composition rate that is, increasing the number of subscribers to mobile and wireless telephone lines by (1%) Leads to an increase in GDP composition rates by (2.04%) per annum approx. The variable usage intensity of personal computers per 100 people has had a negative impact (-1.14%) on the composition of GDP and was statistically moral at a moral level (5%) This may be due to the growing computer illiteracy of the Iraqi public and the

lack of expansion of users of personal computers despite being one of the important applications of ICT. The Internet intensity variable per 100 people has come in morally and positively in GDP composition rates, increasing the variable by (1%) and increasing GDP composition by 1.48% This underscores the importance of widespread Internet use in economic sectors.

At the top of the Table 7, error correction flexibilities are shown, and the estimated results show that the personal computer intensity index per 100 people is statistically significant at a morale level (5%). The personal computer intensity indicator for every 100 people (X2) was negative in the sense that an increase in the value of the index by (1%) in the short term would result in a decrease in the composition of GDP by (1.13%) In the short term, other variables have no apparent impact on GDP in the short term.

In the light of the results shown in Table 7, note the morale of the error correction limit slowing factor at a moral level (1%) The purpose of the slowing factor of the error correction limit is to identify the slowness or speed of the return of the estimated model variables to the state of equilibrium. The morale of the error correction limit factor indicates a long-term balance relationship. It is necessary to limit its value between (0.1) to not falling into the problem of false regression. *This confirms the existence of a long-term balance relationship [14]

From the foregoing in the theoretical and applied framework of the study it can be emphasized that the study's hypothesis has not been achieved but the standard analysis has shown a moral correlation between ICT indicators and changes in GDP varying between the short and long term. The benchmark analysis showed a negative correlation between the personal computer intensity index per 100 people and the short-term composition of GDP and the unaffected GDP by other indicators. The benchmark analysis also showed that the relationship between ICT indicators and the long-term composition of GDP other than the second indicator (X2) is evolving.

4. Conclusion and Recommendation

4.1. Conclusion

1) The results of Table 7 show that the personal computer intensity index per 100 people had a negative impact on the composition of GDP in the short and long term. This is due to the researcher's belief that the widespread computer illiteracy in Iraqi society and the use of personal computers in areas beyond the field of investment and economic growth, the non-use of this important application of information technology and the lack of interest in this important and vital specialization by the Iraqi Government led to that result.

2) Table 7 results show that GDP has not been affected by the indicators of the number of mobile and wireless lines and the intensity of Internet use per 100 people in the short term. This is due to objective reasons indicating that these indicators have a clear impact on the composition of GDP in the long term.

3) The results of the benchmark analysis in the same table indicated that the number of mobile and wireless lines is statistically morale and affects GDP by (2.04%) in the long term.

4) The Internet intensity index per 100 people was statistically moral and influenced GDP by 1.48% in the long term.

4.2. Recommendation

Among the previous findings, the study found a number of recommendations, most notably:

1) The need to accelerate digital transformation in diverse economic activities, especially those that have a direct and influential impact on the composition of GDP, and to urge the Iraqi Government through the Ministry of Communications as the sectoral entity to build a national strategy for the development of the ICT sector.

2) The need to introduce ICT curricula into university studies as a preliminary phase for the dissemination of computer culture and ICT-related science that has an impact on the composition of GDP.

3) The need for legislation mandating the use of ICT applications in productive sectors, especially those directly affecting the composition of GDP, to ensure high rates of economic growth.

4) The need to engage the private sector by encouraging the creation of technological incubators and encouraging investment in the ICT sectors to ensure an increase in the composition of GDP and increased economic growth rates.

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