ANALYTICAL PREDICTION MODEL FOR THE POTENTIAL ECONOMIC IMPACT OF ICTS (2000-2021): EGYPT CASE STUDY

Author[1], Author[2]

Mustafa ALMAHDI, School of Management of Technology, Nile University, Giza, Egypt

Dr. Mohamed Sayed Abed, Business School, Nile University, Giza, Egypt

Abstract

Ordinary Least Squares (OLS) regression model has been employed to analyze and investigate the relationship between the dependent variable (GDP per capita) and the independent variables (mobile and fixed broadband subscriptions, government expenditure on ICTs, mobile broadband capable device penetration, ICTs regulatory tracker, population, ICT capital, and labor) and to develop a prediction model to measure the economic impact of ICTs in Egypt from 2000 to 2021. The study adopted Augmented Dickey-Fuller (ADF) t-statistic and cointegration Johansen's maximum eigenvalue tests to check for presence of unit roots in the dataset variables. The eestimation results show that a 10-percentage increase in the subscriptions of fixed broadband and mobile broadband and capital ICTs investment, GDP per capita increase by 0.3268%, 0.064%, and 0.3535%, respectively in Egypt. The empirical results of the cointegrated dataset using STATA software resulted in a high R-squared value indicating that the model explains a significant amount of the variability in GDP per capita. In addition, the results showed that the main OLS model is significant, valid and reliable and that the data tools used for the study are 84.67% reliable and can be used over time.

Keyword: Broadband Technologies, Economic growth, ICTs, GDP per capita and Ordinary Least Squares (OLS) regression

---

1. INTRODUCTION

The rapid development and widely spread of Information and Communication Technology (ICT) is now clearly witnessed and its impact on economic growth and development in both the developed and developing countries has been increasingly emerged during the past three decades. That rapid advancement in ICT and its huge impact on socioeconomic development have attracted several academic research and studies in the field.

Nearly 60% of Egyptian homes have Internet connection this year [1]. Chart (1.1) below shows that in 2020, there were 7.57 fixed broadband subscribers and 59.34 mobile broadband subscriptions for every 100,000 people. The number of people subscribing to mobile broadband has been steadily growing over the last several years, with estimates placing the rise at anywhere from 1.5 to 5.4 subscribers per 100 residents between 2015 and 2019. Slower growth or a minor decline in fixed broadband penetration was seen between 2019 and 2020. By the end of the second quarter of 2020, National Telecommunications Regulatory Authority (NTRA), Egypt's Information and

Communications Technologies (ICTs) regulator had announced that Egypt had 7.99 million fixed broadband users and 45.71 million mobile broadband subscribers.

The International Telecommunications Union (ITU)'s Global Symposium for Regulators (GSR)-21 Best Practice Guidelines [2] recommend that governments "design and implement demand creation for broadband services and digital literacy programs, including with focus on women and girls, people with disabilities, and marginalized groups," which is consistent with the goal of expanding access to the internet for all.

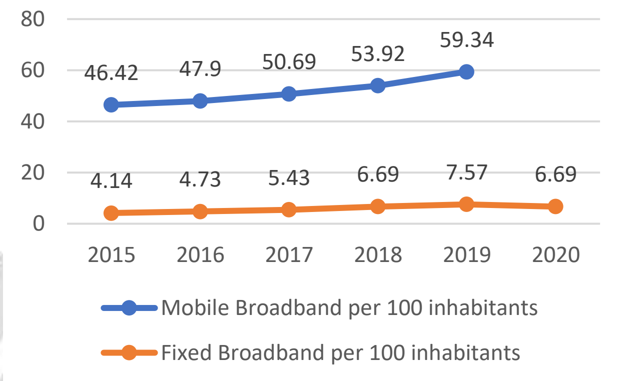

Chart-1.1: Mobile and fixed broadband penetration rates in Egypt (2000-2021)

Source: ITU ICT Eye

The ICT Regulatory Tracker was created by the ITU about ten years ago as an evidence-based tool to assist decision-makers and regulators in keeping up with the ever-changing landscape of ICT regulation.

With the use of quantitative and qualitative data, the Tracker can spot shifts in the ICT regulatory environment, paving the way for benchmarking and the identification of trends in ICT legal and regulatory frameworks.

ITU's ICT Regulatory Tracker 2020 classifies Egypt as a Generation 4 (G4) country. Through integrated regulation driven by social and economic objectives, a G4 nation paves the way for investment, innovation, and access under the generations of regulation model. In these nations, the ICT industry has progressed to a level of advanced liberalization, and there is a distinct regulatory body with decision-making autonomy.

Similarly, to the bulk of the Arab states evaluated, Egypt scored fifth regionally and was categorized as having attained the "transitional" level in the ITU's 2021 G5 Benchmark a year later. Due in large part to its strong showing in Pillar III, the Digital Development Toolbox, Egypt's economy is among the highest scoring among the transitioning Arab States.

Egypt Vision 2030 [3] sets out national economic, social, and environmental development priorities. The plan aims to increase GDP per capita in order to reach high-middle-income country status, reduce poverty and contribute to food and nutrition security; to protect vulnerable and needy people by enhancing the efficiency and scope of the social protection and subsidy systems, reducing societal, gender and generational gaps and achieving a balanced geographical distribution of services; and to achieve the efficient management of and water and enhanced resilience to climate-related shocks for sustainable food production.

Egypt is undergoing unprecedented developments in the ICT sector, that are particularly accelerated due to the COVID-19 pandemic. As part of the country's digital transformation strategy, the Egyptian government has launched the 'Digital Egypt' initiative [4] which aims to turn towards knowledge–based economy strengthened by a young tech-savvy population, growing investment in the ICT sector and close engagement with the private sector. Egypt's economy continues to be characterized by an increasing growth trajectory in gross domestic product and growing energy consumption.

In recent years, there has been a rise in the study of how Telecom. /ICTs affect economic and social growth in recent years. Services and applications enabled by ICTs have seen extensive growth in recent years. As a result of various ICTs indicators, such as the generations of developing technologies like broadband technologies and the regulatory tracker, it is now possible to gauge the influence or contribution of ICTs on economic growth. There is a pressing need for further in-depth research on these impacts in Egypt. In addition, the information and communication technologies (ICTs) sector aspire to meet the rising need for massive amounts of data transmission to facilitate the transition to smart societies and a knowledge-based economy. Researchers, especially economists, have therefore begun investigating the economic impact of broadband technologies, digitalization, and ICTs regulation to reap the benefits of these advancements. Despite this, numerous studies have been conducted by various researchers to evaluate or predict this contribution, which is represented by the increase or decrease in GDP at a global, regional, or country level considering various ICT indicators and economic factors. However, not a single study has looked at how the development of Egypt's digital infrastructure and the sophistication of its ICTs regulatory environment affects the country's economic growth.

The main issue of this study is that it would like to examine the nature of the impact of digital ICTs technologies and the regulatory metrics at the macroeconomic level. Namely, the study will try to show how fixed, mobile broadband and ICTs regulatory frameworks and its development can contribute to economic growth in the Egypt for which data are available.

1.1 Research problem statement

Not a single study has looked at how the development of Egypt's ICTs digital infrastructure and the sophistication of its ICTs regulatory environment affects the country's economic growth. Specifically, this study will investigate whether the rise of fixed and mobile broadband penetrations, Egypt expenditure on ICTs, mobile broadband capable device penetration and ICTs regulatory tracker is correlated with economic progress in Egypt.

1.2 Research objectives

The main aim of the study is to develop a model to measure the Economic Impact of ICTs in Egypt. The sub objectives of the study are:

- To investigate empirically how various indicators of ICTs impact the economic growth (macroeconomic control variables) in Egypt as measured in GDP per capita.
- To predict the contribution of Fixed Broadband, Mobile Broadband, Expenditure in ICTs, Mobile Broadband Capable device penetration to the GDP in Egypt (measuring the contribution/impact of digital ICTs technologies on the national economy).
- To examine which type of digital ICTs has a maximum magnitude or effect and acts as an important driver for the economic growth of Egypt.

1.3 Hypotheses of the study

- The impact of fixed broadband has a significant positive impact on national GDP growth.
- The impact of mobile broadband has a significant positive impact on national GDP growth.
- The impact of Egypt Government expenditure on ICTs is significant positive impact on national GDP growth.
- The impact of mobile broadband capable device penetration is significant positive impact on national GDP growth.
- Impact of the development of policy and regulatory framework (ICTs Regulatory Index (RI)) is significantly positive.
- The development of policy and regulatory framework (ICTs Regulatory Index (RI)) accelerates digital transformation.

The suggested prediction model provided answers to a wide range of concerns, such as those about the effects of fixed and mobile broadband technologies on the GDP per capita, as well as those concerning the relationship between economic factors such as population, labor and investment in ICTs and GDP per capita. Impact of the country's ICT regulatory environment development on GDP per capita has been addressed.

That is, this current study investigates the nexus relationship between GDP per capita and fixed and mobile broadband penetrations, Egypt expenditure on ICTs, mmobile mbroadband ccapable device penetration and ICTs regulatory tracker. Hence, this study is the first of its kind in the literature to examine the multivariate regression analysis of some ICTs related indicators, ICTs regulatory tracker score and economic growth in Egypt.

The remainder of the paper is organized as follows: In section 2, reviewed related literatures on the study; the sample data, primary as well as secondary data collection methods, data analysis, positivism paradigm, explanatory research design, quantitative research approach methods employed in the study is presented in section 3; the empirical findings and discussion are given in section 4; and lastly section 5 contains the study's conclusions.

2. LITERATURE REVIEW

The socioeconomic development impact of information and communication technology (ICT) has been examined over the past three decades by many authors and researchers using different methodologies, data sources, and different time periods. Some empirical studies have concluded that increasing ICT use can lead to GDP growth, productivity, and employment. Here are some examples for studies conducted globally, in the Arab and Africa regions and during the period (1990 to 2018) because of similar climate and level of ICTs and economic development.

In this section, researcher presented a review of previous studies from three aspects: ICTs broadband technologies impact on GDP; ICTs diffusion and economic growth, relationship between ICTs investments and economic development in Egypt, impact of ICTs technologies on economic growth.

2.1 ICTs broadband technologies impact on GDP

A lot of research has been done in the past two decades to study the relationship linking economic growth, ICTs broadband technologies (fixed broadband and mobile broadband), and ICTs capital and government expenditure. This is because of the critical role that ICTs broadband technologies play in economic growth development. There is numerous research about the relationship linking ICTs broadband technologies and GDP growing to the fact that the relationship between fixed broadband, mobile broadband and GDP have significant policy implications. For example, Moyer, (2012), Fernández-Portillo, (2020) [5], have found a lot of evidence that ICT is important for economic growth concluded that a rise in broadband technologies result in a rise in GDP.

Colecchia and Schreyer, (2002) [6] in their study entitled “ICT Investment and Economic Growth in the OECD countries, compared the impact of ICT investment on economic growth in 9 OECD countries. The study results showed that ICT capital investment contributed between 0.2% and 0.5% points per year to economic growth of OECD countries. For the period from 1995 to 2000, ICT contributed a higher percentage from the preceding period ranging from 0.3% to 0.9% points per year. Results showed that the United States was not the only country that gained benefits from the positive impacts of ICT capital buildup on economic growth. Impacts have obviously been biggest in the United States, and then in Australia, Canada, and Finland, but the countries Germany, Japan, Italy, and France recorded the bottommost contribution of ICT investment impact on economic growth among the nine studied countries. One of the most influential drivers of growth as ICT investment in the study case is preparing appropriate ICT framework conditions and not essentially in ICT sectors itself. Researchers used growth accounting as the most widely used approach to measure the contribution of ICT investment to economic growth.

Nour S. (2002) [7], in her study on “The Use and Economic Impacts of ICT at the Macro-Micro levels in the Arab Gulf Countries” found that at the macro and micro levels the demand for ICT (measured by the use and spending on ICT) is characterized by considerable dynamism over time, i.e., shows a dynamic increasing trend across countries, but an opposite decreasing trend across firms. At the macro level the use/demand for ICT increases with income (measured by GDP per capita) and decreases with price. At the micro level, total spending on ICT increases with firm size (capital and labour) and industry level. At the micro level, found positive correlations between the total spending on ICT, output and profit. At the macro level, spending on ICT as percentage to GDP shows a positive significant correlation with GDP- as an indicator of economic growth - and a positive insignificant correlation with schooling. Therefore, the total spending on ICT shows positive but somewhat inconclusive economic impacts at both micro and macro levels in the Gulf countries. Study used descriptive approach and Ordinary Least Squares regression (OLS) technique.

Pantelis Koutroumpis, (2009) [8], in his study of 15 European countries to examine how the infrastructure of broadband telecommunications penetration affects these countries' economic growth for the period 2003-2006. The consequences of this study show a significant positive relation between broadband investment and GDP, where these percent of effects ranged from 1.04% for Netherlands to 0.57% for Ireland with an average impact of 0.63% for the study sample of 15 European Union (EU) countries. The impact of broadband infrastructure on GDP increases as the investment in broadband infrastructure increases and the highest level of impact was recorded to the Scandinavia countries (Netherlands, Denmark, Finland, and Sweden) with high broadband penetration level more than 20%. The study of Koutroumpis used a macroeconomic production function.

Study conducted by Mohammad Ali MORADI and Meysam KEBRYAEE (2009) [9], who have investigated the relationship between ICT investment and the economic growth in 48 selected members from the Organization of the Islamic Conference (OIC), they have concluded their study that there is a direct positive and important impact between the ICT and GDP, especially for oil-producing countries, the results have confirmed that ICTs has become an important contributor to the growth of the economy in the OIC. Mohammad MORADI and Meysam KEBRYAEE used panel regression with fixed effects panel data to examine the factors affecting economic growth.

Qiang et al., (2009) [10], developed study for ITU about the impact of broadband as an ICT indication on economic growth of 120 countries, mostly developing countries. The adopted model is composed of GDP per capita growth rate for the period 1980-2006, as a dependent variable, GDP per capita in 1980, investment to GDP ratio from 1980 to 2006, primary school enrollment rate, average penetration of broadband in addition to other telecommunication services for developed and developing countries between 1980 and 2006 and dummy variables for Latin America, sub-Saharan and Caribbean countries. The results of this study showed that there is positive impact of ICT investment and broadband on GDP per capita, and the elasticities of these variables are significant. After that other ICT variables were added such as fixed telephone subscriptions and mobile phone subscribers. The results for this study were as follows: (i) If fixed-line penetration rate in countries with low and mid incomes rises by 1%, then the economic growth rises by 0.043%, and 0.073% in high-income countries, (ii) if mobile phone penetration increases by 1%, then the GDP per capita will increase by 0.06% for low and mid income countries, and 0.081% for countries with high income, (iii) if broadband penetration increases by 1%, then GDP per capita will increase by 0.121% for countries with low and mid incomes, and 0.138% for high income countries. Researchers used a cross sectional analysis to examine the impact of various ICTs including fixed broadband on GDP growth and the framework is based on the endogenous growth model (Barro 1991).

In a study of Khelifi (2010) [11] about the relationship between the digital divide and development level, the sample included 17 states during the period 1995-2007. These states are divided into two groups. The first group includes the countries Algeria, Tunisia, Marco, Egypt, Israel, and Jordan of the MENA region. The second group includes the countries Bulgaria, Denmark, Finland, France, Germany, United Kingdom, Sweden, Italy, Holland, Spain, and Slovenia of the EU. The author tried in this study to investigate the relationship between economic growth represented by GDP and the ICT spread indicators. The author used the Internet usage index as it has the greatest impact on economic growth, as well as the digital divide appearing more in the online index. The model was estimated using the generalized squares method applied to the three groups containing MENA region, EU and the third group represents the whole sample. The elasticities of the variables of Internet usage and ICT investment were significant and positive, but the elasticity of human capital was negative and insignificant. However, these elasticities of internet and ICT investment that represent their impact on GDP per capita were more for the European countries than the MENA countries. The results for this study were as follows: (i) If the use of internet rises by 1%, then GDP per capita will rise by 0.026% for the whole group of MENA and European countries, and it rises by 0.27 for EU and 0.07 for MENA countries, (ii) if ICT investment rises by 1%, then the GDP will rise by 0.018% for the whole group, 0.15% for EU and 0.093% for MENA countries. This study concluded that the Internet usage index and ICT capital affect positively economic growth, but it did not take into consideration the rest of the ICT indices such as mobile phone technology that frequent studies illustrated its positive impact on economic growth.

2.2 ICTs diffusion and economic growth

Several research studied ICTs diffusions and economic growth globally, regional and in Egypt. Nair, (2020) [12] stated that since the 1980s, theorists have debated the link between ICT and GDP development, with the premise that technological advancement is a primary driver of GDP expansion.

According to Kallal, (2021) [13], the term "information and communication technology" (ICT) encompasses both computer hardware and software. There has been a widespread uptick in the incorporation of these forms of ICT into a wide range of manufactured access to information and new methods of sharing it are made possible by advances in ICT.

Cheng, (2021) [14] stated that studies on the spread of information and communication technologies have progressed in recent years. Since ICT gives high-performance tools and software to economic sectors, it is widely agreed that it contributes favorably to economic development.

According to Gheraia, (2022) [15], Telecommunications services account for as much as 80% of the value added in the ICT industry in most emerging nations, but this figure is closer to 30% in wealthy Organization for Economic Co-operation and Development (OECD) economies. Mobile phones and data services were the primary sources of income for emerging nations. For instance, “Qatar, Saudi Arabia, and the United Arab Emirates have comparatively low rates because of their large GDP, although Bahrain, Jordan, Morocco, and Tunisia have the highest earnings” and almost all developing nations had a drop in telecommunications earnings between 2010 and 2015, with the biggest drops seen in Jordan, Morocco, Tunisia, Saudi Arabia, and Sudan. Furthermore, in terms of the spread of information and communication technologies, Egypt and Tunisia are ahead of its neighbours.

Zhao, (2022) [16] pointed out that for a close relationship betIen investments in information technology and subsequent increases in worker productivity, and it was found that the rate of growth in IT-heavy sectors is 2% higher than in others.

According to Pradhan, (2019) [17], previous research on the benefits of ICT on economic development in underdeveloped nations has shown varied results. The research focused on emerging nations is still in short supply and there are at least two possible causes for the inconsistent results.

According to Perez-Trujillo, (2020) [18], while there is consensus among studies of established economies about the benefits of ICT dissemination, the research draws parallels betIen developed and developing countries. Researchers argue that a panel method across nations may introduce bias due to large levels of variability, especially when considering structural factors. A third body of research focuses specifically on the problem of ICT dissemination in low-income countries. For 17 MENA nations between 1960 and 2009, the impacts of financial development and ICT dissemination on economic growth Ire analysed and found to be positive. According to Díaz-Roldán, (The authors used a system generalized method of moments (GMM) estimator in a dynamic panel model to demonstrate that ICT (through various proxies) positively affects economic development. Intriguingly, the authors demonstrated that a more advanced ICT infrastructure reinforces the influence of financial development on growth, with such nations only benefiting from financial development until a certain threshold is met in ICT development.

Zhang, (2022) [19] stated that from 2000 to 2012, 49 nations in sub-Saharan Africa Ire investigated to see whether the use of ICT might mitigate the harmful impact of pollution on human development. They found that ICT promotes inclusive human development based on instrumental variable Tobit regressions. Researchers looked examined the impact of ICT on income inequality in 48 African nations between 1996 and 2014, focusing on the banking and financial sector. “The GMM helps them verify that there is a strong correlation between the use of mobile phones and access to formal financial services in these countries. Another research looked at the relationship between CO_2 emissions, total factor productivity (TFP), a proxy for national GDP, and ICT in Tunisia between 1975 and 2014”. Using an autoregressive distributed lag (ARDL) method it was found that ICT has had zero effect on sustainable development and a negligible effect on CO_2 emissions as a proxy for pollution. For 42 nations in sub-Saharan Africa,

According to Myovella, (2020) [20] for developing nations, the effect of ICT on GDP development is still up for debate. We provided a fresh sectorial analysis for a chosen MENA nation which Egypt is part of, adding to the existing body of research on this topic and demonstrating the relevance of my work to the third line of inquiry.

2.3 Impact of ICTs investments on economic development in Egypt

According to Mohamed, (2021) [21] since the 1980s, governments all around the globe, but especially those in developing countries, have recognized ICT as a vital platform for economic progress. There have been many shifts in economic activity all around the world because of the impact of ICT. When supported by adequate infrastructure, ICT has been shown to contribute to societal and economic growth. Study conducted by Mohammad Ali MORADI and Meysam KEBRYAEE (2009) [6], who have investigated the relationship between ICT investment and the economic growth in 48 selected members from the Organization of the Islamic Conference (OIC), they have concluded their study that there is a direct positive and important impact between the ICT and GDP, especially for oil-producing countries, the results have confirmed that ICTs has become an important contributor to the growth of the economy in the OIC. Mohammad MORADI and Meysam KEBRYAEE used panel regression with fixed effects panel data to examine the factors affecting economic growth.

Tsang, F., Yaqub, O., Van Welsum, D., Thompson-Starkey, T., and Chataway, J. (2011) [22] studied the impact of ICT in the Middle East and North Africa (MENA) region. Their analysis was correlational in nature, studying the relationship between fixed internet and mobile broadband subscriptions and Gross National Income (GNI) for Bahrain, Kuwait, Oman, Saudi Arabia, and United Arab Emirates. The authors found that the relationship between the variables evolved over time. For example, in Bahrain between 2000 and 2002, fixed Internet subscriptions increased rapidly while GNI increased only modestly. Between 2003 and 2005, the penetration of fixed Internet subscriptions stagnated while GNI continued to grow, though in 2005–2008, fixed Internet subscriptions per 100 inhabitants increased steadily with GNI.

Magdy Al-Shorbagy (2011) [23] in his study which aimed at measuring the impact of ICTs on growth in 17 Arab countries during the period 2000 to 2009. The study used time series data approach for cross-sectional data (the panel data approach) using three models which are: Pooled Regression Model (PRM), Fixed Effects Model (FEM) and Random Effects Model (REM) and the study concluded that there is a positive and moral impact of information and communication technology on economic growth. This means that the increase in the use of the Internet, fixed and mobile phones led to an increase in the average per capita income of the real GDP, and that to increase the average per capita share of the real GDP, the Arab countries must continue in increasing investment in information and communication technology for its direct and indirect impact on economic growth.

In a study of Al-Omari Al-Haj (2012) [24], study of the impact of ICTs on economic growth, the case of Algeria (1995-2009), the researcher tried to answer the problem “What is the impact of information and communication technology on Economic growth in Algeria? The study concluded that the reform of the telecommunications sector in 2000 by introducing a structural variable concluded that this reform did not has a positive impact on the information society, but it had an impact in general on economic growth, while investment in ICTs contribute significantly to economic growth. Researchers used economic growth models to examine the impact of ICTs.

Katz and Callorda, (2015) [25], according to a structural model developed with Tunisian time series, the authors estimated that 1 % increase in fixed broadband lines results in 0.101 % of GDP growth. According to this coefficient, fixed broadband has contributed annually an average of US$ 225 million to Tunisia’s economic growth between 2008 and 2014. They have also been unable to measure the impact of mobile broadband due to the recent technology diffusion which prevented measuring a real impact.

Salahudinne M. and Gtow J (2016) [26] in their research which was aimed to search for the relationship between the use of the Internet on the economic growth, financial development, and trade openness in 11 South African countries and the study concluded that there is a positive long-term relationship of using the Internet to stimulate growth of the economy in the region. The results of the study also confirmed that the use of the Internet does not affect economic growth during the period (1990 - 2012) only but will have an increasing impact on economic growth in the region in the future during period (2013-2034).

ElShenawi, Nagwa (2016) [27] conducted a study measuring the economic impact of fixed broadband in Egypt. By relying on data between 2002 and 2010, the author built a regression model measuring the impact on per capita GDP growth rate of broadband penetration, investment rate, literacy rate and a dummy variable for the 2008 financial crisis. The results showed that in Egypt a 10-percentage point increase in broadband penetration leads to about one percentage point increase in the growth rate of per capita GDP. However, the study does not provide an indication of the statistical significance of the model results. The study used data panel method to measure the economic impact of fixed broadband in Egypt.

Taha Bin Al Habib (2018) [28], in his study titled “ The Impact of Information and Communication Technology on Economic Growth in developing countries which is a benchmark study during the period (2005-2015) and aimed to measure the impact of ICTs on economic growth in developing countries, the study was based on the independent variables represented by Internet usage, the mobile phone, inflation rate, population growth rate, trade openness, and GDP growth as a dependent variable. The study concluded that the Internet index has a negative and moral effect in the long term, which is evidence of the inverse relationship between it and economic growth variable and the mobile phone variable, had a negative and insignificant effect, meaning that it had no effect on economic growth in the developing countries. The study used the least squares model to estimate the impact of ICTs on economic growth.

Belhoushat Muhammad Al-Amin (2018) [29], in his study which aimed to measure the impact of information and communication technology on economic growth in Arab countries through a benchmark study that included cross-sectional data for 18 Arab countries during 2018, based on the independent variables represented by internet subscribers, mobile phone subscribers per 100 inhabitant, fixed phone subscribers per 100 inhabitant, in addition to economic growth expressed as average per capita of the GDP as a dependent variable, and used statistical analysis technique represented by cluster analysis, the Arab countries were classified into three groups and according to the ICTs index and the Gulf countries were at the fore, and a gradual regression analysis method was used. Mr Belhoushat concluded that the variable rate of Internet subscribers had the only effect on economic growth in the Arab countries. The researchers used the least squares model to estimate the impact of ICTs on economic growth.

Raul Katz and Fernando Callorda (2019) [30], in their ITU study on the economic contribution of broadband, digitization and ICT regulation: Econometric modeling for the Arab States, which was based on methodologies and econometric models used for assessing global effects, the Arab report was focused on the impact of broadband, digital transformation and policy and regulatory frameworks on the growth of markets for digital services in the Arab States. The study provided evidence of the importance of regulatory and institutional variables in driving digital growth, illustrated that broadband technologies and effective ICT regulation can have positive impacts on the development of national economies and prosperity. This landmark regional study of many countries in the Arab State region confirms that an increase of 10 per cent in mobile broadband penetration in the Arab States would yield an increase in 1,81 per cent in GDP per capita. In addition, it suggested that a 10 percent drop in fixed broadband penetration will yield an increase of 0.71 per cent in GDP per capita. Researchers have employed cross-sectional models using administrative units.

As shown above, most the previous studies reflected the main goal to measure the impact of ICT on economic growth represented by GDP per capita and measured in PPP and there are other significant variables that may affect the GDP per capita which most studies didn't take them into consideration. In addition, different measurement/methodological approaches have tried to capture the different aspects of ICTs. These measurements have not been comparable for the most part, leading to a lack of clarity on how ICTs related metrics should be measured.

This part of the research reviewed more than 40 previous studies with focus to recent papers and studies aligned with the time frame for the study (2000-2021) and some available reference models for estimations/prediction of the ICTs contribution or its expected potential impact on the economic growth in the Egypt as well as other countries who have similar climate of Egypt and explore and examine the factors that were not taken into considerations in the recent development in the ICTs sector (mainly the policy and regulations (ICTs regulatory tracker) variable).

3. DATA AND METHODOLOGY

The previous sections served as an introduction to the subject, a discussion of its relevant goals, and a review of past works of literature. This assisted in forming the framework for the current research. The study paradigm, research design, sample strategies used, data collection procedures and methodologies for data interpretation are explained in this section.

3.1 Research questions

- How do various indicators of ICT technologies including Egypt's government expenditure on ICTs, mobile broadband capable device penetration and ICTs regulatory tracker impact the economic growth (macroeconomic control variables) in Egypt proxied by GDP per capita?
- What is the contribution of different digital ICTs technologies to the GDP in Egypt (measuring the contribution/impact of digital ICTs technologies on the national economy)?

- Which type of digital ICTs technologies have a major magnitude or effect or act as an important driver for the economic growth of Egypt?

Many studies have shown that doing any kind of research, along with other motivational initiatives, requires a comprehension of the concepts and theories used in the study. This is why the most important part of a research study has traditionally been research methodology.

Human acts and behaviors should be scientifically tested to prove a technical fact, according to proponents of the positivist research theory. Hence, the current study has adopted a positivism paradigm.

The explanatory research design has been used for the current investigation. The formulation of the causal relationship between the many study variables is necessary for this type of research design. For completing the study's overall needs, a quantitative research approach has been adopted. In the study analysis using quantitative data, this technique has incorporated the inclusion of several data collection methods.

Furthermore, the study has used the primary and secondary methods for collecting and to be presented in a thematic way. The study also used stationary test method (Augmented Dickey-Fuller (ADF) t-statistic test) and cointegration Johansen's maximum eigenvalue test to investigate the linear combinations of variables that are stationary, investigate the short and long-run relationship between all the independent variables and the GDP per capita and simple random sampling method have been used from (ICTs and economic indicators) data.

The choice of technique depended on the nature of the data and the research questions. A regression model using OLS technique and STATA software has been employed to develop a prediction model to measure the economic impact of ICTs in Egypt. In addition, the OLS models used to investigate empirically how various indicators of ICTs impact the economic growth (macroeconomic control variables) in Egypt as measured in GDP per capita, to predict the contribution of Fixed Broadband, Mobile Broadband, Expenditure in ICTs, Mobile Broadband Capable device penetration to the GDP in Egypt (measuring the contribution/impact of digital ICTs technologies on the national economy) and examine which type of digital ICTs has a maximum magnitude or effect and acts as an important driver for the economic growth of Egypt.

To investigate the impact of the ICTs on national GDP per capita of Egypt, the model constructed with one dependent variable and a panel of eight independent variables, and their data sources are primarily from ITU, Global System for Mobile Association (GSMA), the World Bank World Development Indicators (WDI) database which has been collected through standardized survey sent to ITU members every year. Data on GDP per capita are obtained from World Bank’s World Development Indicators (WDI) as primary World Bank collection of development indicators, compiled from officially recognized international sources including Egypt’s national statistical agency and between 2000 and 2021. Other relevant economic indicators such as ICT capital and labor have been gathered from ITU World Telecommunication/ICT Indicators database. The aggregated panel data has been taken on an annual basis to construct a time series model.

Charts, 3.1, 3.2, 3.3 and 3.4 show the respective trend of GDP per capita in Egypt (constant international US$), the subscription of fixed broadband per 100 inhabitant, mobile broadband per 100 inhabitant, overall score of the ICTs regulatory index and government expenditure on ICTs and mobile broadband capable device penetration (penetration of devices capable of attaining broadband access), respectively and for the period under study (2000-2021).

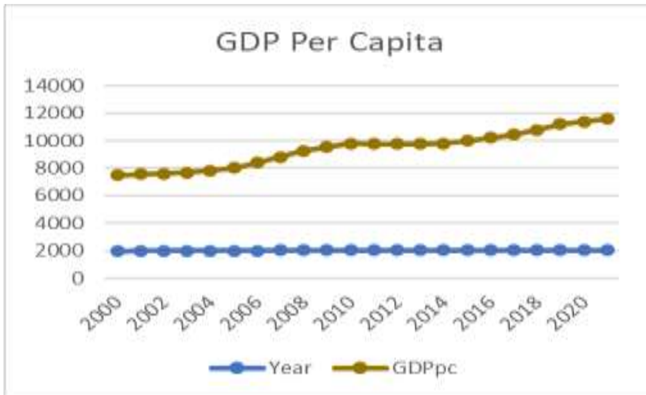

Chart-3.1: Trend of GDP per capita in Egypt (2000-2021)

Source: World Bank

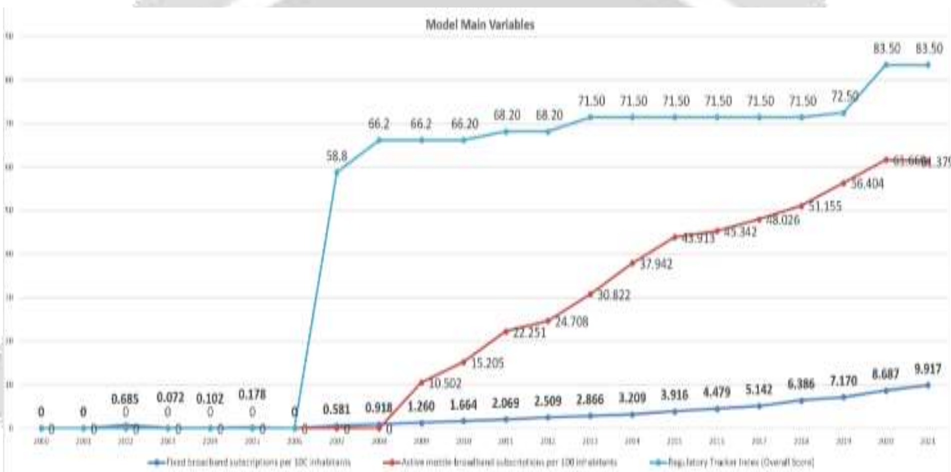

Chart-3.2: Trend the subscription of fixed broadband, mobile broadband, overall score of the ICTs regulatory index

Source: ITU ICT Eye

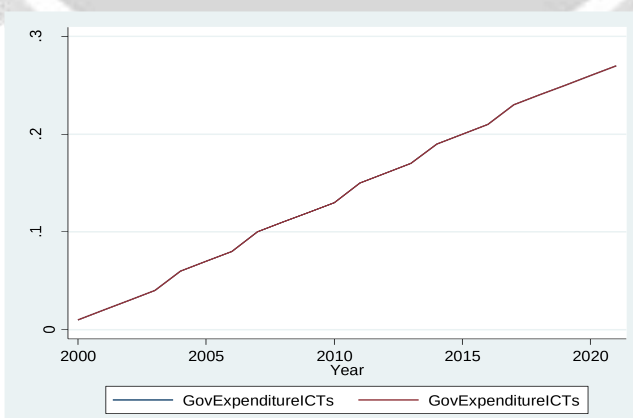

Chart-3.3: Trend of government expenditure on ICTs

Source: ITU ICT Eye

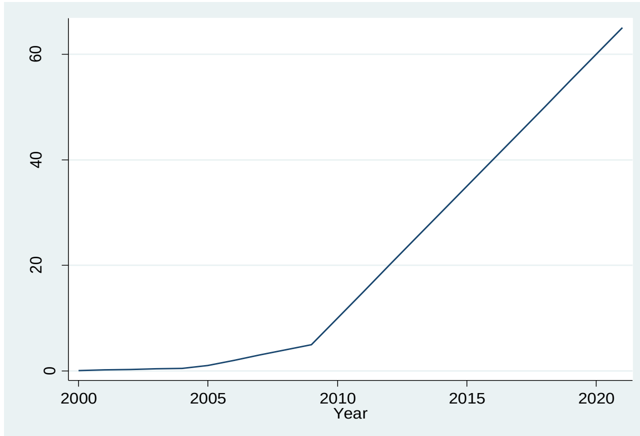

Chart-3.4: Trend of mobile broadband capable device penetration

Source: Global System for Mobile Association (GSMA)

In the following subsections, methodology used in the paper which is based on dataset unit roots, cointegration and OLS regression models have been described. The study used this methodology since it is the most relevant one for the analysis of data time series and to determine and investigate casual relationships between dependent and independent variables.

3.2 Econometric model specifications

This study analyses the relationship between the dependent variable (GDP per capita) and the independent variables (mobile and fixed broadband subscriptions, government expenditure on ICTs, mobile broadband capable device penetration, ICTs regulatory tracker, population, ICT capital, and labor) to form a multivariate framework (multi-regression model) as given in Equation (1). The general model specification is given below:

GDPP= f ((Population, labor, capital, (ICTs broadband technologies fixed and mobile), and regulatory index, Government expenditure on ICTs and Mobile Broadband capable devices) **(1)**

The measures of broadband technologies include fixed and mobile broadband subscriptions per 100 inhabitants as well as impact of the institutional, policy and regulatory factors (Regulatory Index). The GDP factors include the production function developed by Charles Cobb and Paul Douglas which can assist quantifying the effect on ICTs on economic growth. Therefore, equation (1) can be rewritten as:

GDPP =f (K, L, A (FB, MB, RI, GovExpenditureICTs, MB Capable device)) **(2)**

The econometric model for measuring the effect of ICTs on national GDP per capita can be specified as follows and as shown in equation 3:

GDP per capita or GDPpc = $\beta 0 + \beta 1K + \beta 2Pop + \beta 3L + \beta 4GovExpenditureICTs + \beta 5FB + \beta 6MB + \beta 7MB$ Capable device+$\beta 8 * RI + \varepsilon t$ **(3)**

Where is

GDPpc is the GDP per capita: The dependent variable representing the level of economic output per person in a country.

Fixed broadband per 100 inhabitants (FB): The independent variable representing the number of fixed broadband subscriptions per 100 people in Egypt.

Mobile-broadband per 100 inhabitants (MB): The independent variable representing the number of active broadband subscriptions per 100 people in Egypt.

Mobile Broadband Capable device penetration (MB Capable device): mobile devices such as smartphones, TABLEts, and laptops support use of high-speed internet connection that uses cellular networks to provide internet access.

Regulatory Index (RI) = ITU's ICT Regulatory Tracker overall score (regulatory maturity indicator)

Population (Pop): An independent variable, representing the total number of individuals in a given population at a given time.

ICT capital investment (K): An independent variable, representing the ICT capital investment in ICT sector of Egypt.

Egypt Government expenditure on ICTs (GovExpenditureICTs): An independent variable, representing money spent by governments on ICTs such as infrastructure, research and development, training, and other related activities.

Labor (L): The independent variable representing the total number of people employed in ICTs sector of Egypt.

Error term (ε): The error term representing the unobserved factors that affect GDP per capita but are not included in the model.

$\beta0$: The intercept of the regression model, representing the expected value of the dependent variable when all independent variables are equal to zero.

$\beta1$, $\beta2$, $\beta3$, $\beta4$, $\beta5$, $\beta6$, $\beta7$ and $\beta8$ are the coefficients, representing the expected change in dependent variable for a one-unit increase in each independent variable, holding all other independent variables constant.

The research is specfically looking for the following coefficients parameters to be estimated:

$\beta4$: The coefficient representing the effect of Government expenditure on ICTs on GDP per capita.

$\beta5$: The coefficient representing the effect of fixed broadband technology subscriptions on GDP per capita.

$\beta6$: The coefficient representing the effect of mobile broadband technology subscriptions on GDP per capita.

$\beta7$: The coefficient representing the effect of Mobile Broadband Capable device penetration

$\beta8$: The coefficient representing the effect of ICTs regulatory tracker on GDP per capita.

The presence of unit roots in the dataset variables is established using statistical stationary test (Augmented Dickey-Fuller (ADF) t-statistic test) has been performed for all model variables to determine if a time series data is stationary or not. These tests do not impose an autoregressive structure on the error term and results concluded that results, researcher concluded that all the variable in the dataset have no unit root, or all variables are non-stationary.

3.3 Cointegration

The presence of unit-root is a precondition for the cointegration test of Johansen as the dataset have been tested and resulted in non-stationary and in order to have a more reliable and valide model, stationey dataset is required. A cointegration Johansen's maximum eigenvalue method has been used to investigate the existence of cointegration between study variables. Therefore, in such cases it is more efficient to use the Johansen test of cointegration= andnull hypothesis of the Johansen test of cointegration is that all model variables are not cointegrated.

The STATA results showed that the critical value (alpha (0.05)) of all models variables are greater than the trace statistic (p-value) and accordingly rejected the null hypothesis. This implies that the model variables are co-integrated.

The presence of cointegration relationships between population, labor, capital, (ICTs broadband technologies fixed and mobile), and regulatory index, Government expenditure on ICTs and Mobile Broadband capable devices and economic growth. Hence, the OLS can be applied.

Using the STATA software and OLS regression, analysis has been performed using the regress command. This command estimated the coefficients of the model and provides a range of statistics to evaluate the model, including R-squared, adjusted R-squared, and standard errors as shwon in table 3.1 of the regression of the main model below.

Table-3.1: Regression of the main model

```
. regress GDPpc K Population L GovExpenditureICTs FB MB MBCapableDevices RI
```

Source	SS	df	MS
Model	35315303.4	8	4414412.93
Residual	184459.787	13	14189.2144
Total	35499763.2	21	1690464.91

Number of obs =	22
F(8, 13) =	311.11
Prob > F =	0.0000
R-squared =	0.9948
Adj R-squared =	0.9916
Root MSE =	119.12

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	1.24e-07	7.34e-08	1.69	0.115	-3.46e-08	2.83e-07
Population	.0000426	.0000989	0.43	0.674	-.0001711	.0002563
L	.0464695	.0148306	3.13	0.008	.0144299	.078509
GovExpenditureICTs	3535.309	12043.8	0.29	0.774	-22483.75	29554.36
FB	326.7583	71.75368	4.55	0.001	171.744	481.7727
MB	12.13886	10.19139	1.19	0.255	-9.878295	34.15601
MBCapableDevices	-43.16173	20.8599	-2.07	0.059	-88.22681	1.903342
RI	.2280314	3.807575	0.06	0.953	-7.997735	8.453798
_cons	1758.054	7036.519	0.25	0.807	-13443.42	16959.53

4. EMPIRICAL FINDINGS AND DISCUSSIONS

4.1 Empirical findings

From the above regression model, the p-value of F-test is 0.0000 is less than the predefined level of significance, which is 0.05, i.e., 0.05>0.0000. As such, the study rejected the null hypothesis and concluded that the overall performance of model is significant. The difference between the value of R-squared and adjusted R-squared showed that the variables in the model are contributing significantly to the model's explanation of the dependent variable, GDP per capita. The low difference value between R-squared and adjusted R-squared means that no additional variables in the model are required and are not contributing significantly to the model's explanatory power.

The model has a high R-squared value of 0.9948, indicates that the independent variable(s) are good predictors of the dependent variable. Specifically, the R-squared value represents the percentage of the variance in the dependent variable that can be explained by the independent variable in the model. In other words, this high R-squared value suggests that the model is a good fit for the data and that the independent variable(s) are strongly associated with the dependent variable indicating that the model explains a significant amount of the variability in GDP per capita. Furthermore, as the p-value for the model is less than 0.05 means that there is strong evidence that the model is statistically significant.

Overall, the results suggest that fixed broadband subscriptions per 100 people, capital ICTs adjusted investment, full-time labor in ICTs adjusted labor and MB Capable Devices have a positive effect on GDP per capita and statistically significant.

Tables 4.2, 4.3, 4.4, 4.5 and 4.6 further investigated and illustrated the main individual models of the variables (mobile and fixed broadband subscriptions, government expenditure on ICTs, mobile broadband capable device penetration, ICTs regulatory tracker) with GDP per capita respectively.

Table-4.2: fixed broadband technology and GDP per capita

regress GDPpc K Population L GovExpenditureICTs FB

Source	SS	df	MS
Model	35251276.3	5	7050255.26
Residual	248486.879	16	15530.4299
Total	35499763.2	21	1690464.91

Number of obs	22
F(5, 16)	453.96
Prob > F	0.0000
R-squared	0.9930
Adj R-squared	0.9908
Root MSE	124.62

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	2.04e-07	4.12e-08	4.95	0.000	1.16e-07	2.91e-07
Population	-.0000452	.0000778	-0.58	0.569	-.0002101	.0001196
L	.04816	.0126063	3.82	0.002	.0214358	.0748841
GovExpenditureICTs	11753.79	10331.36	1.14	0.272	-10147.72	33655.29
FB	216.9856	47.87872	4.53	0.000	115.4872	318.4839
_cons	7888.652	5828.555	1.35	0.195	-4467.333	20244.64

Table-4.3: mobile broadband technology and GDP per capita

regress GDPpc K Population L GovExpenditureICTs MB

Source	SS	df	MS
Model	34945683	5	6989136.6
Residual	554080.211	16	34630.0132
Total	35499763.2	21	1690464.91

Number of obs	22
F(5, 16)	201.82
Prob > F	0.0000
R-squared	0.9844
Adj R-squared	0.9795
Root MSE	186.09

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	1.80e-07	6.44e-08	2.80	0.013	4.40e-08	3.17e-07
Population	.0002495	.0000916	2.72	0.015	.0000553	.0004438
L	.0540086	.01873	2.88	0.011	.0143028	.0937144
GovExpenditureICTs	-21678.61	12365.23	-1.75	0.099	-47891.73	4534.518
MB	-6.354665	10.22169	-0.62	0.543	-28.02369	15.31436
_cons	-13293.68	6992.589	-1.90	0.075	-28117.3	1529.952

Table- 4.4: ICTs regulatory tracker and GDP per capita

regress GDPpc K Population L GovExpenditureICTs FB MB MBCapableDevices RI

Source	SS	df	MS
Model	35315303.4	8	4414412.93
Residual	184459.787	13	14189.2144
Total	35499763.2	21	1690464.91

Number of obs	22
F(8, 13)	311.11
Prob > F	0.0000
R-squared	0.9948
Adj R-squared	0.9916
Root MSE	119.12

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	1.24e-07	7.34e-08	1.69	0.115	-3.46e-08	2.83e-07
Population	.0000426	.0000989	0.43	0.674	-.0001711	.0002563
L	.0464695	.0148306	3.13	0.008	.0144299	.078509
GovExpenditureICTs	3535.309	12043.8	0.29	0.774	-22483.75	29554.36
FB	326.7583	71.75368	4.55	0.001	171.744	481.7727
MB	12.13886	10.19139	1.19	0.255	-9.878295	34.15601
MBCapableDevices	-43.16173	20.8599	-2.07	0.059	-88.22681	1.903342
RI	.2280314	3.807575	0.06	0.953	-7.997735	8.453798
_cons	1758.054	7036.519	0.25	0.807	-13443.42	16959.53

Table-4.5: Government expenditure in ICTs and GDP per capita

. regress GDPpc K Population L GovExpenditureICTs

Source	SS	df	MS
Model	34932298.8	4	8733074.7
Residual	567464.406	17	33380.2592
Total	35499763.2	21	1690464.91

Number of obs =	22
F(4, 17) =	261.62
Prob > F =	0.0000
R-squared =	0.9840
Adj R-squared =	0.9803
Root MSE =	182.7

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	1.92e-07	6.03e-08	3.19	0.005	6.53e-08	3.20e-07
Population	.0002186	.0000756	2.89	0.010	.0000592	.0003781
L	.0546292	.0183628	2.97	0.008	.0158871	.0933713
GovExpenditureICTs	-19048.4	11407.35	-1.67	0.113	-43115.81	5019
_cons	-11110.41	5936.633	-1.87	0.079	-23635.61	1414.794

Table-4.6: Mobile broadband capable devices penetration and GDP per capita

. regress GDPpc K Population L MBCapableDevices

Source	SS	df	MS
Model	34947513.5	4	8736878.37
Residual	552249.731	17	32485.2783
Total	35499763.2	21	1690464.91

Number of obs =	22
F(4, 17) =	268.95
Prob > F =	0.0000
R-squared =	0.9844
Adj R-squared =	0.9808
Root MSE =	180.24

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	2.40e-07	7.05e-08	3.41	0.003	9.13e-08	3.89e-07
Population	.0000469	.0000254	1.84	0.083	-6.76e-06	.0001006
L	.0494092	.015871	3.11	0.006	.0159243	.0828942
MBCapableDevices	21.93438	12.0136	1.83	0.085	-3.412106	47.28087
_cons	1316.411	1531.599	0.86	0.402	-1914.98	4547.802

The results concluded model's outputs are consistent to the study hypothesis (impact of model variables are significant positive impact on national GDP growth.) and confirmed that in the long and short run, there is a positive effect of all model variables on GDP per capita in Egypt. However, the relation between all model variables and GDP per capita is the strongest except the regulatory tracker variable and government expenditure in ICTs. The analysis also showed that fixed broadband technology has the major contribution to the GDP per capita.

4.2 Validity and reliability of the model

Testing for the validity and reliability of the model constructed, the study adopted statistical tests (T-tests, F-tests, and R-squared) tests to verify if the model is valid and reliable. Table 4.7 shows the output results of the validity and reliability test.

Table-4.7: Output results of the model validity and reliability test

. regress GDPpc K Population L GovExpenditureICTs FB MB MBCapableDevices RI

Source	SS	df	MS		
Model	35315303.4	8	4414412.93	Number of obs =	22
Residual	184459.787	13	14189.2144	F(8, 13) =	311.11
				Prob > F =	0.0000
Total	35499763.2	21	1690464.91	R-squared =	0.9948
				Adj R-squared =	0.9916
				Root MSE =	119.12

GDPpc	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
K	1.24e-07	7.34e-08	1.69	0.115	-3.46e-08	2.83e-07
Population	.0000426	.0000989	0.43	0.674	-.0001711	.0002563
L	.0464695	.0148306	3.13	0.008	.0144299	.078509
GovExpenditureICTs	3535.309	12043.8	0.29	0.774	-22483.75	29554.36
FB	326.7583	71.75368	4.55	0.001	171.744	481.7727
MB	12.13886	10.19139	1.19	0.255	-9.878295	34.15601
MBCapableDevices	-43.16173	20.8599	-2.07	0.059	-88.22681	1.903342
RI	.2280314	3.807575	0.06	0.953	-7.997735	8.453798
_cons	1758.054	7036.519	0.25	0.807	-13443.42	16959.53

As shown in the table above, the p-value of F-test is 0.0000 which is less than predefined level of significance which is 0.05, i.e., 0.05>0.0000. Hence, we reject the null hypothesis and concluded that the overall performance of model is significant. The difference between the value of R-squared and adjusted R-squared showed that the variables in the model are contributing significantly to the model's explanation of the dependent variable, GDP per capita. The low difference value between R-squared and adjusted R-squared means that no additional variables in the model is required and are not contributing significantly to the model's explanatory power and as such researcher concluded that the model is best fitted, reliable and valid.

In addition, ARMA technique and Wald Chi-Square test have been used as important indicators of the reliability and accuracy of the model and as shown in the table 4.8 below.

Table-4.8: Output of ARMA technique and Wald chi- square test

Sample: 2000 - 2021 Number of obs = 22
Wald chi2(10) = 5290.21
Log likelihood = -120.3056 Prob > chi2 = 0.0000

GDPpc	Coef.	OPG Std. Err.	z	P>|z|	[95% Conf.	Interval]
GDPpc						
Population	-8.64e-06	.0000425	-0.20	0.839	-.000092	.0000747
FB	142.8944	85.61151	1.67	0.095	-24.90112	310.6898
MB	4.248027	6.861204	0.62	0.536	-9.199687	17.69574
MBCapableDevices	-63.756	16.26338	-3.92	0.000	-95.63163	-31.88037
K	1.08e-07	5.30e-08	2.04	0.041	4.20e-09	2.12e-07
GovExpenditureICTs	833.448	244.4926	3.41	0.001	354.2514	1312.645
L	.0208893	.0116396	1.79	0.073	-.0019239	.0437025
RI	.1638161	2.57133	0.06	0.949	-4.875899	5.203531
_cons	5904.007	3044.203	1.94	0.052	-62.5201	11870.54
ARMA						
ar						
L2.	-.2682143	4.805052	-0.06	0.955	-9.685943	9.149514
ma						
L2.	.3453135	4.606702	0.07	0.940	-8.683657	9.374284
/sigma	57.34534	13.94186	4.11	0.000	30.0198	84.67088

From above table, Wald chi square value is equal to 5290.21 and because of the alpha (level of significance (0.05)) is greater than p-value which resulted that the calculated value of Wald chi square is greater than table value of chi square and shows that overall model is significant, valid and reliable and that the data tools used for the study are 84.67% (84.67% represent the confidence interval of sigma value in an ARMA technique (which is important indicator of the reliability and accuracy of the model) reliable and can be used over time.

4.3 Discussions

Generally, from ADF test, the results suggest that fixed broadband subscriptions, mobile broadband subscriptions, fulltime labor, and regulatory tracker are strongly positively associated with GDP per capita, while capital invest is also positively associated with GDP per capita but to a less degree of association with GDP per capita in Egypt. This result agrees with the study hypothesis and the results achieved from OLS, ARMA and Wald chi square that at 5% level of significance, there is short and long-run causality and is consistent with the result of the model. This result contrasts with many studied who have conducted previously and concluded that ICTs is contributing to the economic growth in Egypt. This disparity may be a result of the data not being collected rightly and tested correctly which plays a major role in econometrics models constructions and validation. The author concluded that the corresponding model variables have p-value less than 0.05, indicating that it has a significant effect on GDP per capita which means the data collected supports the hypotheses. It also means that the observed result is unlikely to have occurred by chance, and therefore the null hypothesis can be rejected in favor of the alternative hypothesis which supports the hypothesis of the study. According to the findings from the regression analysis of transformed data (logarithmic data or Ln data) that fixed broadband has a sizable influence effect on national GDP growth which shows the main broadband technology has major contribution to GDP growth in Egypt. Mobile broadband has a considerable beneficial effect on the growth of the national GDP but less than fixed broadband. This result could be interpreted that the usage of fixed broadband by business is higher than the usage of individuals of mobile broadband.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Using OLS model, multivariate causality analysis between the independent variables (mobile and fixed broadband subscriptions, government expenditure on ICTs, mobile broadband capable device penetration, ICTs regulatory tracker, population, ICT capital, and labor) and the dependent variable GDP per capita (proxied as economic growth) in Egypt during 2000-2021 is explored in this work.

Generally, the prediction and investigation procedure involved main five steps: unit root testing using Augmented Dicker Fuller; cointegration test using Johansen cointegration test; and investigating the short and long-run relationship between model variables and adjustment rate via t-tests, F-tests, and R-squared, ARMA and Wald chi square tests based on OLS. Additionally, the study performed several diagnostic, validity and reliability tests.

In the short and long-run, the evidence from the OLS shows that mobile and fixed broadband subscriptions, government expenditure on ICTs, mobile broadband capable device penetration, ICTs regulatory tracker, population size, ICT capital, and labor and GDP per capita are cointegrated. The results revealed that Fixed Broadband and Mobile Broadband have a positive correlation, which suggested that as fixed broadband subscriptions increase, active mobile broadband subscriptions increase. Similarly, capital ICTs have a positive correlation with both Fixed Broadband and Mobile Broadband, which suggests that as capital investment increases, fixed broadband and active mobile broadband subscriptions increase. Correlations between model variables show that fixed broadband, fulltime labor, active mobile broadband subscriptions, and regulatory tracker are strongly positively correlated with GDP per capita, while government expenditure is also positively associated with GDP per capita but to a less degree of association with GDP per capita.

Statistical tests from the short and long-run causality revealed that a 10-percentage increase in the subscriptions of fixed broadband technologies and mobile broadband technologies and capital ICTs adjusted investment, GDP per capita increase by 0.3268%, 0.064%, and 0.3535%, respectively in Egypt. This means that in the long run, an increase in subscriptions of fixed broadband technologies and mobile broadband technologies and capital ICTs adjusted investment will increase GDP per capita and contribute to economic growth of Egypt. In contrast, the results obtained from government expending on ICTs and ICT tracker showed a positive impact on GDP per capita with less degree which implies that policymakers in Egypt spend more on ICTs sector and should strive to improve the regulatory quality, which can help boost the country's economic performance and contribute to Egypt's digital transformation journey.

Overall, the results showed that the main OLS model is significant, valid, and reliable and that the data tools used for the study are 84.67% (84.67% represent the confidence interval of sigma value) reliable and can be used over time.

5.2 Research limitations

During the study, researchers observed that OLS ICTs economic predictor model has some limitations in terms of its assumptions, data quality, and potential confounding variables. As such, it is very important when investigating relationships between variables using OLS, we carefully consider and address these limitations when interpreting the results of any economic predictor model.

5.3 Policy implications and recommendations and future studies

The following policy implications and recommendations are made based on the study's findings:

1. Government of Egypt should invest in mobile broadband infrastructure to increase the number of mobile broadband subscriptions. The model suggests that an increase in mobile broadband subscriptions is positively associated with an increase in GDP per capita. This finding suggests that investing in mobile broadband infrastructure may have a positive impact on economic growth.

2. Government of Egypt should continue to invest in ICT capital and labor, spend more on ICTs sector to support the growth of the broadband technologies industry. The model suggests that ICT capital and full-time labor are positively associated with GDP per capita. This finding suggests that investing in ICT capital and labor may be an important way to support the growth of the mobile broadband industry and contribute to economic growth.

3. Government of Egypt should consider policies to encourage mobile broadband adoption among the population, such as subsidies for low-income households (access and affordable service to individuals). The model suggests that mobile broadband adoption, specifically mobile broadband capable devices have a positive effect on GDP per capita, and increasing adoption rates may be an effective way to promote economic growth.

4. Government of Egypt should continue to monitor the evolving ICTs regulatory environment, adjust regulations to support enabling environment for digital transformation and regulation and its impact on the economy to inform future policy decisions. The model predicted the effect of ICTs regulatory tracker on GDP per capita. Governments should monitor industry trends and adjust policies accordingly to support continued economic growth.

5. Government of Egypt should continue to advocate for digital transformation and digital regulation to ensure sustainable growth of the ICTs and digital economy.

The following recommendations have been suggested for future studies:

Unit root tests are used in this time series analysis to determine if a series is stationary or not. Stationarity is an important assumption for many econometric techniques, such as this OLS regression. The results in this work show that the individual series are nonstationary. However, unit root tests have low power if the data are fractionally integrated. To estimate the parameters of a fractionally integrated model, specialized estimation techniques such as maximum likelihood or method of moments may be used. Thus, fractional orders of integration can also be considered when analyzing these kinds of time series data. By extension, the long run equilibrium relationship can also be examined from a fractional viewpoint, using fractionally cointegrated models or by using the Fractionally Cointegrated Vector Autoregression (FCVAR) approach, which is a methodology used for analyzing multivariate time series data. In an FCVAR model, the variables are modeled as a function of their own past lags, as well as the past lags of the other variables in the system. The future development of OLS regression and other econometric techniques will likely involve the incorporation of more sophisticated statistical and machine learning methods, as well as the integration of big data sources and artificial intelligence.

One of the promising areas of development is incorporating non-linear relationships between variables, such as using polynomial, spline, or other non-linear regression models. Additionally, improvements in robust regression and model selection techniques can help address issues such as multicollinearity and overfitting.

Machine learning methods such as artificial neural networks, decision trees, and support vector machines may also be integrated into econometric analyses, potentially allowing for better predictive accuracy and more nuanced analyses of complex relationships.

Finally, the rise of big data sources, such as social media, sensor networks, and other digital sources, presents opportunities and challenges for econometric analysis. New methods for handling and analyzing these large, complex data sets will need to be developed to help extract actionable insights and inform decision-making in a rapidly evolving ICTs, economic and social landscape. Work in these directions is now in progress.

ACKNOWLEDGMENT

Words cannot express my gratitude to my supervisor **Prof. Dr. Tarek Khalil**, NU Founding President & Dean of Graduate School of MOT and co-supervisor **Prof. Dr Mohamed Sayed Abed**, Dean of the Undergraduate Studies, Business School for their excellent support, guidance and invaluable patience and feedback. I also could not have undertaken this research journey without the support of Management of Technology (MoT) Programme coordinator, **Prof. Dr Mohamed Awny** and the staff of School of Management of Technology, who generously provided knowledge and expertise. Additionally, this endeavor would not have been possible without the generous support from my employer, International Telecommunications Union (ITU).

I would like to extend my gratitude to **Prof. Dr. Mohamed Ezzat** for the knowledge and expertise shared and provided in areas of statistical analysis which helped me a lot during my dissertation path.
I would be remiss in not mentioning my family, especially my parents, spouse, and children. Their belief in me has kept my spirits and motivation high during this process.

Finally, I am also grateful to my classmates and cohort members, especially my regional colleagues for moral support. Thanks, should also go to the librarians, MoT assistants, and MoT colleagues from the university, who impacted and inspired me.

STATEMENTS AND DECLARATIONS

The authors declare that they have no conflicts of interest related to this research paper and that there are no financial or non-financial interests that are directly or indirectly related to this research work submitted for publication. In addition, we declare that this research paper is an original work of our research, has been written by us and has not been submitted for any previous degree nor journal.

The methodology and experimental work are entirely our own work; the previous studies and contributions have been indicated clearly and acknowledged. References resources were used have been provided using international recognized references and citation style.

REFERENCES

[1]. MCIT, Egypt, Ministry of Communications and Information Technology https://mcit.gov.eg

[2]. ITU GSR-21, Best Practices Guidelines: Regulatory uplift for financing digital infrastructure, access and use, p. 5 (June 2021),https://www.itu.int/en/ITU-D/Conferences/GSR/2021/Documents/BPG%20Adopted/GSR-21_Best-Practice-Guidelines_FINAL_E.pdf.

[3]. Egypt Vision 2030, http://sdsegypt2030.com/?lang=en

[4]. Digital Egypt, https://mcit.gov.eg/en/Digital_Egypt

[5]. Moyer, J. D., & Hughes, B. B. (2012). ICTs: do they contribute to increased carbon emissions?. Technological Forecasting and Social Change, 79(5), 919-931

[6]. Colecchia and Schreyer, (2002). "ICT Investment and Economic Growth in the 1990s" compared the impact of ICT investment on economic growth in 9 OECD countries.

[7]. Nour. Samia Satti O. M. , (2002). The Impact of ICT on Economic Development in the Arab world: A comparative study of Egypt and the Gulf countries, The United Nations University (UNU)-Institute for New Technologies (INTECH).

[8]. Pantelis Koutroumpis, (2009). "How the infrastructure of broadband telecommunications penetration affects these countries' economic growth, (2003-2006).

[9]. Mohammad Ali MORADI and Meysam KEBRYAEE, Impact of Information and Communication Technology on Economic Growth in Selected Islamic Countries, ECOMOD 2009 conference, Faculty of Social Sciences, University of Ottawa, Ottawa, Canada, June (2009).

[10]. Qiang et al., (2009). ITU study on the impact of broadband as an ICT indication on economic growth of 120 countries.

[11]. Khelifi, O. (2010), Fracture numérique et niveau de développement économique. VIème colloque international, Prospective strategies et développement durable, 21-23 juin, Hammamet (Tunisie); 2010. Available from: http://www.nzaher710.free.fr/informatique.pdf.

[12]. Pradhan, R. P., Arvin, M. B., Nair, M., & Bennett, S. E. (2020). Sustainable economic growth in the European Union: The role of ICT, venture capital, and innovation. Review of Financial Economics, 38(1), 34-62.

[13]. Kallal, R., Haddaji, A., & Ftiti, Z. (2021). ICT diffusion and economic growth: Evidence from the sectorial analysis of a periphery country. Technological Forecasting and Social Change, 162, 120403.

[14]. Cheng, C. Y., Chien, M. S., & Lee, C. C. (2021). ICT diffusion, financial development, and economic growth: An international cross-country analysis. Economic modelling, 94, 662-671.

[15]. Gheraia, Z., Abid, M., Sekrafi, H., & Abdelli, H. (2022). The moderating role of ICT diffusion betIen financial development and economic growth: a bootstrap ARDL approach in Saudi Arabia. Information Technology for Development, 28(4), 816-836.

[16]. Zhao, S., Hafeez, M., & Faisal, C. M. N. (2022). Does ICT diffusion lead to energy efficiency and environmental sustainability in emerging Asian economies?. Environmental Science and Pollution Research, 29(8), 12198-12207.

[17]. Pradhan, R. P., Arvin, M. B., Nair, M., & Bennett, S. E. (2020). Sustainable economic growth in the European Union: The role of ICT, venture capital, and innovation. Review of Financial Economics, 38(1), 34-62.

[18]. Perez-Trujillo, M., & Lacalle-Calderon, M. (2020). The impact of knowledge diffusion on economic growth across countries. World Development, 132, 104995.

[19]. Zhang, J., Gong, X., & Zhang, H. (2022). ICT diffusion and health outcome: Effects and transmission channels. Telematics and Informatics, 67, 101755.

[20]. Myovella, G., Karacuka, M., & Haucap, J. (2020). Digitalization and economic growth: A comparative analysis of Sub-Saharan Africa and OECD economies. Telecommunications Policy, 44(2), 101856.

[21]. Mohamed, M. M. A., Liu, P., & Nie, G. (2021). Are technological innovation and foreign direct investment a way to boost economic growth? an egyptian case study using the autoregressive distributed lag (ARDL) model. Sustainability, 13(6), 3265.

[22]. Tsang, F., Yaqub, O., Van Welsum, D., Thompson-Starkey, T., and Chataway, J. (2011). The impact of ICT in the Middle East and North Africa (MENA) region.

[23]. Magdi Al-Shorbagy, The Impact of Information and Communication Technology on Economic Growth in the Arab Countries, an International Forum on Intellectual Capital in Organizations Arab Business in the Light of Modern Economies, Department of Economics, Misr University for Science and Technology, 6th of October City, November (2011)

[24]. Katz and Callorda, (2015). Impact of fixed broadband in economic growth of Tunisia, (2008-2014).

[25]. Al-Omari Al-Hajj (2012), a standard study of the impact of information and communication technologies on economic growth (1995 - 2009), Department of Economic Sciences, Faculty of Economics, Commercial Sciences and Management Sciences, University of Algiers, Algiers,

[26]. Salahudinne M. and Gtow J, The effects of Internet usage, financial development and trade openness on economic growth in South Africa: A time series analysis, journal of Telematics and Informatics, Volume 33, Issue4, November (2016).

[27]. ElShenawi, Nagwa (2016). The economic impacts of broadband in Egypt. Presentation to the ITU/BDT Regional Economic and Financial Forum of Telecommunications/ICTs for Arab States. Muscat, Oman, December 6-7.

[28]. Taha bin Al-Habib, The Impact of Information and Communication Technology on Economic Growth in Developing Countries (2005-2015), Journal of Economic Research and Finance, Volume: Fifth, Issue: 01, Faculty of Economics, Commercial Sciences and Management Sciences, Larbi Ben Mhidi University, Oum El Bouaghi, Algeria, June 2018, pg: 561

[29]. Mohamed Lamine Belhouchet and Taha Benlahbib (2018): The Impact of Information and Communication Technology on Economic Growth: A Case Study of Arab Countries, Université de Tébessa.

[30]. Raul Katz and Fernando Callorda (2019). ITU study on the economic contribution of broadband, digitization and ICT regulation: Econometric modeling for the Arab States