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AN INVESTIGATION OF THE RELATIONSHIP BETWEEN ICT INFRASTRUCTURE AND ECONOMIC GROWTH OF EMERGING MARKET

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ABSTRACT

The study examines the link between Information and Communication Technology, institutional quality, and economic growth in emerging markets over the period of 2000 to 2019, using the system Generalized Method of Moments. The connection between economic growth and technology lies on the framework of exogenous growth model. The following findings are discernible from the study. First, a substantial positive relationship exists between internet usage and economic growth, while a negative association between economic growth and fixed telephone users is evident. Second, a positive association between growth and innovation exist in emerging markets, whilst institutions reveal a negative association. These findings have a significant policy implication for policymakers to monitor innovation factors rather than institutional quality to bypass the digital divide. Consequently, policymakers should pay attention to the benefits of Information and Communication technology usage by means of reducing entries cost whilst improving network facilities transfers.

CHAPTER ONE
INTRODUCTION
1.1 Problem Statement

Infrastructure expansion and economic growth have long been central discussion interests for academics and policymakers. Worldwide, access to infrastructure has grown into the modern life of all individuals, prioritized by the organization; developed and developing countries have invested a significant portion of government budgets dedicated to infrastructure spending. According to the International Labour Organization (2011), developing countries allocated 40% of their budget spending on infrastructure, while developed countries allocated 20%. In recent times, the proliferation of Information Communication Technology (ICT) has emerged as a new infrastructure, attracting significant research attention due to its potential influence on the economy's growth.

The World Bank (2013) discovered that ICT infrastructure spurs economic growth and reduces unemployment. In the report, a 10% increase in ICT infrastructure penetration results in a 0.75% development in Gross Domestic Product (GDP) and a negative growth of 1.02% in the unemployment rate. In today's interconnected world, businesses, governments, and individuals rely on ICT to communicate, transact, and access information. While the progress of the ICT sector has been substantial, developing countries still lag in ICT infrastructure development. In the least developed countries, only 20% of the population has access to the network, Sudhir et al., (2015) point out that examining this relationship in emerging markets provides insight. Emerging markets have a significant number of middle-class households and some residents living under the poverty threshold. These markets account for more than 65% of the world's populace and 40% of global output, making their development crucial to the global economy. The World Bank, International Monetary Fund (IMF), and the International Telecommunication Union (ITU) are among the major international organizations emphasizing the prominence of investing in ICT infrastructure in emerging markets to promote economic growth and reduce poverty and inequality.

ICT is recognized as laptops and desktops, smart and cellular phones, network routers and landlines, software, and more. These technologies have transformed by process, converting, storing, and communicating information and data between people and communities. Technology has also automated the production of goods and services (Adeleye & Eboagu, 2019; Varadarajan, Welden, Arunachalam, Haenlein, & Gupta, 2022) . The widespread adoption of

ICT has made businesses more productive, efficient, and competitive. It has also created new industries and business models, such as e-commerce and social media, that have generated new jobs and economic opportunities. The digital economy has also enabled businesses to reach new markets and customers domestically and internationally, contributing to economic growth.

Numerous studies have examined the relationship between ICT infrastructure and economic growth. In contrast, some studies have found that the impact of ICT infrastructure on promoting economic growth is insignificant in developing countries compared to developed countries, highlighting the persistence of the digital divide (Dewan & Kraemer, 2000; Aldashev & Batkeyev, 2021; Lythreatis, Singh, & El-Kassar, 2022). Researchers frequently assess the quest to determine the driver behind the digital divide. However, a relatively low research volume has examined the role of innovation and institutional quality. The potential gap between developed and developing markets may arise through the difference in the degree of innovation and quality of institutions in their countries. In particular, research focuses on the view of intellectual property, such as patents, to measure innovation. The constraint of the patent application is recognized as a source of the technology gap between developed and developing markets (Park, 2013; Sharma, Sharma, & Panda, 2022).

However, in contrast to developed markets, patents have yet to be studied enough to measure innovation and the outcome of human capital for ICT infrastructure on economic growth in emerging markets, according to Nguyen & Doytch (2022). In addition to the lag of patent knowledge within emerging markets, management and protection of intellectual property with policymakers are essential. It articulates the institution's efficiency in creating an innovation-friendly environment for ICT infrastructure and promoting economic growth. Additionally, institutional factors can affect the adoption and utilization of ICT (Kiessling, 2007). Given these considerations, this paper examines the interplay of ICT infrastructure, human capital outcomes, institutional factors, and economic development.

1.2 Research Questions

Considering the context, this research aims to address the following questions:

i. How do the utilization, accessibility, and proficiency of ICT infrastructure affect the growth of the economy?

ii. What is the effect of innovation on ICT infrastructure and economic growth?

iii. What is the impact of institutions on the nexus of ICT infrastructure and the economy's growth?

1.3 Objectives of the Study

The core objective of this paper is to evaluate the effect of ICT infrastructure on the development of the economy, with the specific agenda as follows:

i. Examine the relationship between the usage, accessibility, and proficiency of ICT infrastructure on economic growth.
ii. Determine the impact of innovation on the relationship between ICT infrastructure and economic growth.
iii. Analyze the influence of institutional quality on the relationship between ICT infrastructure and economic growth.

1.4 Justification for Study

The positive contribution of ICT is supported by several existing literature proposing ICT encourages economic growth through the channel from the enhancement of communication, efficiency, and productivity through its ability of ease of communication, reduction of production cost, access to human resources knowledge (Meijers, 2014; Chen et al., 2018; Prieger, 2013; Pradhan et al., 2014). Numerous research has partially considered the nexus of ICT infrastructure and economic growth in the view of the population and enrolment of education (Oluwatobi, Olurinola, and Taiwo, 2015), R&D investment (Nair, Pradhan, & Arvin, 2020; Pradhan, Arvin, Nair, Bennett, & Bahmani, 2019), and institutional quality (Esfahani and Ramirez, 2003).

However, the blend of patents, institutional factors, ICT infrastructure, and the development of the economy remains underexplored. The study by Arora, Ceccagnoli, & Cohen (2008) suggests that individuals and firms protect intellectual property outcomes with patents, fostering innovative activities of ICT. It highlights the importance of institutional factors in innovation, yet the strength of the legal framework provides both positive and negative impacts; strong legal institutions protect patent applicants (Li & Shao, 2021). However, it provides high entries cost for new entrant in the field (Duchêne, Sen, & Serfes, 2015). Therefore, the study addresses the debate of ICT infrastructure with economic growth, examining the interplay between institutional factors and innovation toward the correlation between ICT infrastructure concerning economic growth.

1.5 Organization of study

This paper is presented in the structures organized as follows. Section 1 is the introduction and background of existing research on ICT. Afterwards, section 2 comprises a theoretical and empirical literature review. Section 3 encompasses the theoretical, empirical model, and data description, which this study adopted, and Section 4 discusses the model estimation result. Finally, section 5 presents the paper's conclusion and potential recommendations.

CHAPTER TWO

LITERATURE REVIEW

This section looks over the theoretical and empirical literature about this research. Theories that depict the association between the development of the economy and ICT infrastructure are discussed.

2.1 Theoretical Review

Numerous theoretical works have explored the relationship between technology, capital, and economic growth, proposing various assumptions about the connection between these factors. Most of the literature confronts that the ICT construct positively impacts the development of the economy. One of the foundational studies in this field is Solow's (1956) exogenous growth model under a closed economy. The version of the exogenous growth model extends the Harrod-Domar model by considering variables such as the labour force, savings ratio, capital, and technological output level as elements of economic growth. Solow's model employs the Cobb-Douglas function as a mathematical model representation within a closed economy. A significant refinement of the Harrod-Domar model is the assumption that labour is a factor of production, allowing for changes in the capital-output ratio, which generates vital assumptions such as constant return to scale and the fix-proportion of production, which underlie the diminishing returns of capital. Drawing on the diminishing returns of capital, the model suggests that technology progress factors are crucial for an economy's output growth in the long term. However, a significant limitation of the model is that it needs to account for technological changes, such as human capital investment. Therefore, several augmented models have been developed from the baseline model.

In addition to exogenous growth theories, endogenous growth models have been developed, which incorporate increasing returns to scale on various forms of capital. Marvin (1962) introduced a physical capital endogenous growth model based on the principle of a unitary elastic association between the long-term economic growth rate and the saving rate. The model suggests that the long-term growth rate is distributed through the investment rate, which increases proportionally. Consequently, increasing returns to scale are achieved when technological improvements are combined with a fraction of capital used for innovative units, which may be present in the development of organizations, the external scale of economics, labour, and technology.

In contrast, Romer (1986) developed an endogenous growth model based on intellectual property. This model presumes that technology is driven by profit-maximizing agents who accumulate intangible assets under competitive equilibrium. The intangible asset produces long-term economic growth with a saving rate, enabling production to achieve increasing returns to scale, even under concave production in competitive equilibrium.

Mankiw, Romer, & Weil (1992) proposed an augmented version of the Solow model with the inclusion of human capital as a factor of production. This human capital includes knowledge, skills, competencies, and other individual behavior values relevant to economics. Bernanke & Gürkaynak (2001) support the MRW model, which can be used broadly to estimate economic growth. Also found that restrictions of the Solow model tend to be rejected in the MRW model.

The study uses the MRW model to form the theoretical basis of our model. The growth model mentioned above describes different considerations of growth. However, when considering innovation in the aspect of the human capital outcome, it is best described with the MRW model, as other studies have neglected the association between technology and growth attributed to the activity of research and development. Moreover, the MRW model has been widely adopted in the literature when establishing the relationship between research and development, ICT infrastructure, and economic growth (Pohjola, 2000; Oluwatobi & Ogunrinola, 2011; Nair, Pradhan, & Arvin, 2020).

2.2 Empirical Review

With the advent of the digital age, ICT has transformed how businesses operate, people communicate, and the government's functions. It has opened new avenues for economic growth, innovation, and development. This literature review aims to critically examine the nexus between ICT, patent, and institutional factors with economic growth, with a particular focus on the factors that drive this relationship. Different measures for ICT are considered in research. The majority of studies employ either a single or combination of mobile cellular subscripted (S. H. Lee, Levendis, & Gutierrez, 2012; S. Lee, Han Kim, & Son, 2015), fixed telephone subscribers (Hardy, 1980) and internet user (Meijers, 2014) as a proxy for ICT infrastructure. Mardikyan et al., (2015) suggest that technology has drastically transformed the trajectory of economic, environmental, and social perspectives. Nevertheless, many diverse studies with opposing results are frequently attributed to distinct employment of the scope of the study, time frames, and econometric approach. The following literature provides different dimensions of estimation attributes.

Adeleye & Eboagu (2019) evaluated 54 African countries, separated into five sub-samples from 2005 to 2015, adopting the estimation procedures of Pooled Ordinary Least Square (POLS), Random effect (RE), fixed effect (FE)and Generalised Method of Moments (GMM) model. The empirical result found that three ICT infrastructure indicators, internet user, mobile subscription, and fixed telephone subscription, positively and statistically significantly contribute to economic growth. Amongst others, mobile subscriber shows the most extensive output elasticity overall specification. In a similar trend, Bojnec and Ferto (2012) evaluated the effect of broadband facilities on the development of the economy in 34 OECD countries from 1998-2009. Implementing GMM, their estimate found that access and capital investment display an optimistic and statistically significant influence on economic growth. However, its effect varies across different economic settings.

The impact of different indicators across various countries depicts diverse effects regarding mobile penetration, (Gruber and Koutroumpis, 2011) found that lower-income countries have relatively lower mobile subscription rates compared with high-income countries, the effect towards economic growth is measured at 0.11%, and 0.2% respectively. Another research conducted by (Habibi and Zabardast, 2020) on OECD and Middle East nations suggests that internet user has a relatively lower impact within Middle East countries, while mobile penetration is relatively higher compared with OECD countries.

Hofman et al., (2016) examine the association between the construct of ICT to growth in Latin America's economy from 1990-2013 using growth accounting approaches. The approach discovered that ICT investment significantly accelerated the U.S. economy's growth. It suggests that the gap between Latin America and the U.S. is due to the lack of ICT. The driving factor of such divergence includes the deficiency of physical capital, human capital, and efficiency problems. An alternative approach to ARDL is adopted by Gheraia, Abid, Sekrafi, & Abdelli (2022). The author discovered that in using the period from 1990-2019 within the region of Saudi Arabic, ICT adoption provides an indirect impact on economic growth, and it promotes the impact of financial development.

In addition, Niebel (2018) employed panel data estimation across 59 developed, developing, and emerging markets from 1995-2010. They found that ICT capital contributes higher output growth to developed countries than developing and emerging markets. Similarly, Dedrick, Kraemer, & Shih (2013) collected 45 sampling countries combined with upper-income developing and developed markets from 1994 to 2007. Employing panel data estimates, the author founds that developed countries show a relatively more significant output elasticity than developing countries. Furthermore, Sassi & Goaied (2013), Jorgenson & Vu (2016), and Bahrini & Qaffas (2019) press attention on different markets confirmed that all the proxies of ICT affiliate positively with economic growth at the micro and macro levels.

Some research found that ICT has an inconclusive or non-substantial impact on the role of economic growth (Jayakar and Park, 2013; Elitan, 2011; Acemoglu, Autor, Dorn, Hanson, & Price, 2014). Pohjola (2002) examined 42 nations from 1985 to 1999 and found a neglectable association between the ICT construct and economic growth from all the sample data. The result is not isolated; Ishida (2015) used the ARDL approach from 1980-2010 in Japan, and ICT has a statistically insignificant relationship with production output in the long term. The research conducted by Aldashev and Batkeyev (2021) considered the relationship between broadband infrastructure and economic growth from 2006 to 2016 in the rural area of Kazakhstan. The paper uses an instrumental variable framework and finds inconsistent sector results. The short-run impact of high-speed broadband penetration positively influences the retail and agriculture sectors. The specific magnitude is a 1% increase in penetration rate corresponding with 0.11% in agricultural and 0.2% in retail, which is statistically significant. While no significant impact in the manufacturing sector. In the long run, the effect on agricultural and retail is 0.12, and 0.23 suggest no contemporaneous effect.

Moreover, a 0.66 unit of growth in the retail sector is statistically significant. On the opposite, the agriculture and manufacturing sector are statistically insignificant. Additionally, the broadband speed of fewer than 10 Mbps significantly impacts, while speeds larger than 10 Mbps are statistically insignificant.

Drawing from the above research, the disparities of the effect may result from the difference in research and development and the quality of institutions in the market. Most research has emphasized the relationship between ICT infrastructure and economic growth, while the role of research and development and institutional factors remains underexplored. Innovation drives the speed of upgrading and maintaining ICT infrastructure (Lee et al., 2016). Innovation produces intellectual property for the private and public sectors to release and protect the research outcome. Intellectual property is in the form of patents, copyright, trademark, and more (Nath Saha and Bhattacharya, 2011). Various economic papers recognize that patents are adequate tools for measuring innovation, and valid patents positively promote economic development (Beltrán-morales, Almendarez-hernández, & Jefferson, 2018; Mabrouki, 2018;

Mabrouki, 2022). Furthermore, the usage of network and ICT devices promote the distribution of information and knowledge and reduces the cost of learning (Cowan and Jonard, 2004), which implies that ICT structure may be a driver for the speed of innovation (S. Lee, Marcu, & Lee, 2011).

Adedoyin, Mavengere, & Mutanga (2022) studied the association of patents and the South African market using the Autoregressive Distributed Lag model (ARDL) and Kernel-Based Reguaried Least Square (KRLS) approach from 1980-2020, with the interaction variable including, government spending, gross fixed capital formation, workforce, trade openness. The empirical result shows that government expenditure, labour force, and trade openness have an increasing relationship with the growth of the economy in the short and long track. While the patent depicts a more negligible immediate impact, the impact rise and shows a sustainable effect on economic growth. Developing and emerging markets lagged in patent capacity and efficiency regarding ICT development (Yan, Shi, & Yang, 2018). Chinn & Fairlie (2010) find this may arise from the disparities of income, telephone penetration, human capital, and quality of institutional factors which contributed to protecting and encouraging innovation. Patent efficiency is significantly associated with institutional factors (Fu and Yang, 2009). Institutional factors describe the government's degree of capacity and efficiency to facilitate and maintain its policy. They also describe the right resident and foreigners receive economically and socially. Institutional measures are considered essential for the development of the economy by protecting property rights and investments. (Rodrik, Trebbi, & Subramanian, 2002; Asiedu, 2006; Osabuohien & Efobi, 2015). Hawthorne & Grzybowski (2021) collected a survey from 134000 individuals between 2009-2014, that regulation of law moderates the effect of mobile subscriptions. The positive association is supported by Adams & Akobeng (2021), which confirmed that the ICT and governance indicators estimates serve as an important estimate for reducing poverty and stimulating economic growth.

Beecroft, Osabuohien, Efobi, Olurinola, & Osabohien (2020) examine the financial and political institutional interventions with economic trade. Employing the estimation approach SGMM covering 14 West African countries, the quality of institutions, especially of transparency, accountability, control of corruption, the rule of law, and regulatory control, enhance the impact of ICT infrastructure in export capacity.

Asongu & Biekpe (2017) evaluated 49 Sub-Saharan African countries from 2000-2012, with the measure of penetration of mobile phones, fixed phones, and the internet, while the inclusion of interaction factors of governance indicator institutional governance shows a more significant effect in ICT adoption compared to economic governance and financial governance. Furthermore, the study discovered a positive association between political stability and the rule of law between the mobile cellular subscriber and internet user, while an inverse relationship in the long run.

In the light of the existing research, the relationship between ICT infrastructure and economic growth has been extensively explored, but the findings are mixed across developed and developing markets. However, there is a lack of studies examining the underlying interrelation that leads to a consistent digital divide between these markets, which is influenced by the availability of patents as a source of innovation. Developed countries tend to hold a significant number of patents, creating barriers in terms of ICT development and usage. Moreover, the crucial role of institutional quality, which serves as a foundation for innovation and growth, has been overlooked in previous research. Therefore, the objective of this study is to contribute towads the interplay between ICT infrastructure, innovation, and institutions in promoting economic growth.

CHAPTER THREE

THEORETICAL MODEL AND METHODOLOGY

The section provides the analytical framework, model specification, and methodology adopted in the paper. In addition, it encompasses the description of the source and type of data used.

3.1 Theoretical Model

The primary goal of this paper is to assess the interdependence of ICT infrastructure, patents, and institutional quality on economic growth. The study seeks to establish how these factors are related to one another and how they collectively contribute to the growth of an economy. To achieve this, we propose a growth model based on the seminal work of Mankiw et al., (1992). The proposed growth model builds upon the Solow Model, a well-established framework for studying economic growth. We extend this model by incorporating a Cobb-Douglas function under perfect competition, using cross-country data to examine the relationships concerning ICT infrastructure, patents, institutional quality, and economic growth.

$Y_{it} = K_{it}^{\alpha} H_{it}^{\lambda} [A_{it} L_{it}]^{1-\alpha-\lambda}$, assuming 0<α<1 [1]

In this context, Y_{it} denotes the domestic productivity level at a given time. At the same time, A_{it} represents the technology parameter, K_{it} represents capital formation, H_{it} represents human capital and L_{it} represents the labour force, all considered essential factors influencing productivity. To model the dynamics of these factors over time, we employ the framework developed by Solow, who assumes a constant return to scale. According to Solow's model, the labour force and technology parameters increase exogenously over time at rates represented by the parameters n and Ψ, respectively.

$L_{it} = Le^{nt}$ [2]

$A_{it} = Ae^{\Psi t}$ [3]

Equations [2] and [3] provide valuable insights into the dynamics of labour productivity and capital accumulation. In particular, the sum of the variables n and Ψ represents the growth of the effective unit of labour rate. Moreover, the theory assumes that a fixed proportion of output (represented by the variable s) is invested into capital formation. Differentiating the symbols using uppercase and lowercase, $k = \frac{K}{AL}$ refers to the level of stock per effective per-worker quantities, $h = \frac{H}{AL}$ represent level of human capital per effective unit of labour, and $y = \frac{Y}{AL}$

defines the level of output per effective unit of labour. According to Romer (2012), an increase in the gross investment rate (sy_{it}) will cause a continuous rise in the level of k until it reaches k*. Beyond this point, any further rise in the investment rate will result in a constant k, assuming human capital depreciate at same rate with physical capital, it implies α+λ<1, diminishing return of all capital. The fraction invested in physical and human capital is represent by $s_k y_{it}$ and $s_h y_{it}$, respectively.

In light of the changing aspects, the production and capital accumulation functions can be represented as follows:

$$y_{it} = K_{it}^{\alpha} H_{it}^{\lambda} \quad [4]$$

$$\acute{k}_{it} = s_k y_{it} - (n + \Psi + \delta) k_{it} \quad [5]$$

$$\dot{h}_{it} = s_h y_{it} - (n + \Psi + \delta) h_{it} \quad [6]$$

The concept of depreciation is critical in understanding the dynamics of capital stock growth over time. Specifically, the variable δ represents the rate at which the capital stock depreciates, an important consideration for policymakers seeking to promote sustainable economic growth. The underlying hypothesis suggests a fixed and common growth rate for various factors influencing economic growth. Based on equations [4], [5], and [6], the steady state at where $\acute{k}_{it}$=0 and $\dot{h}_{it} = 0$ implies the following:

$$s_k y_{it} = (n + \Psi + \delta) k_{it} \quad [7]$$

$$s_h y_{it} = (n + \Psi + \delta) h_{it} \quad [8]$$

Similarity, equation [7] and [8] is equivalent to:

$$k^{\alpha-1} h^{\lambda} = \frac{n+\Psi+\delta}{s_k} \quad [9]$$

$$k^{\alpha} h^{\lambda-1} = \frac{n+\Psi+\delta}{s_h} \quad [10]$$

Therefore, it implied the economy converges to k^{ss} and h^{ss}, that are presented at the following:

$$k^{ss} = \left(\frac{(s_k)^{1-\lambda}(s_h)^{\lambda}}{n+\Psi+\delta}\right)^{\frac{1}{1-\alpha-\lambda}} \quad [11]$$

$$h^{ss} = \left(\frac{(s_k)^{\alpha}(s_h)^{1-\alpha}}{(n+\Psi+\delta)}\right)^{\frac{1}{1-\alpha-\lambda}} \quad [12]$$

Recall equation [4], substituting equation [11] and [12],

$$y^{ss} = \left(\frac{(s_k)^{\alpha}(s_h)^{\lambda}}{(n+\Psi+\delta)^{\alpha+\lambda}}\right)^{\frac{1}{1-\alpha-\lambda}} \quad [13]$$

Recall that $y = \frac{Y}{AL}$,

$$\frac{Y_{it}}{L_{it}} = Ae^{\Psi t}\left(\frac{(s_k)^{\alpha}(s_h)^{\lambda}}{(n+\Psi+\delta)^{\alpha+\lambda}}\right)^{\frac{1}{1-\alpha-\lambda}} \quad [14]$$

It is important to highlight that the fraction of capital to labour positively correlates to the saving rate and is inversely attached to the population growth rate. These relationships have significant implications for the long-run growth prospects of an economy and the policies that should be implemented to promote sustainable development.

To quantify these relationships, we can look at the Balanced Growth Path (BGP) value for the output per worker (y_{it}^{ss}) and take its natural logarithm form. The BGP value represents the steady-state level of output per worker that an economy can achieve over the long term. This equation reveals that the BGP value of output per worker is positively related to the level of technology and the effective capital per worker and negatively connected to the share of labour in national income. These relationships highlight the importance of promoting technological progress and increasing the capital-labour ratio to achieve sustainable economic growth. Specifically, the BGP value for output per worker can be expressed as:

$$Log\ y_{it}^{ss} = ln\ A_{it} + \Psi t + \frac{\alpha}{1-\alpha-\lambda} log\ s_k + \frac{\lambda}{1-\alpha-\lambda} log\ s_h - \frac{\alpha+\lambda}{1-\alpha-\lambda} log(n + \Psi + \delta) \quad [15]$$

3.2 Methodology

In order to empirically assess the association between ICT and economic growth using dynamic panel data, we employ a quantitative approach for panel data analysis. To this end, we begin by using the static panel estimation approach to evaluate the upper and lower bounds of the estimation parameters. Employing the Hausman test to assist in selecting the suitable model using the results of the static panel estimation. The DGMM and SGMM methods are suitable for analyzing dynamic panel data because the estimation approach allows for including lagged dependent variables and using instruments to address endogeneity issues. By comparing the outcomes and considering the bounds of the estimation parameters, it assists in the selection most suitable approach for analyzing the relationship between ICT and economic growth in the context of dynamic panel data.

3.3 Model specification

$$Log\ Y_{it} = \gamma_0 + \gamma_1 + \gamma_2 ICTI_{it} + \ B_1 Log\ K_{it} + B_2 Log\ H_{it} + B_3 Log\ L_{it} + \mathcal{E}_{it} \quad [16]$$

Patents serve as a means of documenting knowledge and, in turn, drive the development of novel production methods and products. Following the previous research, the inclusion of Fixed telephone, internet user are used as proxy for ICT infrastructure (Majeed & Ayub, 2018; Haftu, 2019; Appiah-Otoo & Song, 2021). Qian (2018) propose that patent protection can spur innovation and economic growth. Meanwhile, the quality of institutions represents a key factor behind the efficacy of policies to foster innovation and production, as argued by (Rodrik et al., 2002; Kumari, 2022). Consequently, incorporating both patent and institutional factors into the analysis can offer insights into their influence on economic growth. By considering these factors in conjunction with ICT infrastructure, the study can provide a more comprehensive examination of the interplay between various elements in the process of economic growth:

$$Log\ Y_{it} = \gamma_0 + \gamma_1 + \gamma_2 ICTI_{it} + \ B_1 Log\ K_{it} + B_2 Log\ H_{it} + B_3 Log\ L_{it} + B_4\ LogIF_{it} + \ \mathcal{E}_{it} \quad [17]$$

Based on the proposed hypothesis for the general estimation model and its compatibility with our dataset, we can adjust the baseline model to incorporate relevant variables and further analyze the relationship between them:

$$lnGDPC_{it} = B_0 + B_1 lnGDPC_{it-1} + B_2 InL_{it} + B_3 lnGFCF_{it} + B_4 lnGFCF_{it-1} + B_5 lnP_{it} + B_6 lnSE_{it} + B_7 lnAGI_{it} + B_8 FT100_{it} + B_9 I_{it} + \mathcal{E}_{it} \quad [18]$$

Where i denotes the emerging countries, t denotes the years from 2000 to 2019, and $GDPC_{it}$ is the dependent variable, the logarithm of the output per worker. B_0 is the constant term, and B_1 to B_9 are the parameter coefficients of the explanatory variables. GDPC indicates GDP at

Constant price, L indicates labour force participant, GFCF indicates Gross fixed capital formation, GDP_{it-1} and $GFCF_{it-1}$ denote lagged constant GDP and GFCF, respectively. P indicates Patents, SE indicates secondary education, AGI indicates Average Aggregate Governance indicator, FT100 indicates fixed telephone subscriber, I indicate internet user, and Ɛ indicates disturbance term.

3.4 Estimation Technique

This research considers the relationship between ICT infrastructure and emerging markets' economic growth while accounting for interacting factors. However, panel data estimation presents several challenges. Endogeneity is a significant concern, as it implies that the input and dependent variables have a joint effect on each other. Moreover, the heteroskedasticity of the data suggests that standard approaches, such as OLS, may generate biased results. The instrumental variable (IV) framework can provide an alternative approach for correcting endogeneity, but finding a suitable instrument is often challenging.

To address these issues, Arellano & Bond (1991) proposed a Difference GMM (DGMM) method, which involves differencing the regressors to remove fixed effects. However, this approach can reduce the number of observations and magnify information breaks in unbalanced panels. To overcome these limitations, Arellano & Bover (1995) and Blundell & Bond (1998) introduced the system GMM (SGMM) specification. This method expands the list of instruments to include orthogonal conditions between variables, such as lagged levels and differences, to discourse the sources of endogeneity and autocorrelation that may exist in the data. Consequently, SGMM extends the limits of the DGMM method.

The key assumption of the SGMM approach is that the instruments used to generate exogenous variables are uncorrelated with fixed effects. This assumption suggests the following orthogonal conditions:

$$E\left(\Delta y_{i,t-1}\,(\mathcal{E}_{it})\right) = 0 \qquad [17]$$

Using the orthogonal conditions outlined previously, the SGMM approach can effectively tackle the challenges of endogeneity and heteroskedasticity commonly encountered in panel data estimation. Specifically, the moment condition permits the application of lagged first difference as an instrument in the model.

$$y_{it} = \Upsilon y_{i,t-1} + A_i' + u_{it} \quad [18]$$

Bringing to mind equation [3], which denotes the technology innovation rate over time, we can see that ICT investment in R&D hastens the creation of new knowledge and ideas, fuelling the technology innovation process. This relationship can be expressed as follows:

$$\Psi_{it} = \gamma_1 + \gamma_2 ICTI_{it} \quad [19]$$

Therefore, it suggests that, in natural logarithm forms, we substitute equation [16] into [3]:

$$Log\ A_{it} = \gamma_0 + \gamma_1 + \gamma_2 ICTI_{it} \quad [20]$$

3.5 Source of Data

This study utilizes the GMM estimation methodology to analyze the relationship between ICT infrastructure and growth in emerging markets economies. The selection of the list of emerging nations is from the top economic prominence countries, and the challenge of data constraint is further considered. Stata 17 is used as the estimation tool, and annual data is collected from the World Development Indicators (WDI) and World Governance Indicators (WGI) between 2000 and 2019. Table 1 presents the range of emerging markets considered in this study.

Table 1: List of emerging countries

Country Code	Country
CHN	China
IDN	Indonesia
IND	India
KOR	South Korean
MYS	Malaysia
PHL	Philippines
RUS	Russian
THE	Thailand
VNM	Vietnam
EGY	Egypt
SAU	Saudi Arabia

ARG	Argentina
BRA	Brazil
CHL	Chile
COL	Colombia
MEX	Mexico
MAR	Morocco
POL	Poland
ZAF	South Africa
TUR	Turkey
HUN	Hungary
PER	Peru

The study employs several variables to measure economic growth and development aspects. Real GDP growth is used as a proxy for overall economic growth. In order to measure the outcome of innovation, the natural logarithm of the total amount of patents is used as a proxy. GFCF represents capital, while the labour force is selected from the population aged between 15 and 65. Secondary education enrolment is used to characterize the measure of human capital. Proxy variables for ICT infrastructure include internet users and fixed broadband subscriptions per 100 inhabitants. The Average Aggregate Governance Indicator (AGI) variables represent the institutional proxy.

Table 2: Summary of Data Sources

Variable	**Description of the variable**	**Data Source**
$\boldsymbol{GDPC_{it}}$	The study uses constant GDP to measure economic growth as the dependent variable. Real GDP is a measure of economic growth using the current U.S. dollar.	WDI
Independent Variable		
$\boldsymbol{P_{it}}$	The measure used in this study for patent applications is the quantity of applications filed by residents of the country, which have been accepted	WDI

	either through the Patent Cooperation Treaty procedure or through the national patent office.	
$GFCF_{it}$	Gross fixed capital formation refers to public and private sector investment in capital, infrastructure, and asset expressed in the current U.S. dollar.	WDI
L_{it}	The labour force comprises individuals aged 15 to 64 and is economically active as a proportion of the total population.	WDI
SE_{it}	Admission of gross enrolment in secondary education is measured for the population group, irrespective of age, corresponding to their education level.	WDI
I_{it}	Internet users as a percentage of the population who have had access to the network in the past three months collected annually over the emerging market.	WDI
$FT100_{it}$	Fixed telephone subscription measures the number of fixed telephone lines, public payphones, VoIP services, and wireless local loop connections per 100 inhabitants.	WDI
AGI_{it}	The Averaged Aggregated Governance indicator measures the average rule of law, political stability, control of corruption, government effectiveness, regulatory quality, voice, and accountability, where all estimated range from the absolute value of 2.5, the higher the estimate suggest better governance.	World Health Organisation (WHO) and WGI

CHAPTER FOUR
EMPIRICAL RESULT AND ANALYSIS

This section examines the panel data employed from emerging markets using fixed effect, random effect, and GMM estimations approach.

4.1 Preliminary analysis

The analysis of our model consists of several preliminary steps, beginning with a descriptive analysis presented in Table 3, which provides an overview of the characteristics of the data. Additionally, Table 4 reports the correlation matrix of variables and scatter plots with the mean values of variables. Descriptive statistics provide insight into the general trends of the data, including measures such as mean, median, standard deviation, and range of the variables.

The analysis covers the period from 2000 to 2019, with data collected from 22 emerging countries. Observing Table 3, the average fluctuation of the data is substantial, ranging from -0.0124% to 85.88%. Secondary education has the highest mean value (85.88), while the AGI has the lowest average value at (-0.124). The percentage of internet users is the most volatile, with a standard deviation of 25.95, while the AGI (0.533) is the least volatile.

Table 3: Description of Statistic

Variable	Obs	Mean	Std. Dev	Min	Max	Skewness	Kurtosis	Jarque-Bera
l	460	65.08	9.208	47.87	83.21	-0.0040	2.1324	4.71
se	385	85.88	18.63	22.51	120.7	-1.1332	4.1931	2.92
i	459	35.52	25.95	0.254	96.16	0.3945	1.9837	19.83
ft100	458	16.47	11.59	1.283	60.25	1.3714	5.5487	5.37
agi	437	-0.119	0.533	-1.184	1.218	0.6754	2.8592	0.95
lgfcf	454	25.25	1.669	22.94	37.26	3.4127	23.7284	5.05
lgdpc	460	26.79	1.846	24.16	41.80	4.075	27.6156	13.40
lp	451	7.031	2.185	3.296	14.15	1.0528	3.9264	16.00

Source: Author's compilation

Apart from labour and secondary education being negatively skewed, the majority of the variable is positively skewed, however, the skewness observed for labour force, internet user, and AGI around zero, proposing potential normality. Observing the kurtosis value surrounding two and the Jarque-Bera statistic supporting normality distribution of the data, while other series reject the hypothesis of normality. These findings provide valuable perceptions into the nature of the data and will inform subsequent analysis of the model.

Table 4 presents the correlation matrix of the parameter incorporated in this study. This analysis aims to uncover the relationships among the variables and identify any outliers that may influence the estimation results. The correlation matrix allows us to establish the degree of linear association between the variables, while the graphical representation helps visualize their relationship's nature. The correlation values range from zero to one, within the range of -1 and 1, a positive value indicating an optimistic connection and a negative value indicating an inverse correlation.

The results reveal that real GDP positively correlates with labour force participation, secondary education, internet user, fixed telephone subscriber, and GFCF but negatively with the governance indicator. However, the relationship is insignificant for labour force participation. At the same time, the correlation ranges from weak to moderately significant at the 1% level for secondary education, internet user, fixed telephone subscriber, and GFCF. Total patents exhibit a positive relationship with all the variables, with labour force and secondary education significant at the 5% level and internet user, fixed telephone subscriber, the governance indicator and gross fixed capital formation substantial at the 1% level.

Table 4: Correlation Matrix

	l	se	i	ft100	agi	lgfcf	lgdpc	lp
l	1							
se	0.362***	1						
i	0.146***	0.636***	1					
ft100	0.141***	0.475***	0.450***	1				
agi	0.0410	0.452***	0.434***	0.525***	1			
lgfcf	0.089*	0.172***	0.238***	0.193***	-0.0640	1		
lgdpc	0.0460	0.205***	0.159***	0.162***	-0.079*	0.560***	1	
lp	0.163***	0.235***	0.330***	0.525***	0.139***	0.632***	0.550***	1

***Source**: Author's compilation.*

***Notes**: * designates the variable is significant at the 10% level, ** indicates variables are significant at the 5% level, and *** denotes variables are significant at the 1% level.*

Figure 4.1 and 4.2 presents the relationship between real GDP, percentage of internet user, and fixed telephone subscriber, respectively. For instance, in Figure 4.1, China demonstrates a high level of constant GDP while its internet user-level remains in the median to low quantile. Conversely, Korea, with the highest internet user level, has a constant GDP level at the median level amongst emerging markets. Similarly, the pattern is observed with fixed telephone subscribers and real GDP. The figures indicate a strong positive relationship between total patents and constant GDP. China exhibits a high level of total patents and constant GDP, suggesting that China has efficiently commercialized the result of human capital. Yet, Saudi Arabia depicts a high level of constant GDP while having a low level of total patents.

Figure 4.1: Percentage of Internet users with constant GDP.

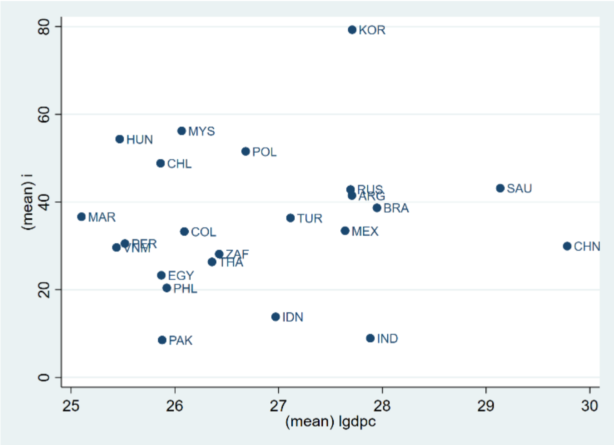
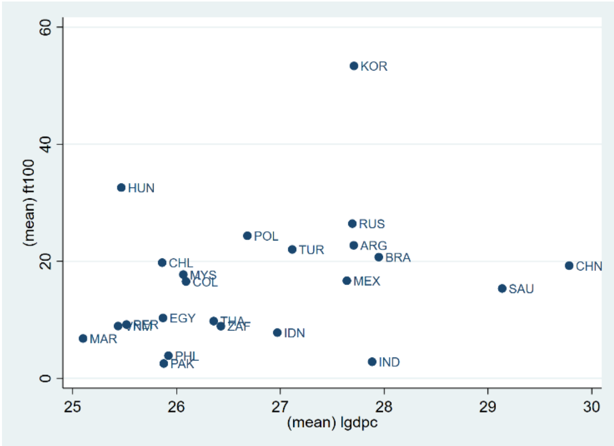


Figure 4.2: Fixed telephone subscriber with constant GDP



Figures 4.3 and 4.4 also describe the interaction of innovation factors with ICT infrastructural proxies, while Figure 4.5 and 4.6 shows the interplay of average aggregate governance indicator with ICT proxies. It is noteworthy that there are diverse impacts observed in emerging markets. For instance, diverse relationships are observed in Figures 4.3 and 4.4, where Korea depicts a strong positive relationship, ranking amongst the top nations with a high degree of patents and internet users. However, China is in the low quantile of ICT infrastructure is associated with a high degree of patents. Lastly, in Figures 4.5 and 4.6, the majority of the countries depict an encouraging connection between the level of ICT users and the governance level.

Figure 4.3: Innovation with internet users.

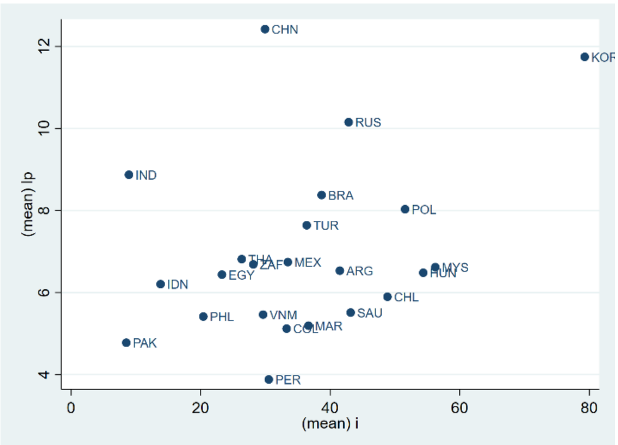


Figure 4.4: Innovation with Fixed telephone subscriber

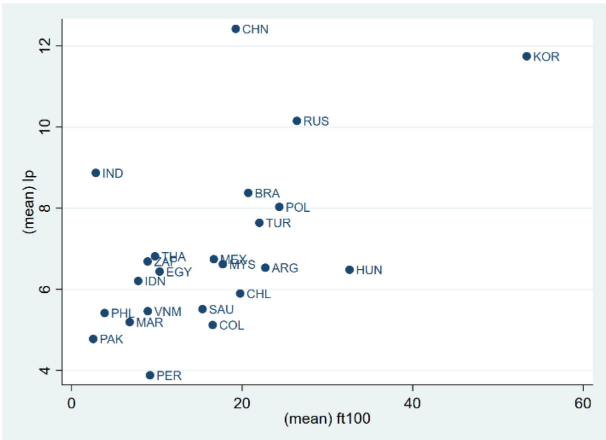


Figure 4.5: AGI with internet user

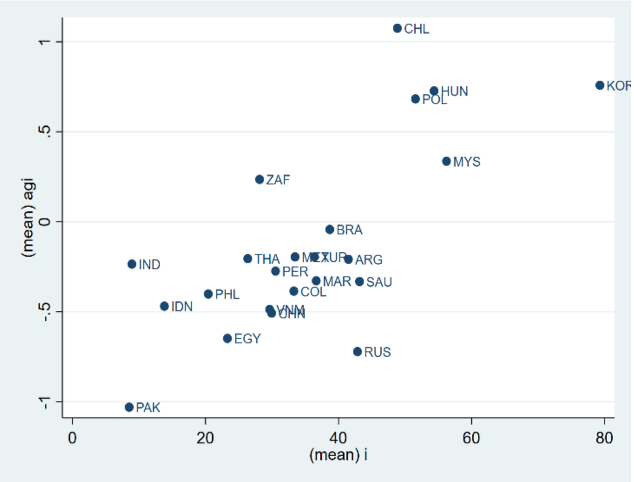
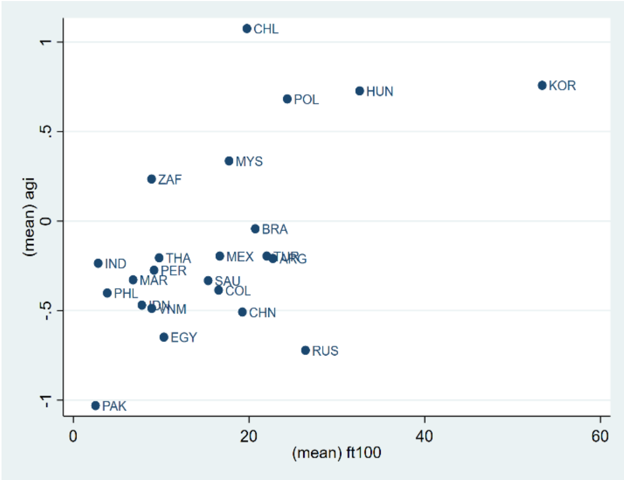


Figure 4.6: AGI with Fixed telephone subscriber



4.2 Model Estimation and Discussion

We begin our analysis with a static panel estimation procedure using data from 2000-2019 across 22 emerging countries. Table 5 summarises our results, where Model (1) employs a fixed effect estimation technique, and model (2) utilizes a random effect estimation approach. The coefficients presented in logarithmic form represent the elasticities. Our findings reveal that patent has a substantial positive influence on economic growth in all the models, with a significance level of 1%. However, the contribution of ICT and institutional factors has mixed results. Model (1) suggests a positive correlation between these variables and economic growth, but the ICT proxy is insignificant.

In contrast, Model (2) indicates a negative relationship between these variables, with different significance levels for fixed telephone subscribers and economic growth (significant at 5% level) compared to internet users and the AGI, which are insignificant. The fixed effect model controls for individual effects by eliminating time-invariant elements (Blackwell, 2005), assuming strict exogeneity for time-invariant variables. The random effect model assumes that the unobservable effect is exogenous to the independent variable in the model (Bartels, 2008), allowing for the inclusion of time-invariant variables, with the crucial assumption that the disturbance term is uncorrelated with independent variables.

Table 5: Estimation result with static panel procedure

Models	**Model (1)**	**Model (2)**
Variables	**Lgdpc**	**lgdpc**
lgfcf	**0.186*****	**0.270*****
	(0.0007)	**(0.0000)**
se	**0.0074**	**0.0082***
	(0.2218)	**(0.0385)**
l	**0.0202**	**0.0106**
	(0.2771)	**(0.1737)**
i	**0.0039**	**0.0015**
	(0.2243)	**(0.5174)**
ft100	**0.0054**	**-0.0139***
	(0.6817)	**(0.0349)**
agi	**-0.0771**	**-0.336***
	(0.7652)	**(0.0112)**
lp	**0.360*****	**0.307*****
	(0.0001)	**(0.0000)**
Constant	**17.30*****	**16.49*****
R-Square	**(0.0000)**	**(0.0000)**
The result of the Hausman Test		
Test Summary	**Chi-square Statistic**	**Probability**
Model: Constant GDP	**17.60**	**0.0139**

***Source**: Author's compilation.*

***Notes**: 1. Model (1) indicates Fixed effect estimate, and Model (2) indicates Random effect estimate. 2. * designates the variable is significant at the 10% level, ** indicates variables are significant at the 5% level, and *** denotes variables are significant at the 1% level. 3. Value within the parenthesis indicates p-value.*

According to Chmelarova (2007), the Hausman test can regulate whether a FE or RE model is suitable. The test proposes the following propositions to be evaluated:

H0: $cov(x, \varepsilon) = 0$, indicating that the RE model is more efficient.

H1: $cov(x, \varepsilon) \neq 0$, indicating that the FE model is more efficient.

The acceptance of the null hypothesis means that the difference in coefficient is non-systematic, which in turn suggests that the efficiency of the RE model is established. The null hypothesis is excluded if the p-value is less than 0.05, indicating that the FE model is more efficient. The null proposition cannot be forbidden if the p-value is larger than 0.05. In this study, the Hausman test yielded a p-value of 0.0139<0.05, demonstrating that the FE model should be preferred over the RE model.

According to the FE model result, increasing the number of patents by 1% would result in a 0.36% increase in constant GDP. Conversely, a unit increase in the governance indicator suggests a 0.08 unit decrease in the economy's growth. These findings support previous studies by (Adedoyin et al., 2022; Ozpolat et al., 2016; Toader et al., 2018), which suggest that innovation is the main driver of economic growth. However, the study's analysis of the ICT proxy did not yield significant results. Nasab and Aghaei (2009) have noted that fixed and random estimation techniques can help account for heterogeneity and time-varying effects. However, they may need to address issues related to pre-determined or endogenous variables fully. Additionally, the static panel estimation technique does not account for specific unobservable effects that may persist in different countries; to overcome this challenge, the study suggests using GMM, which allows for estimating lagged dependent variables to explain endogeneity effects.

The study also conducted a Variance Inflation Factor (VIF) analysis, which indicated weak levels of multicollinearity. When VIF values are less than 3, it suggests that correlation conditions are acceptable (Montgomery, Peck, & Vining, 20021). All variables in this study had VIF values less than 3, indicating that acceptable correlation conditions were met.

Table 6: Diagnostic Test

Variable	**VIF**	**1/VIF**
lp	3.05	0.3283
ft100	2.34	0.4265
lgfcf	2.24	0.4461
i	1.92	0.5203
se	2.01	0.4977
agi	1.64	0.6088
l	1.18	0.8500
Mean VIF	2.05	

Source*: Author's compilation.*

4.3 Dynamic panel estimation result

Table 7 presents the results of this study's dynamic panel estimation techniques. Model (4) provides estimates obtained through DGMM, while model (5) reports the results obtained using SGMM. These estimation techniques are useful for addressing issues related to endogeneity, unobserved heterogeneity, and the inclusion of lagged dependent variables in the assessment.

Table 7: Dynamic panel estimation result

Models	**Model (3)**	**Model (4)**
Variables	**lgdpc**	**lgdpc**
lgfcf	0.198*	0.238*
	(0.0273)	(0.0360)
se	0.0044	-0.0007
	(0.4938)	(0.9022)
l	0.0538*	0.00558
	(0.0441)	(0.7511)
i	0.0085**	0.0042*
	(0.0079)	(0.0452)
ft100	0.0645**	-0.0194
	(0.0046)	(0.0890)
agi	0.0279	-0.154*
	(0.6846)	(0.0327)
lp	0.154	0.222*
	(0.1349)	(0.0312)
L.lgdpc	-0.0132	0.0527
	(0.6049)	(0.2458)
L.lgfcf	0.170*	0.216*
	(0.0397)	(0.0192)
Constant		12.16**
		(0.0033)
Observations	311	348

Number of Groups	22	22
AR (2) statistic	0.147	0.113
Hansen Statistic		0.206

***Source**: Author's compilation*

***Notes**: 1. Model (3) indicates Difference GMM estimates, and Model (4) indicates System GMM estimates. 2. * designates the variable is significant at the 10% level, ** indicates variables are significant at the 5% level, and *** denotes variables are significant at the 1% level. 3. Value within the parenthesis indicates p-value.*

The estimation results for DGMM are reported in Model (4), with a relatively smaller number of observations than SGMM. However, using DGMM has a major shortfall in eliminating fixed effects by first differencing the data set. To address this, SGMM was introduced as a remedy, as suggested by Blundell & Bond (1998).

To determine the choice of estimation between DGMM or SGMM, Bond, Hoeffler, & Temple (2001) recommend comparing the lagged dependent variable outcomes from POLS and FE models. Table 8 provides the analysis outcomes using POLS, which proposes an upper bound estimate and FE indicative of a lower bound estimate. To decide between the DGMM and SGMM, the measurement for the lagged dependent variable from the DGMM estimate (-0.0132) was compared with the fixed effect model estimate (0.0554). The finding indicated that the DGMM was downward biased; thus, SGMM should be considered instead. This comparison provides a useful approach for selecting the appropriate estimation technique for future research.

Table 8: Bound estimate

Models	**Pooled OLS**	**Fixed Effect**
L.lgdpc	0.1518	0.0554
	(0.0000)	(0.0000)

***Source**: Author's compilation*
***Notes**: Value within the parenthesis indicates p-value.*

The issue of overidentification can be assessed by the Hansen statistic, which is recommended when dealing with heteroscedastic matrices. The null proposition proposed is that the overidentifying restrictions are valid. The resulting value of 0.206 suggests we cannot reject the null hypothesis, indicating that the restrictions are valid. Additionally, Roodman (2009) recommends that the p-value fall between 0.1 and 0.8, as a value close to or equal to 1 indicates that the asymptotic properties are unsatisfied. Thus, the optimal criterion falls within that range, indicating our estimation is valid.

In addition, the AR (2) test is commonly employed to test for autocorrelation in idiosyncratic errors, as Arellano & Bond (1991a) specified. The null hypothesis proposed that there is no autocorrelation within the error terms. According to Cameron & Trivedi (2009), the p-value for the AR (2) result is anticipated to be insignificant at a 5% level. In our estimation, the resulting value of 0.114 implies that we cannot reject the null hypothesis, indicating that the error term is not serially correlated.

The result from table 7 indicates a positive correlation between the economy's growth with internet users, innovation, and gross fixed capital formation. However, there is a negative correlation between the institutions and real GDP. Based on the p-value, the relationship between internet users and constant GDP is statistically significant at a 5% significance level. When the variable is in natural logarithm form, a percentage increase in internet users in emerging markets leads to a short-term increase of 0.0042% in constant GDP, holding all other factors constant. The fact that a percentage change in the explanatory variable has less than a 1% impact on the independent variable suggests an inelastic relationship between internet users and economic growth. These findings align with the results of (Sassi and Goaied, 2013; Niebel, 2018).

When examining the proxy of capital investment, the analysis indicates an increasing inelastic relationship. A one percent change in capital investment generates a significant immediate impact of 0.238% on economic growth, while a one-period lagged investment generates a 0.216% increase in economic growth. These results confirm the findings of (Hofman et al., 2016). Additionally, an growing relationship is found between patent and economic growth; a percentage increase in patent application imposes a 0.222 percent rise in economic growth, which align with the result of (Nguyen & Doytch, 2022), supporting the significant effect of patent in the role of ICT infrastructure and economic. Conversely to our expectation, a negative impact is found on the governance indicator. A percentage increase in the institution's governance leads to a 0.154 unit decrease in economic growth. However, the result is supported by (Lin et al., 2022), where the researcher discovered that using institutional factors promotes an inverse impact between developed and developing countries. Further, a negative impact on secondary education, labour force participation, and fixed telephone subscribers shows insignificant negative impacts on economic growth. The insignificance may be justified by the findings of (Bilbao-Osorio and Rodriguez-Pose, 2004), which indicate that only investment in higher education positively correlates with innovation and economic development. In the case of fixed telephone subscribers, the insignificance aligns with the findings of (Thompson and Garbacz, 2011), where no direct effect was found regarding fixed broadband.

In summary, a significant positive impact is discovered for internet users, while negative relation is found with fixed telephone subscribers on the economy's growth. This depicts the pattern of the ICT infrastructure shift from simple fixed telephone to diverse network devices, for example, cellular phones, laptops, and tablets. A positive between economic growth and innovation factor is observed. However, institutions illustrate a negative impact. It shows emerging markets government should shift its policy regarding ICT infrastructure which promotes innovation process, protects intellectual property rights, and reduces the barriers to knowledge transfer.

CHAPTER FIVE

CONCLUSION, LIMITATION, AND POLICY RECOMMENDATION

5. 1 Conclusion

This research examines the interplay between ICT infrastructure, economic growth, patent, and institutional factors across 22 emerging markets. The study's findings reveal that ICT infrastructure, particularly internet usage, has a positive relationship with economic growth in emerging markets. This highlights the importance of policymakers continuing to invest in and broaden their ICT infrastructure to reap the benefits of this positive relationship. Specifically, policymakers should focus on increasing internet usage. This encourages commercial electronic activities and stimulates research and development, leading to the creation of patents and further technological and economic development.

Moreover, the study demonstrates that patent application and institutional factors play a positive role in the economic growth of emerging markets. Policymakers should create an environment that encourages innovation and protects the rights of both firms and individuals, as this can lead to increased economic growth. In particular, the study emphasizes the importance of the governance indicator, as this can serve as a stimulator for economic growth by encouraging firms and individuals to invest and innovate.

To fully capitalize on the opportunities presented by ICT infrastructure development, policymakers should aim to reduce entry barriers and provide incentives for private and foreign sector participation. Upgrading and maintaining the ICT infrastructure is crucial, and policymakers must ensure it is accessible to all citizens to ensure the broadest possible impact on economic growth.

This study provides valuable insights for policymakers and academics promoting economic growth in emerging markets. By focusing on ICT infrastructure, patent protection, and governance factors emerging market economies can unlock their potential for sustainable economic development. As the world continues to move towards the fourth industrial revolution, policymakers must prioritize investment in these areas to remain competitive and ensure the long-term success of their economies.

5.2 Policy Recommendation

The contemporary literature on ICT infrastructure and the growth of the economy emphasizes the correlation between policy and ICT. This study addresses one aspect of this relationship in emerging nations, specifically the role of innovation and institutional quality.

The government should utilize tax subsidies and incentives to improve access to ICT infrastructure. Higher priority should be placed on the internet by encouraging firms to enter the network provider industries, which are dominated by oligopolies in the majority of emerging markets. An increase in competition can reduce the cost of the network and increase efficiency for all users. Investing in internet infrastructure in rural and underdeveloped areas can close the digital divide and increase productivity.

Fostering a supportive institutional environment that facilitates the dissemination of knowledge by investing in education and research is crucial. Encouraging open innovation practices, such as collaboration between firms, can facilitate sharing of knowledge and technology, leading to the creation of new products and services. This, in turn, can promote a culture of innovation and entrepreneurship.

5.3 Limitations of the Study

The empirical analysis of ICT infrastructure on economic growth, as demonstrated at the cross-country level, has only shed limited light on the mechanisms involved in demonstrating the impact of innovation and institutional contribution towards the development of emerging economies. The analysis has been confined to establishing basic interactions amongst common ICT indicators, innovations, and institutions in the growth of emerging market economies, which are recognized to have a digital divide compared with developed markets. Inconsistent record-keeping has hindered the data's accuracy, intensifying the heterogeneity problem. Additionally, the analysis does not account for other ICT indicators, such as mobile cellular and fixed broadband subscribers.

5.4 Suggestions for Further Research

The paper focuses on analyzing the interactions of ICT indicators with institutions and innovation factors on economic growth. For future research, this paper proposes that the other ICT indicators should be included in a more comprehensive manner to analyze the impact from a market basis. The regeneration of ICT at the current time has favoured mobile devices, including smartphones and 5G networks. Further research is interesting to consider the diverse effect of the indicators on the growth of the economy.

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