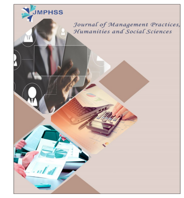
Journal of Management Practices, Humanities and Social Sciences

Vol 7 Issue 3 pp. 35-47

https://doi.org/10.33152/jmphss-7.3.5



ORIGINAL CONTRIBUTION

The Effect of Education, R&D, and ICT on Economic Growth of Middle-Income Countries

Rabia Batool [1*], Hamid Hasan [2]

[1] PHD Scholar, School of Economics, International Islamic University, Islamabad, Pakistan

[2] Assistant Professor, School of Economics, International Islamic University, Islamabad, Pakistan

Abstract— This manuscript examines the impact of education, Research & Development (R&D) and Information and Communications Technology (ICT), on economic growth of middle-income countries using panel data set from1995 to 2019. We employ panel data set using few tests such as panel unit root test and Fully Modified Ordinary Least Square (FMOLS). The main findings indicate mobile subscriptions (proxy of ICT) has positive effect on economic growth of these countries. Education also positively influences economic growth. R&D has been observed to affect economic growth positively. This study concludes with some policy recommendations and suggestions that may be helpful for future studies. It has been found that an increase of the most educated labor force does not lead to a higher growth rate. Therefore, this study concludes that people with tertiary education must be occupied with strong human capital and cognitive skills.

Index Terms— Education, ICT, R&D, Economic growth, Digitalization, Middle income countries

Received: 09 January 2023; **Accepted:** 12 March 2023; **Published:** 31 May 2023

Introduction

Introduction Research on the determinants of economic growth has been one of the most important components of economic research for several decades. All these determinants are invoked, from the great conventional development theories to the modern growth theories, to justify the growth of the gross domestic product or the production process (Saidi & Mongi, 2018).

Then again, endogenous development models recognize those which straightforwardly relate education/human capital with economic growth (Lucas, 1988) and others presented by Romer (1990), Grossman and Helpman (1991) and Aghion and Howitt (1992), who have underscored the vital part of R&D efforts and innovations in driving technical progress, productivity and economic growth. There are only few studies that investigated the impact of education, R&D and ICT on economic growth. Therefore, this study is going to fill this literature gap by examining the combine effect of these variables (education, R&D, and ICT) in the context of middle-income countries.

Education is generally considered to be important and efficient tool for boosting economic growth and improving earnings, discouraging, and reducing poverty, empowering, promoting health and environmental flexibility, and creation of competition in the economy (Shah, 2011). Education helps and encourages the execution and transformation of those new technologies, which are persistently created (Nelson & Phelps, 1966). Furthermore, the benefits of education do not flow spontaneously to the economy and society, and it is necessary to go through a few education cycles. The most adverse situation is the existence of educated unemployment, which limits the contribution of education to the growth of output in the economy (Rathanasiri, 2020)

[*]Email: rabiabatool1991@gmail.com

The indirect role of education in GDP per capita is through research and development activity (R&D). Thus, some models from endogenous growth theories no longer consider education as a factor of production but as a factor of innovation. Which makes it possible to increase the efficiency with which it is possible to produce wealth from capital and labor by the accumulation of an intangible stock of ideas and knowledge. Thus, education can have another role, to promote technological innovations and their adaptation (Lucas, 1988).

Therefore R&D not only creates knowledge but also makes better use and capitalization of existing knowledge and the most efficient technologies are adopted and implemented faster by the countries with the richest advanced human capital (Nelson & Phelps, 1996; Cohen & Levinthal, 1989). The core assumption of the literature is that R&D drives economic growth through the stream of innovations it produces. More recently, emerging empiric literature has considered the role of foreign R&D knowledge spillovers in understanding productivity growth. R&D investment has historically been seen as one of the main strategies for capturing technical potential and, thus, innovation and economic development (Trajtenberg, 1990).

R&D can have both positive and negative externalities. This leaves the question of whether under-or over-investment in R&D (compared to the social optimum) is technically unclear. By attempting to shed light on this uncertainty, both are empirical proof and calibration exercises in R&D-based economic growth models strongly suggest that the social return to R&D greatly exceeds the private return to R&D (e.g., Jones & Williams, 1998, 2000; Park, 2004; Alvarez-Pelaez & Growth, 2005). For instance, Jones and Williams (1998) argue that a "conservative estimate indicates that optimal investment in research is more than two to four times actual investment" (p. 1134).

The world has undergone remarkable changes over past few decades as the ICT revolution has gained momentum, rapidly spreading across nations, sectors, and organizations. Although ICT has a profoundly transformative influence on how individuals and organisations communicate, work, and spend their time, quantitatively establishing the link between ICT and economic performance has been proven difficult. Indeed, for the last three decades, many economists have been troubled by the "productivity paradox," which has gained attention since Nobel Laureate Robert Solow famously said in 1987 that computers are everywhere except in productivity statistics. As a result, a wealth of research has been produced, most of which focuses on examining the causal link between ICT and economic growth (Vu, Hanafizadeh, & Bohlin, 2020)

The relationship between ICT and growth is another important element in economic literature. Accelerating the widespread use of ICT has been one of the most remarkable advances over the past thirty years. In both developed, emerging, and developing nations. ICT has emerged as one of the key vectors of economic and social activity (Saidi & Mongi, 2018). Increased investment in ICT in many developed and newly industrialized countries led to increased productivity and output growth in the second half of the 1990s (Lee et al., 2009).

Encouraging ICT is important for most authors, both for improving living conditions and fostering entrepreneurship, creativity, and economic growth, indicating that ICT can promote cross-border communication, financial transactions, and knowledge and information sharing, and can also play a catalytic role in regional integration and trade facilitation (Saidi & Mongi, 2018).

The major contribution of this paper is to check the impact of education, R&D and ICT on economic growth of middle income countries by using Fully Modified Ordinary Least Square (FMOLS). To the best of author's knowledge a very limited research work has been done on above mentioned variables.

The main objective of this study is to determine whether education, R&D, and ICT contribute to improving the performance of economic growth of middle-income countries during the period from 1995 to 2019, using econometric tools. The rest of the paper is organized as follow Section 2 provides a brief summary of the literature on related research. The data and the model definition are presented in section 3. In Section 4, the empirical findings are discussed. Section 5 closes and offers policy implications towards the end.

Literature Review

Since 1960, the interaction between education and economic growth has been investigated with micro-approaches (Psacharopoulos, 1995; Bouaissa 2009) and macro-approaches (Pereira & Aubyn 2009; Odit, Dookhan, & Fauzel 2010).

Existing economic literature accepts education as one of the primary components of human capital. Human capital refers to the stock of competences, knowledge and personality attributes embodied in the ability to perform labor to produce economic value (Bashir, Iqbal, & Zaman, 2011). Education helps and facilitates the implementation and adaptation of those new technologies, which are continuously invented, (Nelsonand Phelps, 1966). Educated human capital encourages and understands the use and importance of technology. Whereas technology takes place in organizations due to educated people. It gives time to make people productive, dynamic, and flexible according to the threats and opportunities, which enables them to walk in the world. Education plays a basic role in growth determination, (Schultz, 1961). The search for new ideas has resulted in domestic technological advancement (Romer, 1990a; Grossman & Helpman, 1991).

Development in education covers the avenues, which start from economic progress to overall national development. It has been found that education was an important determinant of farmer's income (Schultz, 1961). Barro (1991) estimates that the shift from the secondary school enrollment rate of 50% to 100% increases the annual growth rate of income by about 1%. In addition, Benhabib and Spiegel (1994) have studied if the educational attainment of the labor force affects the output and the growth of an economy. They propose an approach associated with the theory of endogenous rooting, which consists in modeling technological progress as a function of the level of education or of human capital and have shown that the stock of human capital plays a key role.

The main studies that have investigated the impact of the educational levels on economic growth are presented below: Liu and Armer (1993) found that both primary and junior-high achievement variables enhance economic growth in Taiwan, but senior-high and college education did not exert any significant effects on growth. Tallman and Wang (1994) showed that higher education has a greater positive impact on growth in relation to primary and secondary education for the case of Taiwan. Mingat and Tan (1996) for a sample of 113 countries found that higher education has a positive statistically significant impact only in the group of developed countries, while the primary has a positive effect in less developed and the secondary a positive effect in developing. Gemmell (1996) for OECD countries concluded that primary education most affects the less developed countries, while secondary and higher education the developed. Mc Mahon (1998) investigated the effect of the three levels of education on economic growth for a sample of Asian countries and concluded that primary and secondary level have a significantly positive effect on economic growth, while higher is negative. Abbas (2001) for the countries of Pakistan and Sri Lanka showed that the primary has a negative effect on economic growth, while secondary and higher education have a positive and statistically significant impact on economic growth in both countries. Rathanasiri (2020) looked at the relationship between government spending on education and economic growth in Sri Lanka from 1974 to 2018 and discovered a positive and significant relationship between higher education spending and economic growth, but a negative relationship between general education spending and education. Petrakis and Stamatakis (2002) found that the growth effects of education depend on the level of development; low-income countries benefit from primary and secondary education while high-income developed countries benefit from higher education. Self and Grabowski (2004) for the case of India showed that except higher education the primary and secondary education had a strong causal impact on economic growth. Villa (2005) investigated the effect of the three levels of education on economic growth for Italy and found that the higher and secondary education has a positive effect on economic growth, while the primary has no significant effect. Gyimah-Brempong, Paddison, and Mitiku (2006) found that all levels of education have a positive and statistically significant impact on the growth of per-capita income in African countries. Lin (2006) for the case of Taiwan found that primary, secondary, and tertiary have a positive impact on economic growth. Chi (2008) showed that in China higher education has a positive and larger impact on GDP growth than primary and secondary education. Pereira and Aubyn (2009) showed that in Portugal primary and secondary education has a positive impact on GDP, while higher has a small negative effect. Loening, Bhaskara, and Singh (2010) for the case of Guatemala found that primary education is more important than secondary and tertiary education. Shaihani et al. (2011) for Malaysia concluded that in the short run only secondary education has a positive and statistically significant coefficient, while the primary and tertiary exhibit negative and statistically significant results. Unlike in the long run only higher has a positive and statistically significant effect.

While Krueger and Lindahl (2001) noted that education is statistically significant and positively related to growth, only for countries with low levels of education.

Barro (2001) uses an endogenous growth model and finds a positive role of education on growth with its sample of 100 countries over the period 1960-1995. These results show that taking into account the quality of education is more important than its quantity measured by the average levels of completion of secondary and higher education. Altinok (2007) uses new indicators, constructed from international surveys of student achievement, to test the relationship between education and growth. Taking into account the endogeneity of education, it leads to a positive effect, both of the quantitative and qualitative indicators of human capital, on the growth of a sample of 105 countries over the period 1960-2000.

Pradhan (2009) examines the causal link between education and economic growth in India during the period1951-2001 through an empirical survey carried out by correlation error modeling. The results of this survey confirmed that there is a unidirectional causality between education and economic growth. In fact, education and especially at the higher level contributes directly to economic growth by making workers more productive and indirectly by leading to the creation of knowledge, ideas, and technological innovations.

Recently, Wang and Liu (2016) have proposed a panel data model to investigate the impact of education on economic growth, using the latest education data of 55 countries and regions from 1960 to 2009. The results obtained indicated that whether it is developed country or developing country education human capital and economic growth all showed a significant positive correlation and that primary education and secondary education does not have significant positive impact on economic growth while higher education has significant positive effect on economic growth. Hanif and Arshed (2016) used three variables for the education for the panel data of SAARC countries, collected from 1960 to 2013, to see whether higher education has better marginal impact on the growth of these countries. The empirical results reveal that tertiary education enrollment has highest impact on growth as compared to primary and secondary education enrollment.

Education could be one of the reasons as to why most developing countries are not getting the full benefit package of technological progress. Paying bills online, for example, does require not only the buyer to have computer and the Internet knowledge, but the vendor to develop and maintain such a billing technology (Adonsou, 2019). Traditionally, investment in R&D has been regarded as one of the key strategies to secure technological potential and, therefore, innovation and economic growth (Trajtenberg, 1990). R&D investment increases the possibility of achieving a higher standard of technology in firms and regions, which would allow them to introduce new and superior products and/or processes, resulting in higher levels of income and growth. Equally, Romer (1990) and Lichtenberg (1992) have shown the relationship between investment in technology and R&D expenditure and increases in productivity and growth. To reduce the reliance on production technology, nations and businesses must foster domestic innovation and boost knowledge transfer (Long et al., 2019; Zhu et al., 2020). As a result, innovation has emerged as a key component of sustaining superior performance, gaining a competitive edge, advancing the economy, and, most significantly, attaining economic growth in the current global economy (Sesay et al., 2018).

There are two roles or 'faces' of research and development (R&D) activity. The first of these roles is in stimulating innovation and has perhaps received most attention in the existing empirical literature. The second role is in facilitating the understanding and imitation of others' discoveries (Griffith, Redding & Reenen, 2001). R&D may have positive as well as negative externalities. This leaves the question whether there is under- or overinvestment in R&D (compared to the social optimum) theoretically ambiguous. By trying to shed light into this ambiguity, both empirical evidence and calibration exercises in R&D-based models of economic growth strongly suggest that the social return to R&D significantly exceeds the private return to R&D (Alvarez-Pelaez & Groth, 2005; Jones & Williams, 1998, 2000; Park, 2004).

Recent theories of economic growth draw attention to endogenous technological change to explain the growth patterns of world economies. According to these so-called endogenous growth models, pioneered by Romer (1986), technological innovation is created in the research and development (R&D) sectors using human capital and the existing knowledge stock. It is then used in the production of final goods and leads to permanent increases in the growth rate of output. At the heart of these models is their postulation that endogenously determined innovation enables sustainable economic growth, given that there are constant returns to innovation in terms of human capital employed in the R&D sectors. Frantzen (2000) supports the view that both R&D and human capital play an important role in productivity. Using data for several OECD countries over the period 1965-1991, the author shows that both domestic and foreign R&D have a significant impact on productivity, but the impact of domestic R&D played more significant role in growth in richer countries, because of their size, as compared to smaller economies, which benefit more from foreign technology spillovers. There is also strong evidence that R&D spillovers from industrialized countries to developing countries have positive effects on the TFP growth of the latter (Coe, Helpman, & Hoffmaister, 1995; Griffith, Redding, & Reenen, 2001).

According to Savvides and Zachariadis (2003), both domestic R&D and foreign direct investment increase the domestic productivity and value-added growth. Zachariadis (2003) compares the effect of R&D on aggregate and manufacturing output and finds that the effect of R&D is much higher for aggregate economy than the manufacturing sector. Gyedu et al (2021) has investigated the impact of innovation on economic growth among the G7 and BRICS countries, from the period 2000-2017. To study the phenomena, the authors used a panel VAR estimator in the GMM approach. Findings showed that R&D, patents, and trademarks—three factors that determine innovation—have a considerable influence on GDP per capita and are factors in both G7 and BRICS nations' economic growth. Hall and Mohnen (2010) conclude that the private returns to R&D are strongly positive in many countries and somewhat higher than those for ordinary capital, while the social returns are even higher, although variable and imprecisely measured in many cases. Khan and Rehman (2014) examine the significance of R&D for economic growth in Pakistan over a period of 1971 to 2009. The results obtained from the Ordinary Squares method showed that R&D contributes significantly in the Real GDP per capita in Pakistan. The Johansen Cointegration test confirmed the existence of long run relationship between R&D and economic growth. Thus, according to the authors, it is recommended to increase investment in R&D to achieve sustained economic growth. It is also recommended to collect and record quality R&D data for effective policy making in the field of science and technology, and social sectors in Pakistan.

Luintel and Khan (2016) investigate the relationship between R&D and economic growth in emerging countries by using a panel of 31 emerging countries. The results indicate convincing evidence of scale effects, which make government policies potent for long-run growth. Innovations show increasing returns to knowledge stock, implying that the diminishing returns assumed by some semi-endogenous growth models might not be generalized. International R&D spillovers raise the innovation bar. Econometric tests of scale effects reveal a statistically significant proportional relationship between the level of R&D inputs and the growth rates of per capita real, productivity, and technology.

Embracing Information and Communication Technology (ICT) has been offering a nation with competitive advantage, convenience, and quality of life. The way people work, communicate, and spend time is now profoundly being influenced by use of ICT. According to Digital Planet, a publication by World Information Technology and Services Alliance (WITSA), global ICT spending grew from $2 trillion in 1999 to approximately $4.7 trillion in 2013 in spite of the great recessionary decline of 3% in 2009 from the 2008 level of spending (Nayam & Hossain, 2016).

The contributions of IT (Information Technology) to economic growth have drawn the attention of researchers and policy analysts since long ago. A large number of studies have tried to explore the role of investment in economic growth and development of nations. Application of ICT can make production more efficient by enhancing existing products and creating new products and services. IT can improve organizational efficiency and responsiveness by increasing its connectivity with the market, customers, suppliers, and other stakeholders.

IT use will increase national productivity by improving both labor productivity and capital productivity. IT is also expected to increase economic growth by creating new industries related to IT use. Though economic growth may be affected adversely if IT use leads to elimination of jobs due to redesign of business processes, these losses should be compensated by the new employment opportunities created by economic growth in IT and non-IT areas.

Productivity growth lays the foundation for improvements in the standard of living. Investments in ICT are seen as a key driver of productivity growth. Literature reviews by Draca et al. (2007), and Cardonaet al. (2013) list a comprehensive set of studies applying different methodologies. To date there is rather weak and ambiguous empirical evidence on the contribution of ICT investments on economic growth for emerging and especially developing countries. Despite the rather ambiguous empirical evidence, the World Bank (2012) takes an optimistic view stating, "ICTs have great promise to reduce poverty, increase productivity, and boost economic growth". The weak and ambiguous empirical evidence of the impact of ICT in developing countries may largely be driven by the lack of high quality micro and macro level data sets on ICT for these countries.

Growth accounting and econometric studies provide the foundation for the macro-level empirical research on the link between ICT and economic growth. ICT capital made economically substantial contributions to economic development in developed nations after the mid-1990s, according to several growth accounting studies (Niebel, 2018).

A priori, there may be valid reasons why the impact of ICT on growth in developing and emerging countries is different from in developed countries. On the one hand, developing and emerging countries might be lacking absorptive capacities like an appropriate level of human capital or other complementarily factors such as R&D expenditures and therefore gains less than developed countries from investments in ICT (Niebel, 2018). On the other hand, ICT could enable developing and emerging countries to 'leapfrog' traditional methods of increasing productivity as mentioned by Steinmueller (2001). The additional productivity gains could be triggered by "ICT-related spillovers or network effects" as ICT may lower transaction costs and speed up the process of knowledge creation. However, these network effects may be more pronounced "when many firms in a region or industry are using similar levels or types of ICT" (Niebel, 2018).

In the past decade, a number of macro-level econometric studies on ICT and productivity in developed countries have been carried out. Stiroh (2002) surprisingly finds a negative output elasticity of ICT capital in his pooled OLS and IV regressions based on US manufacturing industries data for the years 1984-1999. With an updated data set and more detailed industry breakdown, Stiroh (2005) reports positive coefficients of ICT capital in the production function regressions. Oliner and Sichel (2000) found higher contributions. Quah (2002), emphasizing demand over supply, argues that the Information and Communication Technology (ICT) revolution is fostering improvement in labor skills, consumer sophistication, and an increased level of broad-based education. This encourages the improved use of technology and raises labor productivity and as a result, ''drives economic growth, one way or another'' (Quah, 2002, p. 22). Levine (1997) argues that relaxing barriers to information access, of which ICT is believed to be an important driver, promotes faster growth by encouraging increased investment. Even before the Emergence of ICT, the impact of improved access to information and effective communication on economic growth were observed in several economies, such as Japan, Korea, Hong Kong and Taiwan. Their outstanding economic growth during the second half of the 20th century has been attributed, impart, to the fact that their firms and people had better access to market in formation. In addition, they benefited from more effective communication with foreign partners and each other. The link between investment, information technology and growth has been investigated by a wealth of studies.

At the firm and industry levels, Brynjolfsson and Hitt (2003) found appositive relationship between computer investment and firm productivity levels: firms that invested more in computers produced more output per unit of input. Qiang (2009) estimated the effect of ICT on growth for a sample of 120 developed and developing countries over the period 1980-2006. Its results indicate that increase a 10% of the ICT adoption rate has resulted in an increase of 0.81% of economic growth in low- and middle-income countries. Stanley et al. (2018) confirms the growth effect of ICT, with wireless technologies being around twice as powerful as landlines. They do this by using a meta-regression analysis to the results from 59 econometric research on the ICT-productivity relationship using the cut-off of February 2014. Additionally, developed countries have reaped greater benefits from computers than developing ones. The data supporting the growing impact of the internet is still scant, though.

In developing countries, digitalization also plays an important role, mainly through lowering communication costs from the early 2000s. This has played a role in helping the poor in rural areas with limited access to almost all essential services, such as water and electricity (Myovella, Laracuka, & Haucap, 2020). ICT diffusion has substantially improved the efficiency of resources allocation, enormously reduced production costs, and promoted much greater demand and investment in all economic sectors (Jorgenson & Kevin, 1999).

Research on developing nations is still scarce. Two factors might be blamed for the inconsistent results. First, aggregated data is used to determine the connection between ICT and economic growth. Disaggregated statistics, however, are unable to accurately reflect either the variety of ICT development across various economic sectors or realistic ICT integration in the economy for emerging nations. Second, the lack of adequate ICT infrastructure in the majority of developing nations forces large investments in ICT projects, which may have an immediate negative impact on profitability (Kallal, Haddaji, & Ftiti, 2021)

Other than the greater role that telecommunication services could play regarding economic growth, its effect might depend on a country's development level (Ward & Shilin, 2016).

There has been an enormous growth in the number of households utilizing computers and the internet. According to ITU (2018) statistics, ICT usage has been globally on the rise. At the end of 2018, 51.2% of the global population, 3.9 billion people, was estimated to use the Internet. Additionally, mobile broadband subscriptions and mobile phone subscriptions were at levels of 69.3 and 107 per hundred people, respectively. ITU statistics show that the telecommunication infrastructure is mostly used in regions where the literacy rate is higher. For instance, in 2017, the adult literacy rate in high-income countries was 98.67%, while that of the low-income countries was 62.75%. For the same period, the Internet users, broadband subscription, and mobile phone subscription were observed to outnumber their corresponding value in High-income countries. In the Middle East countries, the number of people using the internet has increased from 2.1% in 2005 to 24.4% in 2017, whereas mobile subscriptions stood at 120 per 100 inhabitants (WDI, 2018). The intuitive implication could be the fact that countries with better education access seem to make the best use of telecommunication infrastructure.

Two of the most commonly used indicators of economic development are inflation and economic growth. But today's steady state equilibrium of income per capita and output per worker across world economies varied greatly due to differences in the rate of growth (World Bank, 2020). Generally speaking, policymakers are responsible for creating and enacting macroeconomic measures that, among other goals, result in the achievement of a high and sustainable rate of economic growth (Ghosh & Phillips, 1998).Most developmental economists and politicians now believe that rapid and sustainable growth can only occur in an environment where inflation is under control as a result of the macroeconomic distress that the Organization for Economic Co-operation and Development countries experienced between 1973 and 1984, when inflation averaged 13 percent (Andrés & Hernando, 1997). The existence and nature of the relationship between inflation and economic growth have thus been hotly contested, with contradictory and conflicting conclusions, ever since the birth of Keynesian economics in the late 1930s (Eggoh & Muhammad, 2014; Iqbal & Nawaz, 2009; Andrés, Hernando, & Lopez-Salido., 2004; Mallik & Chowdhury, 2001; Fischer, 1993; Lucas, 1973). Due to the varied and conflicting empirical data on the relationship between inflation and economic growth, the literature on the inflation-growth nexus is neither complete nor universal (Saungweme, 2021).

Methodology

Theoretical Framework

Since 1960, the relationship between education and economic growth has been explored through micro-approaches (Psacharopoulos, 1995; Bouaissa, 2009) and macro-approaches (Pereira & Aubyn, 2009; Odit, Dookhan, & Fauzel, 2010). Current economic literature recognizes education as a primary component of human capital. Human capital refers to the stock of competencies, skills, and personality traits expressed in the capacity to perform labor in order to generate economic value (Bashir, Iqbal & Zaman 2011). As indicated by macro-economic literature, the two main approaches are the augmented Solow neoclassical approach and the "new or endogenous growth theories" (Sianesi & Van Reenen 2003).

The augmented neoclassical model (Mankiw, Romer, & Weil, 1992) simply broadens the basic Solow's (1956) model with education/human capital as an additional production factor. Various studies have focused on that topic (Arnold, 2002; Strulik, 2005; Bucci, 2008, etc.). While education has no role in traditional neo-classical theories of economic growth, these new approaches have explicitly brought the role of education to the fore. A key difference between the new growth theory and the neoclassical growth theory involves the distinction between increasing and decreasing returns to scale. The basic underlying assumption of neoclassical theory is that diminishing returns to capital operates in the production process, while endogenous theory supports the assumption that the production function does not exhibit diminishing but increasing returns to scale. While there is a large amount of evidence on the link between education and economic growth, the effect of formal education levels on economic growth with macro-economic approaches has been studied in the last two decades. The fact that different levels of formal education may have different effects on growth has been addressed in a small set of recent papers (Pegkas & Tsamadias, 2015).

According to Solow model, only technological progress can explain the persistent rise of living standards (Mankiw, 2003). In the following, new growth theories identified technological progress as a factor of great importance concerning economic growth as developed by Mankiw, Romer, and Weil (1992). However, on the contrary to the Solow growth model, where in technology is considered as exogenous, a new growth model emerged to endogenize technological progress. Moreover, it is argued that rates of modern technology do not only affect economic growth and development, but also outcomes such as life expectancy, levels of democracy, health outcomes, poverty rates and literacy (Grossman & Helpman, 1991). Believe that innovation and improvement of existing products stimulates growth Oliner et al. (1994) used the neoclassical framework and incorporate information technology into the growth model. They demonstrate that the growth rate of output depends not only on computing equipment (stock of computers), but also on other types of capital, labor, and multifactor productivity.

Empirical Model:

The main objective of this study is to analyze the impact of Education (ED), Research & Development (R&D) and ICT on Economic growth (GDP) for middle income countries using annual data over the period of 1995–2019.Vu (2013), Yousefi (2011), among others, included the ICT variables in their empirical models to examine their impacts on economic growth. Furthermore, Aghion et al. (2009), Odit (2010), Solaki (2013), among others, include the education variables in their empirical models to examine their impacts on economic growth. In addition, several authors include the R&D variables in their empirical models to examine their impacts on GDP per capita as (Bronzini & Piselli, 2009; Hall et al. 2010; Khan & Rehman, 2014, Blanco, 2016). Inflation is included as a control variable also added by Hanif and Arshad (2016). The general specification of the model we want to estimate can be written as follows:

$$Y_{it} = \beta_0 + \beta_1 ED_{it} + \beta_2 RND_{it} + \beta_3 MCS + \beta_4 X_{it} + \varepsilon_{it} \tag{1}$$

For *i* = 1,... N; *t* = 1995 to 2019

is the constant terms,'t' is the time period, 'i' is the number of countries, X_{it} is representative of control variable which is inflation and 'ε_{it}' is the error term. Where Y_{it} is a GDP per capita (constant 2015 US$), ED is the education, R&D is the research & development, MCS is a mobile cellular subscription, and INF is the inflation rate.

Table I
Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
GDP	300	3.651544	0.593376	2.651544	4.786566
ED	236	73.81645	20.37319	22.51146	107.8590
R&D	199	1.180187	1.577426	0.047560	14.49976
MCS	293	69.97764	61.50380	0.007955	291.6536
INF	300	4.877202	5.004091	-4.009434	58.45104

The Data: Source and Description

In this study, over the period 1995-2019, unbalanced panel data is used to examine the impact of Education, ICT and R&D on economic growth of twelve Middle Income Countries (China, Hong Kong, India, Indonesia, Korea, Malaysia, Nepal, Pakistan, Philippines, Singapore, Sri Lanka & Thailand). The countries were chosen based on the fact that these twelve are middle income countries, with the potential to evolve into developed countries in the twenty-first century. Emerging economies are diversifying their economies as well as becoming more influential in the global economy (Trichet, 2007). The choice of sample and period was dictated by the availability of data as well. All data were extracted from the World Development Indicator (WDI). Therefore, we estimate the long-run coefficients using the FMOLS.

Table II
Variables & Description

Indicator	Explanation	Source
Education (ED)	School enrollment, secondary (% gross)	World bank. World development indicators database (WDI)
Research and Development (R&D)	As measured by the research and development expenditure (% of GDP)	World bank. World development indicators database (WDI)
Mobile Cellular Subscriptions (MCS)	As measured by the mobile cellular subscriptions (per100 people)	World bank. World development indicators database (WDI)
Inflation(INF)	As measured by the consumer prices (annual %)	World bank. World development indicators database (WDI)
Economic Growth	As measured by the GDP per capita (constant 2015US$)	World bank. World development indicators database (WDI)

There are different methods of cointegration estimation in panel data such as DOLS, FMOLS, and OLS . In this analysis, the data consists of a panel of 12 countries for 24 years, where *N* = 12, which is less than T = 24. OLS cannot be applied in case of endogeneity problem whereas the Generalized Method of Moments (GMM) has a problem of number of instruments when T is greater than *N*. Moreover, these parametric methods have strong distributional assumption, which are rarely satisfied. In such situation, the OLS and the GMM estimator are not appropriate for our analysis. Therefore, this research applied Panel Fully Modified Ordinary Least Squares (Phillips & Hansen, 1990) to check the impact of education, R&D and ICT on economic growth. Fully Modified Ordinary Least Square is better than Ordinary Least Squares because it addresses the issue of endogeneity by include leads and lags. FMOLS is a non-parametric approach that measures the correlation between the first alternatives of independent variables and the error term, as well as the presence of a constant term, to solve serial correlation reforms (Mehrara, 2007). White heteroskedastic standard errors are also applied. FMOLS does the same thing utilizing a nonparametric method.

ANALYSIS OF EMPIRICAL RESULTS

Several panel unit root tests have been proposed in the literature to examine the stationarity hypothesis. Hence, panel unit root tests can be classified in many ways. The unit root panel tests are based on IPS tests of time series. Moreover, the central hypothesis of these tests is based on the notion of independence between the individuals of the panel. In the following, an attempt is made to present the various tests in the following tables:

Table III
Results of Unit Root Test

Variables	Level	First Difference	Integration
GDP	-1.9270 (0.0270) **		I (0)
ED	-0.5849 (0.7207)	-2.9741 (0.0015) ***	I(I)
R&D	-1.7622 (0.9610)	-8.7187 (0.0000)***	I(I)
MCS	-0.1747 (0.5694)	-14.4070 (0.0000) ***	I(I)
INF	-4.5653 (0.0000) ***		I (0)

***$p < 0.01$),**$p < 0.05$, *$p < 0.1$

The results of the Table III show that two of the variables are stationary at level and three at first difference. IPS (2003) tests applied to check the stationarity of data. The verification of the stationarity of all the variables of the panel in the first difference leads us to study the existence of a long-term relation between these variables.

In the Table IV, most of the values of coefficients are statistically significant, and the signs are consistent with prior research. More precisely Education (secondary) has positive and significant impact on economic growth, same results are drawn by Keller (2006). Hanif and Arshad (2016) have found that the relationship between education (school enrollment, secondary (% gross) and the growth is positive that shows education is a significant primary input factor for the growth of an economy. Whereas Mobile Cellular subscription which is proxy for ICT is showing positive and significant relation with economic growth. As Niebel (2014) found similar results by investigating the impact of ICT on economic growth in the Middle East and North Africa (MENA) employing a panel Generalized Method of Moment (GMM) over the period of 2007–2016. The results revealed that information and communication technology, such as mobile phone, internet usage, and broadband adoption, were the main drivers of economic growth. The same results are also shown by Myovella, Laracuka, and Haucap (2018) for Sub Saharan Africa (SSA) in comparison with the 33 OECD. R&D has positive and significant impact on economic growth of sample countries and it plays important role in improving productivity. These results are consistent with Khan and Rehman (2014), Blanco et al. (2016) and Luintel and Khan (2016). Inflation which is a control variable, the coefficient of inflation has a negative sign and statistically significant. The proxy of consumer prices (annual %) is used to measure inflation and negative sign shows that inflation has negative impact on economic growth. Inflation is used as control variable followed by Hanif and Arshad (2016). Saungweme (2021) revealed that inflation has a statistically significant negative influence on long-term economic growth. They have used Annual growth rate of the consumer price index as proxy of inflation.

Table IV
Fully Modified Least Square (FMOLS)

Variables	Coefficient (p value)
Education	0.004 (0.0886) *
Mobile cellular subscription	0.001 (0.0248) **
Research & Development	0.123 (0.0000) ***
Inflation	-0.021 (0.0002) **

(***$p < 0.01$, **$p < 0.05$, *$p < 0.1$)

Conclusion and Policy Recommendations

This paper has empirically examined how the Education, R&D and ICT has affected economic growth of middle-income countries during the period 1995-2019 by using Fully Modified Ordinary Least square (analyzing a group of twelve middle income countries). Education has long been viewed as an important determinant of economic well-being which is very important variable of our studies, has positive and significant impact on economic growth. Mobile Cellular Subscription proxy is used to measure ICT which has positive and significant impact. R&D has the positive and significant impact on economic growth of middle-income countries.

For future development stakeholders in sample nations should work on resolving the uneven geographical distribution of higher education resources for future growth. To increase the beneficial impact of innovation on economic development, government should encourage colleges to collaborate with businesses. Enterprises' potential to innovate should be fully leveraged, and R&D investment from companies should be strengthened to boost technical innovation and resource integration. Moreover, the government should encourage businesses to collaborate with universities and research institutions to create high-level technology centres, engineering technology research centres, and valuable patent development and demonstration centres. The findings show that for policymakers must carefully prepare to guarantee a holistic co-development policy framework is in place to strengthen R&D, increase ICT adoption, quality education, and promote economic growth with the middle-income countries in order to continue stable economic growth in these countries. Economic agents can expand their access to resources, information, expertise, and markets by rising advancements in digital technology (derived from the R&D activities in the ICT sector).

Despite encouraging results, the usual warning holds true: there is always need for more research. We did not consider the aspect of quantifying the quality of ICT and internet consumption in terms of productive use of these networks. There should be a distinction between using ICT for recreational purposes such as gaming, chatting, or other forms of amusement and utilising ICT for productive objectives such as helping business administration or digitalizing industrial processes. Moreover, impact of R&D and Education on growth can be checked by using other proxies available and by changing the sample countries.

The fact that this study only takes into account the interacting links among higher education, economic growth, and innovation capability from the perspective of space and time evolution has several drawbacks despite the value of the study. The mechanics of the connection between the three can be thoroughly analysed in future research by a wide range of scientists. In the study that follows, they will be able to give a deeper discussion using information from numerous businesses, academic institutions, and diverse regional examples.

REFERENCES

Abbas, Q. (2001). Endogenous growth and human capital: A comparative study of Pakistan And Sri Lanka. *The Pakistan Development Review, 40*(4), 987-1007. https://doi.org/10.30541/v40i4IIpp.987-1007

Aghion, P. & Howitt, P. 1992. A model of growth through creative destruction. *Econometrica, 60*, 323-51. https://doi.org/10.2307/2951599

Aghion, P., Boustan, L., Hoxby, C., & Vandenbussche, J. (2009). The causal impact of education on economic growth: evidence from US. *Brookings papers on economic activity, 1*(1), 1-73.

Altinok, N. (2007). *Human capital quality and economic growth* (working paper). Institut de Recherche sur l'Education

Alvarez-Pelaez, M. J., & Groth, C. (2005). Too little or too much R&D?. *European Economic Review, 49*(2), 437-456. https://doi.org/10.1016/S0014-2921(03)00045-X

Andrés, J., & Hernando, I. (1999). Does inflation harm economic growth? Evidence from the OECD. In *The costs and benefits of price stability* (pp. 315-348). University of Chicago Press.

Andrés, J., Hernando, I. & Lopez-Salido, J.D. (2004). The role of the financial system in the growth-inflation link: The OECD experience. *European Journal of Political Economy, 20*(4), 941-961.

Arnold, L., G. (2002). On the effectiveness of growth-enhancing policies in a model of growth without scale effects. *German Economic Review, 3*(3), 339-346. https://doi.org/10.1111/1468-0475.00063

Barro, R. (2001). *Economic Growth in East Asia Before and After the Financial Crisis* (Working paper 8330). National Bureau of Economic Research. https://doi.org/10.3386/w8330

Barro, R.J. (1991). Economic growth in a cross section of countries. *The Quarterly Journal of Economics, 106*(2), 407-443. https://doi.org/10.2307/2937943

Bashir, M., Iqbal, M. & Khalid Zaman, K. (2011). Estimating private rate of return on higher education in Pakistan. *Review of Economic and Business Studies, 4*(1), 179-197.

Blanco L., Gu, J. & Prieger, J., (2016). The impact of research and development on economic growth and productivity in the U.S. States. *Southern Economic Journal, 82*(3), 914-934. https://doi.org/10.1002/soej.12107

Bouaissa, M. (2009). *Human capital theory, returns to education and on the job learning: evidence from the Canadian data, preliminary and incomplete version*. CEA, 43rd Annual Conference, University of Toronto, Ontario.

Bronzini, R., & Piselli, P. (2009). Determinants of long-run regional productivity with geographical spillovers: The role of R&D, human capital and public infrastructure. *Regional science and urban economics, 39*(2), 187-199.

Brynjolfsson, E., & Hitt, L. M. (2003). Computing productivity: Firm-level evidence. *Review of economics and statistics, 85*(4), 793-808. https://doi.org/10.1162/003465303772815736

Bucci, A. (2008). Population growth in a model of economic growth with human capital accumulation and horizontal R&D. *Journal of Macroeconomics, 30*(3), 1124-1147. https://doi.org/10.1016/j.jmacro.2007.07.011

Cardona, M., Kretschmer, T., Strobel, T., 2013. ICT and productivity: Causality. *International Journal of Economic Practices and Theories, 3*(2), 133-139.

Chi, W. (2008). The role of human capital in China's economic development: Review and new evidence. *China Economic Review, 19*(3), 421-436. https://doi.org/10.1016/j.chieco.2007.12.001

Coe, D. T. (1995). *Elhanan Helpman and Alexander W. Hoffmaister. North-South R&D Spillovers* (Working Paper No WP/94/144) International Monetary Fund. https://doi.org/10.5089/9781451856385.001

Cohen, W., & Levinthal, D. (1989). Innovation and Learning: The two faces of R&D. *Economic Journal, 99,* 569-96. https://doi.org/10.2307/2233763

Jorgenson, D. W., & Stiroh, K. J. (1999). Information technology and growth. *American Economic Review, 89*(2), 109-115. https://doi.org/10.1257/aer.89.2.109

Draca, M., Sadun, R., & Van Reenen, J. (2007). Productivity and ICT: A Review of the Evidence, In Mansell, R., C. Avgerou, D. Quah and R. Silverstone *The Oxford Handbook of Information and Communication Technologies*. Oxford, UK.

Eggoh, J. C., & Muhammad, K. (2014). On the nonlinear relationship between inflation and economic growth. *Research in Economics, 68*(2014), 133-143. https://doi.org/10.1016/j.rie.2014.01.001

Fischer, S. (1993). The role of macroeconomic factors in growth. *Journal of Monetary Economics, 32*(3), 485-511. https://doi.org/10.1016/0304-3932(93)90027-D

Frantzen, D. (2000). R&D, human capital and international technology spillovers: A cross-country analysis. *Scandinavian Journal of Economics, 102*(1), 57-75. https://doi.org/10.1111/1467-9442.00184

Grossman, G. M., & Helpman, E. (1993). *Innovation and growth in the global economy*. MIT press.

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A contribution to the empirics of economic growth. *The Quarterly Journal of Economics, 107*(2), 407-437. https://doi.org/10.2307/2118477

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. https://doi.org/10.1016/j.telpol.2018.08.005

Gemmell, N. (1996). Evaluating the impacts of human capital stock and accumulation on economic growth: some new evidence. *Oxford Bulletin of Economics and Statistics, 58,* 9-28. https://doi.org/10.1111/j.1468-0084.1996.mp58001002.x

Ghosh, A., & Phillips, S. (1998). Warning: Inflation may be harmful to your growth. *Staff Papers, 45*(4), 672-710. https://doi.org/10.2307/3867589

Griffith, R., Redding, S., & Reenen, J. V. (2004). Mapping the two faces of R&D: Productivity growth in a panel of OECD industries. *Review of economics and statistics, 86*(4), 883-895. https://doi.org/10.1162/0034653043125194

Grossman, G. M., & Helpman, E. (1991). Trade, knowledge spillovers, and growth. *European economic review, 35*(2-3), 517-526. https://doi.org/10.1016/0014-2921(91)90153-A

Gyimah-Brempong, K., Paddison, O. and Mitiku, W. (2006). Higher education and economic growth in Africa. *Journal of Development Studies, 42*(3), 509-529. https://doi.org/10.1080/00220380600576490

Hall, B. H., Mairesse, J., & Mohnen, P. (2010). Measuring the Returns to R&D. In *Handbook of the Economics of Innovation*. North-Holland. https://doi.org/10.1016/S0169-7218(10)02008-3

Hanif, N., & Arshed, N., (2016). Relationship between School Education and Economic Growth: SAARC Countries. *International Journal of Economics and Financial Issues, 6*(1), 294-300.

Iqbal, N., & Nawaz, S. (2009). Investment, inflation and economic growth nexus. *The Pakistan Development Review*, 863-874. https://doi.org/10.30541/v48i4IIpp.863-874

ITU, (2018). *Measuring the Information Society Report 2018*. Retrieved from https://rb.gy/maywi

Benhabib, J., & Spiegel, M. M. (1994). The role of human capital in economic development evidence from aggregate cross-country data. *Journal of Monetary economics, 34*(2), 143-173. https://doi.org/10.1016/0304-3932(94)90047-7

Jones, C. I., & Williams, J. C., (1998). Measuring the social return to R&D. *Quarterly Journal of Economics, 113*, https://doi.org/10.1162/003355398555856

Jones, C. I., & Williams, J. C. (2000). Too much of a good thing? The economics of investment in R&D. *Journal of economic growth, 5,* 65-85. https://doi.org/10.1023/A:1009826304308

Keller, K. R. (2006). Investment in primary, secondary, and higher education and the effects on economic growth. *Contemporary Economic Policy, 24*(1), 18-34. https://doi.org/10.1093/cep/byj012

Khan, J., & Rehman, K. N. (2014). *The Significance of Research and Development for Economic Growth: The Case of Pakistan* (MPRA paper no. 56005). MPRA

Krueger, A. B., & Lindahl, M. (2001). Education for growth: Why and for whom?. *Journal of economic literature, 39*(4), 1101-1136. https://doi.org/10.3386/w7591

Lee, J., Cerreto, F., & Lee, J., 2009. Teachers' intentions toward technology usage: Do different uses lead to different determinants? In C. D. Maddux (Ed.), *Research highlights in technology and teacher education* (pp. 179-187). Chesapeake, VA: AACE.

Levine, R.(1997).Financial development and economic growth: Views and agenda. *Journal of Economic Literature, 35*(2), 688-726. https://doi.org/10.1108/EUM0000000004425

Lichtenberg, F.R. (1992). *R&D investment and international productivity differences* (NBER Working Paper N. 4161). https://doi.org/10.3386/w4161

Lin, T., C. (2006). Alternative measure for education variable in an empirical economic growth model: Is primary education less important?. *Economics Bulletin, 15*, 1-6.

Liu, C., & Armer, M. (1993). Education's effect on economic growth in Taiwan. *Comparative Education Review, 37*(3), 304-321. https://doi.org/10.1086/447192

Loening, J., Bhaskara R. and Singh, R. (2010). *Effects of education on economic growth: Evidence from Guatemala* (MPRA Paper 23665). University Library of Munich, Germany.

Lucas, R. (1973). Some international evidence on output-inflation trade-offs. *American Economic Review, 63*(3), 326-334.

Lucas, R. (1988). On the Mechanics of Economic Development. *Journal of Monetary Economics, 22,* 3-42. https://doi.org/10.1016/0304-3932(88)90168-7

Luintel, K. B., & Khan, M. (2016). *R&D, scale effects and spillovers: New insights from emerging countries* (Vol. 32). WIPO.

M.R. Ward, Z. Shilin, Mobile telecommunications service and economic growth: evidence from China, Telecommun. *Pol. 40* (2016) 89-101, https://doi.org/10.1016/j.telpol.2015.06.005

Mallik, G. & Chowdhury, A. (2001). Inflation and economic growth: Evidence from South Asian countries. *Asian Pacific Development Journal, 8*(1), 123-135.

Mankiw, G., Romer, D., & Weil, D. (1992). A contribution to the empirics of economic growth. *Quarterly Journal of Economics, 107*, 407-437. https://doi.org/10.2307/2118477

Mc Mahon, W. (1998). Education and growth in East Asia. *Economics of Education Review, 17*(2), 159-172. https://doi.org/10.1016/S0272-7757(97)00050-2

Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. *Energy policy, 35*(5), 2939-2945.

Mingat, A. & Tan, J. (1996). *The full social returns to education: Estimates based on countries economic growth performance*. World Bank, Washington, DC.

Mankiw, N. (2003). *Macroeconomics*. New York, NY: Worth Publishers.

Nelson, R. R., & Phelps, E. S. (1966). Investment in humans, technological diffusion, and economic growth. *The American economic review, 56*(1/2), 69-75.

Niebel, T. (2018). ICT and economic growth-Comparing developing, emerging and developed countries. *World Development, 104*, 197-211. https://doi.org/10.1016/j.worlddev.2017.11.024

Odit, M. P., Dookhan, K., & Fauzel, S., (2010). The impact of education on economic growth: The case of Mauritius. *International Business & Economics Research Journal (IBER), 9*(8). https://doi.org/10.19030/iber.v9i8.620

Oliner, S. D. & D. E. Sichel (2000). The Resurgence of Growth in the Late 1990s: Is Information Technology the Story? *Journal of Economic Perspectives 14*(4), 3-22. https://doi.org/10.1257/jep.14.4.3

Oliner, S. D., Sichel, D. E., Triplett, J. E., & Gordon, R. J. (1994). Computers and output growth revisited: how big is the puzzle?. *Brookings Papers on Economic Activity, 1994*(2), 273-334. https://doi.org/10.2307/2534658

Park, J. (2004). International and intersectoral R&D spillovers in the OECD and East Asian economies. *Economic Inquiry, 42*(4), 739-757. https://doi.org/10.1093/ei/cbh093

Pegkas, P., & Tsamadias, C. (2015). Does formal education at all levels cause economic growth? Evidence from Greece. *Review of Economic and Business Studies,* (15), 9-32. https://doi.org/10.1515/rebs-2016-0013

Pereira, J. and Aubyn, M. (2009). What level of education matters most for growth?: Evidence from Portugal. *Economics of Education Review, 28*(1), 67-73. https://doi.org/10.1016/j.econedurev.2007.12.001

Petrakis, P. E., & Stamatakis, D. (2002). Growth and educational levels: A comparative analysis. *Economics of Education Review, 21*(5), 513-521. https://doi.org/10.1016/S0272-7757(01)00050-4

Phillips, P. C., & Hansen, B. E. (1990). Statistical inference in instrumental variables regression with I (1) processes. *The Review of Economic Studies, 57*(1), 99-125. https://doi.org/10.2307/2297545

Pradhan, R. P. (2009). Education and economic growth in India: Using error correction modelling. *International research journal of finance and economics, 25*(1), 139-147.

Psacharopoulos, G. (1995). *The profitability of investment in education: Concepts and methods, human capital development and operations policy* (Working paper No.76). World Bank, Washington, D.C.

Qiang, C. Z. W., (2009). *Telecommunications and Economic Growth*. Banque mondiale, Washington D.C.

Quah, D. (2002). Technology dissemination and economic growth: Some lessons for the new economy. *Technology and the new economy*. Cambridge, MA: MIT Press.

Romer, P. M. (1990). Endogenous technological change. *Journal of political Economy, 98*(5, Part 2), S71-S102. https://doi.org/10.1086/261725

Romer, P. M. (1986). Increasing returns and long-run growth. *Journal of Political Economy, 94*(5), 1002-1037. https://doi.org/10.1086/261420

Saidi, K., & Mongi, C. (2018). The effect of education, R&D and ICT on economic growth in high income countries. *Economics Bulletin, 38*(2), 810-825.

Saungweme, T. (2021). *Inflation and economic growth in Kenya: An empirical examination* (Working Paper).

Savvides, A., & Zachariadis, M. (2003). *International technology diffusion and TFP growth*. forthcoming, Oklahoma: Oklahoma State University, Department of Economics.

Schultz, T. W. (1961), Investment in human capital. *The American Economic Review, 51*(1), 1-17.

Self, S. & Grabowski, R. (2004). Does education at all levels cause growth? India, a case study. *Economics of Education Review, 23*(1), 47-55. https://doi.org/10.1016/S0272-7757(03)00045-1

Shah, A. (2011). *Pakistan Economic Survey 2010-2011: Manufacturing and Mining.* Government of Pakistan.

Shaihani, M., Harisb, A., Ismaila N., & Saida R. (2011). Long run and short run effects on education levels: Case in Malaysia. *International Journal of Economic Research, 2*(6), 77-87.

Sianesi, B. & Reenen, J. (2003). The returns to education: Mqcroeconomics. *Journal of Economic Surveys, 17,* 157-200. https://doi.org/10.1111/1467-6419.00192

Solaki, M. (2013). Relationship between education and GDP growth: A bi-variate causality analysis for Greece. *International Journal of Economic Practices and Theories, 3*(2), 133-139.

Stanley, T. D., Doucouliagos, H., & Steel, P. (2018). Does ICT generate economic growth? A meta-regression analysis. *Journal of economic surveys, 32*(3), 705-726. https://doi.org/10.1111/joes.12211

Steinmueller, W. E. (2001). ICTs and the Possibilities for Leapfrogging by Developing Countries. *International Labour Review, 140*(2), 193-210. https://doi.org/10.1111/j.1564-913X.2001.tb00220.x

Stiroh, K. J. (2002). Are ICT Spillovers Driving the New Economy? *Review of Income and Wealth, 48*(1), 33-57. https://doi.org/10.1111/1475-4991.00039

Stiroh, K. J. (2005). Reassessing the Impact of IT in the Production Function: A Meta-Analysis and Sensitivity Tests. *Annales d'Economie et de Statistique, 79/80*, 529-561. https://doi.org/10.2307/20777587

Strulik, H. (2005). The role of human capital and population growth in R&D-based models of economic growth. *Review of International Economics, 13*(1), 129-145. https://doi.org/10.1111/j.1467-9396.2005.00495.x

Niebel, T. (2018). ICT and economic growth–Comparing developing, emerging and developed countries. *World development, 104*, 197-211.

Tallman, E., & Wang, P. (1994). Human capital and endogenous growth: evidence from Taiwan. *Journal of Monetary Economics, 34*, 101-124. https://doi.org/10.1016/0304-3932(94)01152-4

Trajtenberg, M. (1990). *Economic analysis of product innovation.* Cambridge: Cambridge University

Villa, S. (2005). *Determinants of growth in Italy. A time series analysis* (Working Paper). University of Foggia, Italy.

Vu, K. M. (2013). Information and communication technology (ICT) and Singapore's economic growth. *Information Economics and policy, 25*(4), 284-300. https://doi.org/10.1016/j.infoecopol.2013.08.002

Wang, Y., & Liu, S. (2016). Education, Human Capital and Economic Growth: Empirical Research on 55 Countries and Regions (1960-2009). *Theoretical Economics Letters, 6*, 347-355. https://doi.org/10.4236/tel.2016.62039

World Bank (2012). *ICT for Greater Development Impact.* http://siteresources.worldbank.org/E

World Bank (2020). *World development indicators.* Online database

Yousefi, A. (2011). The impact of information and communication technology on economic growth: Evidence from developed and developing countries. *Economics of Innovation and New Technology, 20*(6), 581-596. https://doi.org/10.1080/10438599.2010.544470

Zachariadis, M. (2003). R&D, innovation, and technological progress: A test of the Schumpeterian framework without scale effects. *Canadian Journal of Economics/Revue canadienne d'économique, 36*(3), 566-586. https://doi.org/10.1111/1540-5982.t01-2-00003