Impact of Digital Economy on Pakistan's Economic Growth

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Abstract

The digital economy has become a major engine of global economic growth, revolutionized traditional industries and opened new opportunities for both businesses and individuals. The study aims to assess the impact of the digital economy on Pakistan's economic growth by using Turner's (2006) bound testing technique of co-integration and Error Correction Model (ECM) methodology. For research purposes, secondary annual time-series data is utilized over the period 1995–2022. Independent variables i.e. mobile cellular subscriptions, percentage of internet usage, fixed broadband subscriptions, gross fixed capital formation, education, and trade openness are selected to analyse the effect on the dependent variable real gross domestic product per capita. Results indicate that internet and fixed broadband penetration significantly boost real GDP per capita in the long run, highlighting the importance of improving access to digital technologies for poverty reduction and economic growth. However, mobile cellular subscriptions significantly impact economic growth in the short run, but their long-term impact is less pronounced. It may be due to several factors i.e. limited technology diffusion, low ICT proficiency among internet users, income inequality, and trade restrictions. Pakistan's government should focus on bridging the digital divide by extending internet access, enhancing digital literacy, and revising trade policies. It will enable citizens to leverage the internet for education and job opportunities, fostering an inclusive digital environment that maximizes economic and social benefits.

Keywords: Digital technology; Mobile Cellular Subscription; Fixed broadband Subscription; ICTs; Internet; Economic growth

INTRODUCTION

Every country's primary goal is to seek solutions that foster sustainable and long-term growth. Technological innovation plays a crucial role in enhancing a country's gross domestic product (GDP) per capita. Countries with higher levels of innovation and technology tend to be more competitive and economically efficient (Solow, 1957). In recent decades, the digital economy has captured the attention of specialists, experts, researchers, the media, politicians, and corporate executives as a sector with tremendous growth potential (Tapscott, 1996).

The diffusion of digital technology is determined by the ICT (Information and Communication Technology) sector of an economy. Several studies have discovered that ICT adoption, particularly the Internet, facilitates the dissemination of codified knowledge and fosters innovation in products, processes, businesses, and cross-company collaboration (Billon et al., 2017). Investment in the ICT sector is crucial since it allows for the diffusion of digital technology and services to remote areas and boosts foreign direct investment (FDI) and labour productivity (Biryukova & Matiukhina, 2019).

In the industrial and manufacturing sectors, diversification reveals new manufacturing methods; while digitalization unlocks new management and organization methods that lead to growing businesses and economic growth in the long run. Digital technologies enable firms to choose production processes, use the most recent data, improve product quality, reduce production costs, and ensure timely production of products that meet client expectations (Chirkunova et al., 2021). For instance, the contemporary fourth industrial revolution declares that the incorporation of big data, robotics, and artificial intelligence into manufacturing sectors will drastically change their business operations and output (Geissbauer et al., 2016).

Digital transformation systems consist of several interrelated elements, including human capital, applications for digital transformation, ICT infrastructure, institutions, laws, regulations, and the ICT services industry (Szeles & Simionescu, 2020). For a guaranteed balance development, ICT investment and policy must be effective as digital technologies such as the internet, 5G, artificial intelligence, and big data expedite deep industry integration (Afonasova, 2019). If digitization is not done properly, the benefits are diminished. Thus, building ecosystems for digital transformation is part of the strategy for developing a digital economy (Hanna, 2012). Similarly, enhanced digital literacy among internet users in least-developed countries is imperative for fostering economic growth and development (Haftu, 2019).

The assessment of ICT via internet, mobile, and broadband has positively impacted economic growth in recent years. In 2016, the tech industry's dominance was evident as Alphabet, Apple, Amazon, Microsoft, and Facebook occupied five of the top ten positions for the world's most valuable companies (PricewaterhouseCoopers, 2016). Policymakers across the European Union have increased investment in modernizing and expanding their ICT infrastructures, leading to a surge in innovation (Pradhan et al., 2019).

Numerous macroeconomic theoretical frameworks suggest that digital development can boost GDP growth, productivity, and real wages through several mechanisms. Firstly, endogenous growth theory proposes that technology amplifies the capital stock available to the labor force, thereby enhancing labour productivity (Solow, 1956). Secondly, neo-classical growth theory suggests that technology exogenously contributes to economic expansion (Romer, 1990). An ICT investment and digital technology diffusion facilitate in the efficient utilization of labour and capital resources, leading to increased total factor productivity.

Investing in ICT infrastructure and automation promotes Industry 4.0, leading to environmental, economic, and social value creation (Davies, 2015). The growth of digital technology is not only contributing to the level of trade in digital commodities, but also flourishing trade in digital services (Zhang et al., 2022). Similarly, it has been observed that ICT infrastructure, venture capital, and economic growth are strongly interconnected. ICT advancements and venture capital boost economic growth, and vice versa (Pradhan et al.,2019).

The proliferation of the digital economy is reshaping labour markets. Advances in digital technology are facilitating global labour mobility (Baldwin, 2018) while automating complex tasks previously requiring specialized skills (McAfee & Brynjolfsson, 2017). This transformation may lead to job displacement and industry disruption. However, research suggests that the digital workplace initiatives can stimulate economic growth by fostering high-tech sectors (Moretti & Thulin, 2013).

In the case of Pakistan, the digital economy has significantly impacted economic growth in various ways i.e. the rise of e-commerce platforms and online marketplaces, IT services and outsourcing, adoption of digital payment systems, digital health services, start-ups, access to avenues for quality education and skills development (McKinsey, 2016). Pakistan's skilled human capital, lower labour costs, and government support have attracted foreign investment in software development, IT infrastructure, call centres, and other related services.

E-commerce is considered as an important factor of success for both Small and Medium Enterprises (SMEs) and large organizations. It helps to approach larger untapped marketplaces, reduce transaction costs and avoid intermediaries (Khaskheli et al., 2017). There were only 3% of the entire population made online purchases when e-commerce first began there in the year 2000. However, it is reported that now internet usage is raised 15%, product demand is up 30% to 40%, and daily e-commerce growth is 10% in Pakistan. It is excellent news for Pakistan that a digital platform e-commerce is showing a tremendous upward drift (Bhatti et al., 2020). However, the present facilities, like technology parks, are primarily restricted to large cities. Furthermore, the deployment of skillsets and ICT infrastructure are limiting the digital trading sector in Pakistan.

It is high time for Pakistan to extend its geographical area and must offer adequate opportunities across various towns to further expand the ICT industry. Similarly, it is necessary to build efficient or competent human capital that aids in promoting ICT-enabled services in Pakistan. This calls for ongoing professional development plans and skills development programs (Javed, 2020).

Pakistan has considerable potential to advance its digital technology landscape. This research study aims to investigate the relationship between the digital economy and Pakistan's economic growth as all the previous studies are targeted to specific niches of the digital economy i.e. freelancing trend, e-commerce patterns, digital payment systems of Pakistan etc. However, the overall impact of the digital economy on Pakistan's economic growth remains largely unexplored.

LITERATURE REVIEW

Every country's fundamental mission in economic development is to diversify and digitalize the economy as per the requirements of the 21st-century era. The digital technology is revolutionizing the way businesses and consumers access information, conduct transactions, and manage operations. The European Commission stated that the digital marketplace is currently the single most significant engine of competitiveness, innovation, and growth, accounting for up to 8% of the GDP of the main G-20 nations.

The ICT sector provides a basis for digital diffusion. The use of ICT is growing throughout the world economy. It has recently been identified as a critical component in driving economic growth and globalization, as well as establishing strong international commercial and communication networks (Maneejuk & Yamaka, 2020). ICT advances a variety of metrics, that involve increased labour and capital productivity, greater access to services, and improved governance efficiency (Singh & Kaur, 2017). As a part of the evolution of Industry 4.0., ICT creates novel methods for sustainable or environmentally friendly industrial manufacturing (Stock & Seliger, 2016).

ICT diffusion and investments significantly enhance the intermediate inputs to capital goods that ultimately boost economic growth (Roger & Enock, 2021). Gomes (2022) investigated the effect of digital diffusion on economic development in 36 OECD nations for the period 2000-2019 by estimating the model using the fixed cross-sectional GMM. The study used mobile cellular subscriptions, internet penetration, and fixed broadband as proxies for ICT development and found that established ICT networks positively contribute to the growth of OECD countries.

ICT-based innovations allow businesses access to larger markets, raise their profits and capacity, and permit them to grow their consumer base. While, ICT services play a huge part in the development and delivery of various services, particularly transportation, financial, royalties, commercial, travel, and insurance services (Nath & Liu, 2017). However, developing nations have challenges in growing the ICT industry, which incorporate the expense of ICT gadgets, language barriers, a dearth of appropriate merchandise, an unfavourable regulatory environment, and a shortage of human resources (Grazzi & Verfara, 2012).

Broadband penetration has been showed to contribute to economic growth in both developed and developing nations (Qiang & Rossotto, 2009). Grimes et al. (2012) pointed out that businesses with broadband connectivity are about 10% more productive. Consequently, the competitiveness of businesses increases on a national and worldwide scale (Bernard et al., 2007).

Similarly, the internet is playing an important role for SMEs as it provides significant opportunities to export their products and services internationally (Meltzer, 2018). Clarke (2001) utilized a gravity model of trade and discovered that internet access had a higher impact on trade for developing countries in terms of exports than it does in industrialized countries. Countries with higher internet penetration export more services to the United States on a comparative basis.

The use of the Internet, web hosts (Liu & Nath, 2013), and ICT framework (Vemuri & Siddiqi, 2009) greatly boost bilateral trade. Increased export flows are further facilitated by the business community's accessibility and adoption of the Internet in both importing and exporting nations (Yushkova, 2014). Software development has emerged as a significant business in the cutting-edge time of ICT, supporting trade activity as well as providing job opportunities and economic growth (Sen, 1995).

It has been discovered that ICTs significantly alter socioeconomic growth. Globally, E-commerce is booming due to technological advancements, government support, and consumer acceptance. (Xanthidis & Nicholas, 2004). Using a capabilities approach, Palvia et al. (2018) discovered that ICTs have reduced business costs for developing nations as they eliminated the need for physical stores and effectively facilitated the businesses for customers and information to be accessed online. ICT access helps businesses maintain long-term relationships with their consumers by promoting connectedness and communication. Furthermore, they discovered that ICTs gave inhabitants more power by giving them access to free online news and educational resources and a stronger "voice" through online forums.

ICT's impact on business performance is mixed. Research on South African manufacturing industries from 1970-2016 shows that sectors heavily using ICT experienced faster productivity growth compared to those with less ICT adoption (Lefophane & Kalaba, 2020). For developing countries, ICT investments can expand markets but don't directly boost labor productivity, especially in the short term (Chowdhury, 2006). This might be due to a skills mismatch that hinders productivity gains, as new technology requires well-educated workers for effective integration (Evangelista et al., 2014). No doubt, a skilled workforce serves as a crucial player in the diffusion of technology. It facilitates the productive use of ICT and physical capital both, the sharing and generation of ideas (Murphy & Siedschlag, 2013).

As per the World Bank (2020) report, a rising trend of social media usage, online shopping, teleservices, and internet access for consumers and enterprises has been recorded. Freund & Weinhold (1996) claimed that businesses with access to the internet export more as a percentage of their total sales than businesses without Internet access. Evans (2019) assessed the effects of internet usage on economic conditions in 45 SSA nations for the years 1995-2015. Results revealed that internet use significantly and favourably impacted the financial state of the economy while internet scams caused SSA's financial stability to decline.

Dewan & Kraemer (2000) conducted a study involving 36 countries from 1985 to 1993 and reported that developing countries have no additional perks of ICT if there is inadequate market regulation and low investment in technological infrastructures. Greater ICT investments result in increased economic benefits for developed countries at the expense of developing countries (Thompson & Garbacz, 2011). On contrary, another study claimed that ICT contributed positively to the economic growth of developed countries only, allowing them an efficient use of human capital, trade liberalization, and favourable or beneficial government policies (Yousefi, 2011; Papaioannou & Dimelis, 2007).

Renowned concepts of production factors such as neoclassical growth theory (Solow, 1956) and Neo-Schumpeterian ideas (Pyka & Andersen, 2012; Bahrini & Qaffas, 2019) have already demonstrated a positive influence of ICT on a country's growth. An increase in ICT investment translated into inputs on the economic supply side in the form of the capital production factor, which improves technological development, labor performance, the manufacturing process, and ultimately, economic growth (Zhang et al., 2022).

Jiao & Shuaitao (2021) examined the mechanism and effect of digital development on urban economic growth for 173 cities in China for the years 2011-2018. Results indicated a significant positive effect of digital development on urban economic growth, and there exists heterogeneity across different cities. Furthermore, the "effect mechanism" of digital growth on economic growth is urban employment.

The information technology sector in Pakistan has experienced substantial growth in recent years, ranking among the fastest-emerging industries as the ICT sector is generating substantial export revenue (Haq, Ali, & Nawaz, 2019) and fostering the expansion of financial services and health care (Arif, 2018).

However, numerous Pakistan SMEs are struggling to capitalize on ICT. Despite government investment, these businesses face challenges in digital adoption and global competition (Nazir & Roomi, 2021). A digital divide between urban and rural areas further hinders SME development (Qalati et al., 2020). A World Bank Group survey highlighted that trade restrictions and export market tariffs are two of the biggest obstacles facing Pakistan's SMEs. Furthermore, Pakistan is facing challenges and limitations of digital avenues i.e. poor e-readiness, limited internet access, reservations or doubts, and computer illiteracy (Shakeel, 2022). It is high time for Pakistan to build a strong ICT infrastructure, reduce fiscal and trade obstacles, and maintain online security and information costs to encourage foreign investment in the digital realm (Javed & Vaqar, 2022).

It is evident that digital diffusion not only positively affects economic growth, but also advocates economic development in terms of average life expectancy, health, education, and poverty reduction (Grossman & Helpman, 1991). Nevertheless, technology has increased employment opportunities in Wales and England (Stewart et al., 2015). However, there are drawbacks to technological advancement such as it has reduced the need for human labour, which may result in fewer jobs being available for conventional workers (Van & Kool, 2015). It is evident from the declining need for human resources in the US and China's industrial sectors (Rotman, 2013).

MATERIAL AND METHODS

3.1 Data and Analysis

The study's universe includes the country Pakistan. The World Bank's World Development Indicators (WDI) and the Pakistan Bureau of Statistics database are used as sources to conduct the research. In our analysis, the sample size for the period 1995-2022 is taken into consideration.

Table 1: Symbols, Units and Data Source of Variables

Variable	Symbol	Units	Data Source
Real GDP per capita	Y	Constant 2015 - US$	WDI
Fixed Broadband Subscription	BB	Per 100 users	WDI
Mobile Cellular Subscription	MOB	Per 100 Users	WDI
Internet Usage	IU	% of total Population	WDI
Gross Fixed Capital Formation	GFCF	ICT Investment - Constant 2015 US$	PBS
Education	EDU	% Gross Enrolments (Secondary + Tertiary Education)	WDI
Trade Openness	TOP	% share of GDP	WDI

Source: Author Computation

The dependent variable of the study is economic growth (Y) represented by real GDP per capita constant 2015 US$. The explanatory variables include mobile cellular subscription (MOB) per 100 subscribers, fixed broadband subscription (BB) per 100 subscribers, education (EDU) based on gross enrolments in secondary and tertiary education, gross fixed capital formation (GFCF) as total ICT investments in constant 2015 US$, internet usage as a percentage of the population that is using internet (IU), and trade openness (TOP) as a sum of imports and exports as a share of GDP.

Regarding the independent variables, mobile-cellular subscriptions, internet usage, and fixed-broadband subscriptions are used as proxies for digital technology. While economic growth, education, investment, and trade openness are among the variables that are examined in this study.

The data is first converted from nominal to real values and then converted into logarithmic form. Logarithmic transformation is frequently employed to cope with issues related to data skewness, minimize variance, and/or transform nonlinear functional forms into linear forms. As our study's model is built on Cobb Douglas function, the coefficients are treated as elasticities.

The study is considering time series data; it is essential to make all of the data stationary to avoid the problem of trended data in time data computation. The data can be stationary at I (0), I(1), or I(2). The stationarity characteristic of the data is examined using the Augmented Dicky Fuller (ADF) test and Phillips Perron (PP) test.

Co-integration methods are utilized to determine long–term relationships among variables. Numerous researchers used the F-test of co-integration for the joint significance of levels terms in ECM (error correction model). This essentially means that the test investigates whether the variables move together in the long run, even if they fluctuate in the short term.

Traditionally, co-integration tests required knowing if the variables were stationary or not. However, recent advancements have made this less crucial. Pesaran et al. (2001) introduced a test that bypassed this requirement, though it needed a large dataset. Narayan (2004) adapted this test for smaller datasets (30-80 observations) by developing critical values, and Turner (2006) further refined this co-integration method by providing response surfaces for the F-test, making the test reliable for very small datasets and expanding its applicability for researchers with limited data.

Lastly, the ARDL bounds testing technique along with the Error Correction Model (ECM) is applied in the analysis. It is widely used for determining both long and short-run relationships among variables. Additionally, the ARDL bound test with ECM is suitable for small data sets and provides the coefficient of speed of adjustment in case of disequilibrium.

3.2 Empirical Model Specification

This study will use the F-test of co-integration developed by Pesaran et al. (2001) and determine critical values for the F-statistics by applying Turner's (2006) response surface method.

$$C_i\ (p) = b_o + b_1 / T + b_2 / T^2 + \varepsilon_t$$

where Ci(p) denotes the p% quantile estimate, values of β's are response surface estimates, ε_t is an error term, t is sample size. Turner's (2006) method will generate critical values for the F-statistic, with the upper bound indicating I (1) variables and the lower bound indicating I(0) variables. If the F-statistic exceeds the upper bound, the null hypothesis of no co-integration is rejected, suggesting a long-term relationship. If it falls between the bounds, the result is unclear, and further analysis is needed. Pesaran et al. (2001) also offer a helpful range of critical values for various data scenarios (i.e. different trends and constants), helping researchers in determining the long-term relationship among variables.

If there is evidence of co-integration among the variables, we will estimate the long-run growth model and derive the short-run dynamic model. For this, the study will use an econometric technique named Error Correction Model (ECM) in the analysis. Specifically, testing for co-integration within the ARDL framework, we estimate the conditional error correction (EC) version of the ARDL model using the following method.

$$\Delta \ln(Y)_t = b_0 + b_1 \ln (BB)_{t-1} + b_2 \ln (MOB)_{t-1} + b_3 \ln (IU)_{t-1} + b_4 \ln (GFCF)_{t-1} + b_5 \ln (EDU)_{t-1} + b_6 \ln (TOP)_{t-1} + \sum b_i\, \Delta \ln (Independent)_{t-i} + \sum b_i\, \Delta \ln(Y)_{t-i} + b_k T + u_t$$

where Δ is defined as the first difference operator, u shows the error term, T shows the time trend, and k denotes all variables in the regression. The error correction term originates from the estimated integrating relationship and captures how variables naturally adjust over time to reach a stable, balanced state (equilibrium).

DATA ANALYSIS & INTERPRETATION

4.1 Descriptive Statistics

Before calculating the growth equation, descriptive statistics are presented to provide a comprehensive overview of the relationship between digital diffusion and economic growth for Pakistan during the period 1995-2022. The summary statistics for the entire sample are presented including minimum, maximum, mean, standard deviation, and Jarque-bera values. The maximum and minimum values provide a range of values. Standard deviations indicate the variables' dispersion of the dataset in relation to their mean. The descriptive analysis results reveal that the mobile cellular subscription (internet users) per 100 persons (Mean = 2.8383; SD =2.0660) is substantially greater than the fixed broadband subscription (Mean= -2.5262; SD = 3.0963).

Table 2: Descriptive statistics

Variables	Mean	Maximum	Minimum	Std. Dev	JB Prob.
Ln Y	7.1512	7.4360	6.9411	0.1656	1.9451
Ln MOB	2.8383	4.4036	-1.729	2.0660	5.7453
Ln BB	-2.5262	0.2848	-11.33	3.0963	5.5460
Ln IU	0.7565	3.0463	-9.0057	3.0458	23.899
Ln GFCF	21.257	22.092	21.225	0.3678	3.2450
Ln EDU	3.4515	3.9973	2.8638	0.3276	1.5165
Ln TOP	3.3815	3.6462	3.0619	0.1530	1.2198

Source: Eviews-12

Moreover, in all situations, Jarque–Bera probability values are greater than the significance level. Consequently, the null hypothesis is accepted with sufficient evidence, indicating that the data is normally distributed.

4.2 Unit Root Test

The presence of unit root is examined by using both the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) to validate the findings.

Table 3: Unit Root Tests

Variables	ADF test statistics (With trend and intercept)		P-P test statistics (With trend and intercept)	
	Level	First Difference	Level	First Difference
Ln Y	-4.7020***	-3.4320*	-2.3950	-3.4320*
Ln MOB	-6.3202***	-2.4273	-1.0942	-3.5379*
Ln BB	0.01625	-4.1598***	-3.8163**	-4.5292***
Ln IU	-7.3724***	-1.6052	-6.3686***	-15.7784***
Ln GFCF	-2.2751	-3.6887**	-2.0042	-3.6956 **
Ln EDU	-4.4885***	-4.2965 ***	-3.9384**	-7.3158 ***
LN TOP	-1.9339	-4.7244***	-1.9777	-4.7233***

Source: EVIEWS-12

Note:

significant at 1%,

significant at 5%

significant at 10%

The results of the unit root tests are shown in Table 2, which indicates that the variables I(0) and I(1) have mixed orders of integration. This allows the study to use the bound co-integration test, which was created by Pesaran et al. (2001).

4.3 Co-Integration Analysis

The next step is to estimate an equation to examine the long-term relationships among the variables. The following tables display the findings of the F-statistic for the co-integration where Turner's response surface (2006) is used to compute the updated critical values of I (0) and I (1).

Table 4: F-statistics for co-integrating relationship

F-test statistics	**Lag**	**Sig. level**	**Adjusted Bound Critical Values*** (unrestricted intercept and no trend)		**Outcome**
			I (0)	**I (1)**	There is co-integration (reject H_0)
11.8075	6	1%	3.15	4.43	
		2.5%	2.75	3.99	
		5%	2.45	3.61	
		10%	2.12	3.23	

Source: EVIEWS-12

Table 4 displays the result of the bound test where fixed broadband, mobile cellular subscriptions, and internet usage are used as proxies of digital variables with other constant variables. The results revealed that the calculated F-statistic of 11.8075, is consistently greater than the adjusted upper bound critical value at the 1%, 2.5%, 5%, and 10% significance level by implementing an unrestricted intercept and no trend. This shows that there is co-integration among the variables, since the null hypothesis of no co-integration is rejected at the 5% significance level.

As our analysis confirms the long run relationship among variables (co-integration), we estimate the long-run growth model and derive the short-run error correction model (ECM). Table 5 displays the long-term model, which is created by standardizing real GDP per capita.

Table 5: Results of the Long-Run Growth Model

Dependent Variable (Ln Y)	**Model**
Broadband (Ln BB)	0.06***(4.124)
Mobile (Ln MOB)	-0.06**(0.023)
Internet Usage (Ln IU)	0.179***(0.024)
Control Variables	
Gross Fixed Capital Formation (Ln GFCF)	0.154***(0.030)
Education (Ln EDU)	0.188***(0.071)
Trade Openness (Ln TOP)	0.011(0.074)
F – Statistic	11.80
K	6

Source: EVIEWS-12

Note:
standard error in parentheses,
significant at 1%,
significant at 5%,
significant at 10%

In the long run, mobile cellular subscriptions have a negative impact on Pakistan's economic growth. It can be due to numerous factors i.e. poor technology diffusion, increased income inequality, and low ICT proficiency among internet users (Haftu, 2019; Aker & Mbiti, 2010; Evangelista et al., 2014). Additionally, excessive investment in mobile infrastructure at the expense of critical sectors, coupled with negative externalities such as environmental and health issues, could further diminish economic benefits (Qiang et al., 2009). The research results further indicate that broadband subscriptions positively influence economic growth, supporting earlier studies that found broadband enhances productivity and fosters innovation (Wamboye et al., 2015; Albiman & Sulong, 2016; Ward & Zheng, 2016; Bahrini & Qaffas, 2019). The internet also demonstrates a strong positive impact on economic growth, especially in developing countries (Bahrini & Qaffas, 2019; Pradhan et al., 2018; Sassi & Goaied, 2013).

The research study finds that education has a statistically significant impact on Pakistan's economic growth. The importance of human capital in driving productivity and innovation is well-documented (Benhabib & Spiegel, 1994; Solow, 1956; Shane & Venkataraman, 2000). Similarly, the analysis reveals that gross fixed capital formation (GFCF) plays a crucial role in technology diffusion, skill management, and knowledge acquisition. Higher GFCF, particularly in ICT investments, is associated with increased digital penetration. This finding aligns with previous research suggesting that physical capital (GFCF) positively influences income and economic growth in the long run (Norhanani, 2010; Ahmed, 2010 & 2011; Shanmugam, 2007). However, trade openness has become less significant in explaining Pakistan's long-term growth due to factors such as reliance on traditional sectors, inadequate infrastructure, and political instability (Ahmad et al., 2019; Balanika, 2013; Ghosh & Anwar, 2015). Policymakers should prioritize improvements in infrastructure and governance to fully realize the benefits of trade liberalization (Arif & Ahmad, 2018).

4.4 Error Correction Model:

It is recommended to estimate the short-run dynamic model since there is a long-term relationship between the variables. ECM is used to analyze the short- and long-run behaviour of real GDP per capita with respect to the explanatory variables. However, there may be disequilibria in the short run, the EC model is used to eliminate divergence from the long-run equilibrium.

Table 6 shows the findings of the short-run dynamic model. The speed of adjustment in removing departure from the long-run equilibrium is indicated by the coefficient of the error correction term. The coefficient is statistically significant at a 1% significance level and has the predicted negative sign (-0.66). It indicates that any deviation from the long-run equilibrium between variables is corrected by about 66 percent for each period to return to the long-run equilibrium level.

Table 6: Error Correction Regression

Dependent variable: Δ Ln(Y)$_t$	
Independent variables	**Coefficient**
Constant	1.8408***(13.17)
Δ Ln (GFCF)$_t$	.018**(2.480)
Δ Ln (MOB)$_t$	0.06***(9.454)
Δ Ln (BB)$_t$	-.014*** (-3.635)
Δ Ln (EDU)$_t$	0.07*** (4.8419)
ECT$_{t-1}$	-0.66*** (-12.0267)
Adjusted R-square **F-statistic** **DW-statistic**	0.9107 39.738 2.583

Source: Eviews-12

Note:
t-statistic in parentheses
significant at 1 % level
significant at 5 % level
Significant at 10 % level

According to log-log model results, a 1% increase in mobile cellular subscriptions boosts Pakistan's economic growth by 6% in the short run, ceteris paribus. Greater access to smartphones and upgraded internet penetration led to expand market access, foster digital entrepreneurship and improve e-businesses, communications, and online financial transactions. It also supports e-commerce and job creation, particularly in developing countries (Sparrow, 2015; Donovan, 2012; Keen & Mackintosh, 2013; Madden & Lavoie, 2016; Zhang & Danish, 2019). Additionally, mobile applications enhance efficiency in sectors such as agriculture and healthcare (Aker & Mbiti, 2010).

The Short Run Dynamics (ECM) results indicate that broadband subscriptions have a negative yet statistically significant impact on Pakistan's economic growth in the short run (β = -0.014), aligning with findings from Zhang and Danish (2019). Technological advancements often displace unskilled and low-wage workers and contribute to income inequality (Freeman, 1997). High initial costs, implementation inefficiencies, and uneven broadband access can limit its short-term economic benefits (Melo & Côrte-Real, 2020; Norris, 2001; Dutton, 2013;

Eger & Görtz, 2019). Addressing these issues is crucial for maximizing broadband potential.

Investment in gross fixed capital formation (GFCF), including machinery and digital infrastructure, positively influences Pakistan's economic growth by enhancing productive capacity and economic efficiency (Kuppusamy & Shanmugam, 2007; Brynjolfsson & Hitt, 2003). It suggests that the expansion of digital technology is a key driver of economic efficiency and reflects increasing returns to scale, which ultimately boost the country's real output. Similarly, increased education levels enhance labour productivity, innovation, and market participation, consistent with human capital theory and related research (Benhabib & Spiegel, 1994; Barro, 1991; Mankiw, Romer, & Weil, 1992; Psacharopoulos & Patrinos, 2004).

The adjusted R-squared value is approximately 91%, showing that the model explains 91% of the variation in economic growth. The F-statistic of 39.7387 with a p-value of 0.0000 confirms the model's overall statistical significance. The coefficient CointEq (-1) * is -0.6653 and statistically significant at the 1% level. This indicates that deviations from the long-run equilibrium are corrected by about 66% each period.

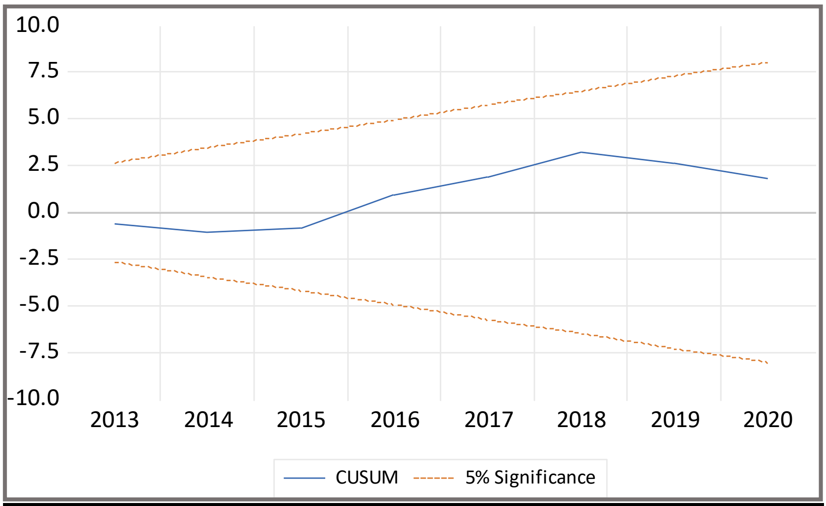

Figure 1: CUSUM Test

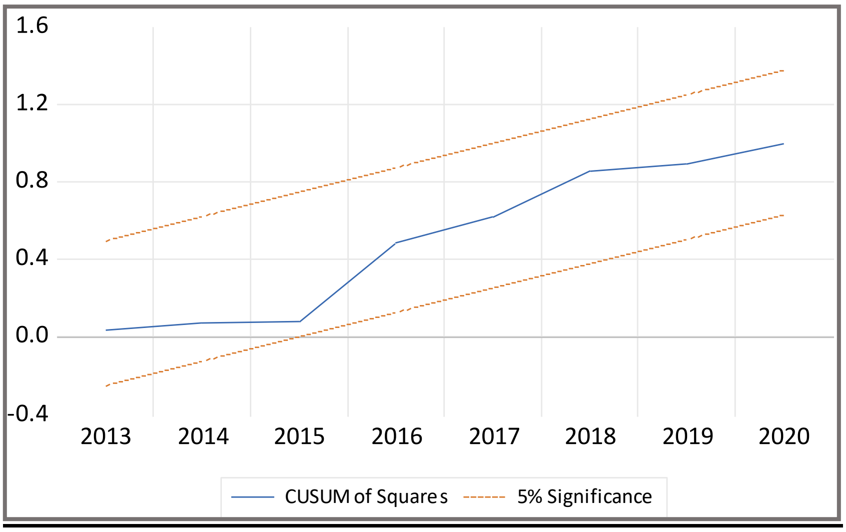

Figure 2: CUSUM of Squares Test

The above figures represent CUSUM and CUSUM of squares tests. These recursive test estimations are widely used to test the stability of coefficients. As the estimated equation (blue curve) lies between 5% confidence interval critical bands (red curves) in both figures, it means that our model is stable at a 5% confidence interval. The chosen model has no structural break, and all the parameters are quite stable.

4.6 Diagnostic Test

Table 7: Diagnostic Test

Test	Null Hypothesis	Statistic	p-value	Inference
Heteroscedasticity Test (Breusch-Pagan)	Homoscedasticity	F =0.7834	0.6650	Fail to reject H_0
ARCH Test (Autoregressive Heteroscedasticity)	ARCH effect does not characterise the model's errors	F = 0.0538	0.8194	Fail to reject H_0
Serial Correlation Test (LM)	Not serially correlated	F =1.1430	0.3205	Fail to reject H_0
Model Specification Test (Ramsey RESET)	Model is correctly Specified	F =1.0371	0.3342	Fail to reject H_0
Normality Test (Jarque-Bera)	Errors are normally Distributed	JB=0.9800	0.6126	Fail to reject H_0

Source: Eviews-12

The diagnostic test indicates that the model is well-fitting. As all probability values are greater than 5%, the model is free of difficulties such as heteroscedasticity, ARCH effect, serially correlated errors, functional form errors misspecification, and non-normality of errors.

Conclusion & Recommendations

The study attempts to analyze the relationship between digital development and Pakistan's economic growth, concluding that diffusion of digital diffusion has a positive and significant impact on the country's economic growth for the years 1995-2022. By examining education, real gross fixed capital formation, and trade openness structure, the study reveals that Pakistan's digital infrastructure leads to increased domestic and international money circulation through e-commerce, e-businesses, and IT services in both the short and long run. The widespread adoption of digital technology is identified as a key driver of economic efficiency and ultimately increases the country's real output.

Specifically, an increase in fixed broadband subscriptions and internet usage significantly fosters economic growth in the long run, indicating a country's shift towards a digitally driven economy. However, the inverse relationship between mobile cellular subscriptions and long-term economic growth highlights challenges i.e. limited technology diffusion, low ICT proficiency, and unfavorable tariff structures. Mobile cellular subscriptions and internet usage together stimulate Pakistan's economic growth in the short run. Meanwhile, the inverse relationship between fixed broadband subscriptions and economic growth reveals issues related to implementation inefficiencies and uneven access to broadband. Policymakers must address these issues to foster small and medium enterprise growth.

It is recommended that the government of Pakistan update its digital infrastructure to align with current demands. Policies should be implemented to bridge the digital divide by expanding internet connectivity to rural and remote areas. This includes establishing regional data centers to support the Digital Pakistan Vision, expanding broadband as well as 3G and 4G cellular services, and developing technology parks, incubators, and technical training institutes. Furthermore, it is advised that the Pakistan government must sustain its efforts to promote the use of digital technology across all sectors, with a particular emphasis on education and training to enhance individual efficiency. Lastly, revising trade restriction policies is also advised to foster a more conducive environment for digital growth.

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