



Impact of Information and Communication Technology, Financial Development, and Trade on Economic Growth: Empirical Analysis on N11 Countries

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Abstract

In the modern era of globalization, information and communication technology (ICT) are the main sectors that stimulate economic development. It enables technical developments in global communication, manufacturing techniques, and contributes in the economic growth. Many economic activities, including international trade and foreign direct investment (FDI), primarily depend on various modern ICT approaches. This study aims to analyze the dynamic relationship between FDI, ICT, international trade, and economic growth in the context of N11 countries from 2000 to 2018. The study expanded an innovative ICT index containing fixed telephone lines, handheld wireless access, and internet penetration as relevant media for dispersion. We use the pooled mean group estimator on a dynamic panel (ARDL) model for conducting a robust analysis of the subject matter. We find that ICT expansion has a significant negative effect on economic growth in the long run in N11 countries. In addition, the results suggest that financial development slows down economic growth in the short and long run. Foreign direct investment and trade indicate a positive and significant relationship with economic growth in the long run.

Keywords Information and communication technology · Financial development · Foreign direct investment · Trade · Economic growth

Introduction

ICT is a significant element in economic growth in the present era of world development. Economic operations like trade mostly rely on current internet sources. Today, the increasing use of the online shopping has an opportunity to be involved

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in financial development, international finance cooperation, gross domestic product (GDP), commerce, productivity development and organizational facilities, employment growth, and poverty reduction (Latif et al., 2017). Online communication also helps to promote economic growth (Erumban & Das, 2016). Many studies described that financial development is a significant driver for a country's economic growth (Adu et al., 2013). The theoretical relationship of the financial development and economic growth can be indicated by the works of Schumpeter (1911), Gurley and Shaw (1955), Goldsmith (1969), McKinnon (1973), and Shaw (1973). However, uncertainty still exists about the relationship between financial development and economic growth (Adeniyi et al., 2015). Some studies attempted to examine the impact of ICT and economic growth. ICT consists of technical tools and resources used for communicating and developing, disseminating, storing, and managing information (Mugeni Ndombi et al., 2014). It indicates a combination of technologies and applications that enables electronic processing, storing, retrieval, and transfer of information to several users (Savulescu, 2015). Financial development has an impact on the trade and economic growth through a variety of mechanisms, including composition impact, scale impact, and technique impact (Grossman & Krueger, 1991). The composition impact, financial development, may increase or decrease trade levels by altering the design of economic activity (Ahmad et al., 2021). For example, if foreign companies use capital-intensive production methods, the trade level will rise, and vice versa, the trade level will fall. The scale impact, IFDI, in general, raises trade levels by expanding the economy (Satrovic & Muslija, 2018).

ICT allows the data exchanges across countries and aids decentralized information processing, and contributes significantly to the new emerging corporate business models. Salahuddin and Gow (2016) explained the spatial interaction of large batches of information that enhances methods of competition and innovation. Information technology tools suggest unique information exchange methods in business transactions that change the financial and other service sectors (Ndombi et al., 2014). Globally, ICT has been one of the fastest-growing industries in the USA in job creation that has grown by 22% up to 2020, a 10% increase in broadband penetration. It leads to GDP growth of 1.4% in emerging markets worldwide and can reach out to international customers (Elene, 2013). ICT development into the financial system has been considered as the form of introduction of ICT gadgets such as automated teller machine (ATM), electronic fund transfer (EFT), clearinghouse automated payments (CHAPs), electronic purse (E-PURSE), and automatic check sorter (ACS). The point of sale electronic and transfer (EFTPOS) made financial transactions easy and convenient (Osabuohien, 2008). These ICT gadgets have eased human life as automation, a reduced transaction in the banking hall, more easeful procedures, and less crowd in banking halls' surroundings in carrying out transactions.

ICT boosts the business innovation through diffusion, usage, and commercial success (Cuevas-Vargas et al., 2016). Dimelis and Papaioannou (2010) linked the past decades' new information economy to increased ICT expansion, higher productivity gains, and increased trade growth. Kumar and Arya (2016) concluded that the demand for ICT skills would rise in the future. ICT skills incorporation will be necessary for problem-solving, innovative, and systemic thinking towards developing cognitive and problem-solving skills. Results from the study strongly support

one of the recurring views shared by Asian NII leaders: The payoff effect of ICT on economic growth can be achieved only through a robust national information infrastructure that supports ICT adoption and applications (Işik, 2013). Vu (2011) identified the three channels through which ICT accelerates economic growth. First, ICT-induced growth is its promotion of creativity and information diffusion from developed countries to developing countries. Second is the improvement in business and household decision-making consistency. Third, ICT penetration lowers the cost of production and increases demand and investment, thereby increasing efficiency and growth rates. Empirically, there is enormous evidence suggesting that ICT benefits economic growth, (Koutroumpis, 2009; Pradhan et al., 2015; Bahrini & Qaffas, 2019; Farhadi et al., 2012; and Lee & Becker, 2012).

However, several studies on the relationship between financial development and economic growth have found mixed results. Empirical results of Ofori-Abebrese et al. (2017), Samargandi et al. (2015), Adeniyi et al. (2015), and Kenza and Eddine (2016) suggested the significant negative influences of the financial development on economic growth. In comparison, empirical studies such as Tarawally et al. (2015) and Abubakar et al. (2015) found a significant positive relationship between financial development and economic growth. However, the studies' empirical results by Adu et al. (2013) and Kabir and Halder (2018) are inconclusive.

The relationship between trade and economic development has drawn considerable interest from scholars and developing-country. Economic growth and trade attraction to relevant policies have been prioritized in these N11 countries during the economic growth and financial development process (Vo et al., 2019). It is commonly observed that FDI and trade reduce the disparity of saving-investment and offers infrastructure used for goods and services production. In a different perspective, it can be argued that foreign trade is one of the main factors in the economic integration process since it enhances the long-term gains and relations between diverse countries. On the one side, among academics, the multiple positive benefits of trade have been debated. FDI not only diversifies the recipient's capital structure, but it also offers favorable externalities such as infrastructure and transfer of information, skilled labor, and technology (Blomström et al., 1994; Caves, 1974; Mansfield & Romeo, 1980; Markusen & Venables, 1999). On the other hand, some previous studies have stated that the influence of FDI on economic growth is negative in the short run, but the effect of FDI on economic growth is positive in the long run (Bosworth et al., 1999; Schoors & Tol, 2002).

Our study primarily contributes in two ways. Firstly, we consider the latest available panel data set for N11 countries from 2000 to 2018 to represent the entire region's scenario and not the chosen countries. Sachs (2015) has listed the N-11 countries (South Korea, Mexico, Bangladesh, Egypt, Indonesia, Iran, Nigeria, Pakistan, Philippines, Turkey, and Vietnam) are contributes the largest chunk in world economy. Sachs (2015) also reported that 7% of the world economy is throughout this region and estimated that these countries would share two-thirds of the G7 economies by 2050. Second, we used the Pooled Mean Group (PMG) autoregressive distribution lag (ARDL) approach by Pesaran et al. (1999). It makes that possible to be homogeneous across countries for the long-run coefficient, while the short-run coefficients and the error correction term lag are heterogeneous throughout the

N11 countries. Third, we measured the role of ICT, trade and FDI in the presence of financial development on economic growth. We conclude that expansion of ICT in N11 nations to have a considerable negative impact on long-term economic development. In addition, the findings indicate that financial development inhibits short- and long-term economic growth. Foreign direct investment and trade show a favorable and substantial long-term connection to economic development.

This study's remaining parts are structured as follows: "Empirical Literature Review" discusses the literature review, "Data and Model Specification" describes the data and methodological approach, and the empirical results are discussed in "Results and Discussion". Lastly, "Conclusion" ends with a conclusion.

Empirical Literature Review

The empirical literature in our research area is divided firstly on the relationship's nature (whether positive or negative, linear or non-linear) between indicators of financial development and economic growth. Secondly, on the index of financial development to evaluate the impacts on ICT and economic growth, and thirdly on the diversity of the intervening variables used to test the effects of finance–growth further. The three groups include a set of empirical studies.

Tarawally et al. (2015) and Singh's (1999) empirical results in Kenya's context corroborated the finance-led growth hypothesis that confirmed a significant positive role in economic growth. Furthermore, Rafindadi and Yusof (2015) examined the relationship between financial development and economic growth. They suggested that financial development raises economic growth in both the short and long run in Nigeria's context. Likewise, Yildirim et al. (2013) provided evidence for the selected countries, including Lithuania, Poland, Romania, and Turkey. However, Bulgaria, Croatia, Hungary, and Latvia suggest both the bidirectional relationship between financial development and economic growth. A considerable amount of literature was unable to establish direct linkages. Ductor and Grechyna (2012) employed the generalized system method of moments (S-GMM) estimation technique. The study's empirical results confirmed a significant negative effect of financial development on economic growth if the rapid increase in private credit is not accompanied by real output growth. Similarly, Adeniyi et al. (2015) confirmed the significant negative relationship between financial development and economic growth, but a sign reversal is shown on accounting for threshold-type effects. More recently, Samargandi et al. (2015) discovered signs of negative short-run growth effect that could be due to the disproportionate financial impact on growth. Samargandi et al. (2015) and Moradbeigi and Law (2017) measured the financial intermediaries in both the short- and long-term impact negatively on MENA's growth rate countries. Ibrahim and Alagidede (2018) employed the Hansen threshold technique. The empirical results concluded that financial development stimulates economic growth; however, financial development does not respond to growth below the 11% threshold level.

Moreover, Ruiz (2018) and Mtar and Belazreg (2020) employed a dynamic panel threshold estimator and GMM technique, respectively. The empirical results suggested that finance plays an essential role in industrialized countries compared to

developing countries. Adusei (2014) studied the relationship between financial development and economic growth by employing multiple financial development measures. It covers mainly domestic credit as a share of GDP, domestic credit to the private sector as a share of GDP, and broad money supply as a share of GDP, which discouraged the economic growth in Ghana's context. Adu et al. (2013) also studied the relationship between financial development and economic growth by employing multiple financial development measures from 1961 to 2010. The empirical results vary for different standards; for instance, the measures conducive to growth include credit to the private sector as a ratio to GDP and total domestic credit. However, the broad money stock-to-GDP ratio did not induce growth. Rafindadi and Yusuf (2015) studied financial development measures such as the ratio of liquid liabilities to GDP and the percentage of credit to the private sector by banks to GDP, along with another variable such as trade openness. The empirical results suggested that in the short- and long-run financial development, trade openness induces economic growth in South Africa.

Overflow the nexus of financial development — economic growth, the emphasis of empirical research has switched to the nature of the multiple intervening variables that improve our understanding of the linkages. Various factors that have been discussed above are human capital roles, openness, investment flows, and technologies. There are extensive studies in that area. For instance, Uddin et al. (2013) studied the relationship between trade openness and economic growth in Kenya's case. Despite occasional external shocks to regional economies via armed conflicts or terror treats, overall global tourism grows by a healthy 4% to 5% annually. The liberalization of foreign trade and financial sectors coupled with technological advances has probably been responsible for this growth (Işik et al., 2017). The empirical results discovered that trade openness acts as resistance to economic growth. In contrast, financial development measured in liquid liabilities as a GDP ratio has a significant positive relationship with economic growth. Egbetunde and Akinlo (2015) examined the effect of financial development indicators (ratio of liquid liabilities to GDP, a percentage of private-sector credit to GDP, and the ratio of commercial bank assets to commercial banks and central bank assets) in economic growth in the SSA context. They discovered that financial development significantly contributes to short- and long-term economic growth, whereas openness of trade has long-term growth-inducing effects. Abubakar et al. (2015) discovered that financial development directly impacts economic growth in case of private bank credit and domestic private credit; however, in human capital accumulation, it indirectly affects it.

Rafindadi and Ozturk (2016) discovered that economic growth stimulates energy consumption; on the other hand, financial development, capital use, and trade openness decrease energy consumption in the context of Germany. Furthermore, Rafindadi and Ozturk (2017) also confirmed that financial development, economic growth, and trade openness spur electricity consumption; however, capital stock disrupts Japan's electricity consumption. Rafindadi and Aliyu (2017) confirmed that both financial development and trade openness stimulate only long-run economic growth in Ghana. Moradbeigi and Law (2017) observed that financial development impedes oil abundance's adverse influence on economic growth. Romer (1990) revealed that financial development, trade openness, and economic growth stimulate efficient energy use in

South Africa. Empirical results from Egbetunde and Akinlo (2015) suggested that financial instability discourages economic growth; however, financial liberalization increases economic growth. One of the relevant strands of empirical literature important here originates from the theoretical perspectives, which established the position of ICTs in the endogenous growth model by effecting technology. One of the more recent research, Koutroumpis (2009), confirmed that information and communication technology stimulates economic growth in the presence of critical mass and infrastructure. Vu (2011) disclosed that personal computer penetration, mobile phones, and internet users had a significant causal effect on growth. Andrianaivo and Kpodar (2011), Yazdan and Hossein (2013), Kumar et al. (2016), and Tunio and Nabi (2021) similarly discovered that ICT has a significant positive impact on growth. Bahrini and Qaffas (2019) concluded that telecommunications infrastructure's development influences economic growth and stimulates itself by growth in the long run.

Scholars worldwide have drawn considerable attention to the relationship between FDI and economic growth (Vo et al., 2019). Tiwari and Mutascu (2011) demonstrated that over the period 1986–2008, both FDI and international commercial activity facilitated economic growth for 23 Asian nations. Borensztein et al. (1998) explored the role of FDI for developing countries in economic growth. Their results suggest that FDI has been an essential intermediary between technology and economic growth. Additionally, if the relevant country had high human capital, they also claimed that FDI would be more effective in an economy. Using a causality test and OLS regression, Omran and Bolbol (2003) demonstrated both a high association and significant causation between FDI and economic growth for Arab countries. They also concluded that local economic and political circumstances were critical factors influencing FDI inflows, along with FDI attraction-focused policies. A negative relationship was found compared to the above-mentioned positive relationship of cross-country data between FDI and economic growth, leading to a significant part of the (unresolved) problem. For 62 countries over the 1975–2000 period, Jyun-Yi and Chih-Chiang (2008) established no association between FDI and economic growth. Similarly, during 1995–1998, Lyroudi et al. (2004) found no FDI influence on emerging market economic growth.

According to Sassi and Goaid (2013), the significant adverse effects of financial development on economic growth, on the other hand, ICT diffusion is one of the essential factors in determining economic growth in the context of selected 17 MENA countries. Pradhan et al. (2018) confirmed a long-run relationship among both ICT infrastructure and financial development on economic growth. Moreover, Salahuddin and Gow (2016) discovered that internet usage, financial development, and trade openness are critical factors for determining long-run economic growth. Both internet usage and financial development have a significant positive relationship with economic growth in the long run. Kumar and Arya (2016) ICT has a significant positive effect on economic growth in the long run; in the same vein, Hofman et al. (2016) confirmed the significant positive relationship between investment in ICT investment and economic growth. Latif et al. (2018) find that ICT, FDI, and international trade play a significant role in economic growth. Like Fufa and Kim (2018) conclusion on the role of finance in development, Niebel (2018) illustrates that ICT significantly contributes to development in industrialized countries

rather than developing ones. In one of the most recent and influential studies in this research area, Pradhan et al. (2018) confirmed that an increase in ICT infrastructure leads to economic growth. The present research focused on these principles, builds on the theoretical and analytical perspectives to understand ICTs, finance, and economic development in a single context.

Data and Model Specification

Data

A panel data of N11 nations is explored in this research. Data were obtained from the World Bank Database for the period 2000 to 2018, World Development Index. The availability of data is thus chosen for the data span and nations. Financial development encompasses private-sector domestic credit (percent of the GDP and money supply) (percent of GDP), economic growth (GDP) is projected to be yearly percentage points of GDP. Different proxies for measuring information and communication technology have been used in literature (ICT). We used as fixed telephone subscription (per 100 persons), mobile cellular subscription (per 100 people), fixed broadband subscription (per 100 persons), individual using internet (per 100 people, percent of population), and secure internet servers (per million people). The present study has used internet users (per 100 people) as a proxy for measuring internet use (Añón Higón et al., 2017; Asongu et al., 2016). Trade is dignified as import and export of goods and services (% of GDP). The foreign direct investment is measured by net inflow percent of GDP. The variables, its descriptions, and measurements are provided in Table 1 below.

Table 1 Description of variables

Variables	Symbols	Measurement	Data sources
Dependent variable			
Economic growth	GR	The growth rate of GDP (%)	WDI
Independent variable			
Telephone subscriptions	TEL	Fixed telephone subscriptions (per 100 people)	WDI
Mobile subscriptions	MOB	Mobile cellular subscriptions (per 100 people)	WDI
Broadband subscriptions	FBB	Fixed broadband subscriptions (per 100 people)	WDI
Internet subscribers	INT	Individuals using the internet (per 100 people) (% of the population)	WDI
Secure internet servers	ISS	Secure internet servers (per 1 million people)	WDI
Trade	TR	Trade (percent of GDP)	WDI
Financial development	FIN	Domestic credit to private sector (% of GDP)	WDI
Financial development	BMS	Money supply (% of GDP)	WDI
Foreign direct investment	FDI	Foreign direct investment, net inflows (percent of GDP)	WDI

The Econometric Model

This paper is at examining the relationship between ICT expansion and economic growth. Five variables have been taken as the proxy for ICT.

This reason for the study is to analyze the null hypothesis empirically; it emphasizes no relationship between ICT expansions on financial development. Whereas, the alternative hypothesis would be that there is a significant positive effect of ICT expansion on financial development.

Based on our discussion, the general linear regression model for panel data employed is given below

$$GR = f(\text{FIN}, \text{ICTINDEX}, \text{FDI}, \text{TR}) \quad (1)$$

$$GR_{it} = \alpha + \beta_1 \text{ICTINDEX}_{it} + \beta_2 \text{FIN}_{it} + \beta_3 \text{FDI}_{it} + \beta_4 \text{TR}_{it} + u_{it}, \quad (2)$$

where $t = 1, 2, \dots, T$ is the time period and $I = 1, 2, \dots, N$ is the cross-section data. The β_1, β_2 , and β_3 parameters represent GR's long-run elasticity estimates for financial development, information and communication technology, trade, and u_{it} is the term white noise error. To analyze the complex relationship between the variables, we used different panel estimation techniques. Firstly, we used the panel unit root test to describe the stationary properties of the variables. This study uses two types of root panel unit tests: the Im et al. (2003) and ADF-Fisher chi-square tests (Dickey & Fuller, 1979).

We use the panel autoregressive distributive lag model (PARDL) framework (Pesaran et al., 1999) to investigate the role of ICT expansion in the economy, since the panel ARDL estimation technique is helpful in the face of $I(0)$ and or $I(1)$ variables and yields consistent estimates in the presence of endogeneity (Pesaran et al., 1999). Additionally, this approach examines the dynamic panel setting's heterogeneity, the short-run dynamic, and the model's long-run equilibrium (Ahmed et al., 2016). Finally, the panel ARDL method separately estimates the short-run and long-run effects (Pesaran et al., 1999).

Panel autoregressive distributed lag (ARDL) (p, q) is given below:

$$\begin{aligned} GR_{i,t} &= \sigma_i + \sum_{m=1} \delta_{im} GR_{i,t-m} + \sum_{m=1} \phi'_{im} Z_{i,t-m} + \mu_{it}; Z_{i,t} \\ &= \text{ICTI}_{i,t}, \text{tFIN}_{i,t}, \text{FDI}_{i,t}, \text{tTR}_{i,t} = (\text{ICTI}_{i,t}, \text{FIN}_{i,t}, \text{FDI}_{i,t}, \text{TR}_{i,t}) \end{aligned} \quad (3)$$

where $t = 1, 2, 3 \dots T$ represents the time dimension (annual) and $I = 1, 2, \dots, N$ the cross-sectional unit is indicated by N . Moreover, the number of time lags is represented by m . Within Eq. (3), $GR_{i,t}$ represents the gross domestic product growth rate for I countries and t period, GR as the dependent variable; the $Z_{i,t}$ vector contains the key explanatory variables. Private sector credit measured financial development (FIN), the ICT index ($ICTI$), the foreign direct investment (FDI), and the trade (TR), and the σ_i index denotes fixed country effects. We used the ARDL framework pooled mean group (PMG) estimator proposed by Pesaran et al. (1999). It is possible to be homogeneous across countries for the long-run coefficient, while the short-

run coefficients and the error correction term lag are heterogeneous throughout the countries.

Results and Discussion

Our study includes a similar number of countries as most previous studies (Sassi & Goaied, 2013; Wamboye et al., 2015). This table clearly shows that the N11 countries have one of the highest GDPPC mean values, which is understandable given that this sample includes the N11 countries as well as other middle-income countries from Asia and North Africa (World Bank, 2017). This study's data criteria include financial development, ICT, and economic growth details for N11 countries: India, Egypt, Indonesia, Iran, South Korea, Mexico, Nigeria, Pakistan, the Philippines, Turkey, and Vietnam. The technology and networking systems such as computers, cell phones, the internet, ATMs, POS machines, and other technological sources reached chosen countries in the early 2000s, it is appropriate to select the time. The variables used in this study are as follows. The dependent variable is the gross domestic product growth rate (*gr*). In contrast, the independent variables are foreign direct investment, trade, and financial development measured by a credit to the private sector as a GDP ratio (*FIN*) following Rafindadi and Yusof (2014) and Rafindadi and Ozturk (2017). The robustness is measured as a broad money supply (*BMS*) (Abubakar et al., 2015; Adu et al., 2013).

The principal component analysis (PCA) is employed on the panel dataset on a mobile cellular subscription per 100 people, fixed telephone subscription per 100 people. The fixed broadband subscriptions per 100 people are individuals using the internet percentage of the population and secure internet server per 1,000,000 people to collect the index of ICT expansion for N11 countries. The PCA is a statistical technique used to produce less variable numbers or an index describing specific differences in the original variables (Olofin, 2013). Another crucial variable worth considering is the trade (*TR*) determined by the total trade (exports plus imports) as a GDP ratio that can account for N11 countries' integration with the developed world. All the data are sourced from the 2018 World Development Indicators (WDI), the World Bank data set. Listed N11 countries are focused on data availability for this analysis and are described in Table 1, while Table 2 contains measures and descriptions of the variables used for this study.

We take a cursory look at our results as a quick review. The descriptive statistics of our data are given in Table 3. Those provide the mean, minimum, maximum, and standard deviation. The results indicate that the average of the growth rate of gross domestic product, financial development (proxied by a credit to the private sector as a ratio of GDP), ICT index, inward FDI (percentage of GDP), and trade (proxied by total trade as a ratio of GDP) are equal to 4.80, 42.32, 3.898, 0.15, and 60.37, respectively. At the same time, the standard deviation values signify high variability in the series. (see Tables 4 and 8)

The table also shows that standard deviations are higher than mean values, particularly in the case of N11 countries. This indicates that changes in the levels of

GDPPC and ICT variables are more significant in the N11 region than in the SSA region over the study period. This is in contrast to the findings of previous studies (see Albiman & Sulong, 2016).

Table 2 Descriptive statistics

Variables	<i>N</i>	Mean	Median	Minimum	Maximum	Std. dev	Skewness	Kurtosis
GR	209	4.80	5.12	−7.44	15.33	2.78	−0.84	7.02
ICT	209	−3.898	−0.02	−2.49	3.53	0.98	0.23	2.70
FIN	209	42.32	32.43	0.00	141.95	35.81	1.34	4.04
FDI	209	0.15	0.16	−1.44	0.98	0.37	−0.55	4.68
TR	209	60.37	49.68	0.00	208.31	34.58	2.06	7.48

Source: Author’s calculation

GR growth rate, *ICT* information and communication technology index, *FIN* financial development, *FDI* foreign direct investment, *Std* standard deviation, *TR* trade

The check for correlation across the repressors (to exclude strongly correlated variables) did not suggest any trouble (as suggested by econometric studies, correlation coefficients were found to be below 0.8). Table 3 describes the coefficients of correlation between the dependent and the independent variables, except for the ICT index. However, we observed that GR was negatively correlated with the ICT index.

Table 3 Correlation

	LN(GR)	LN(ICT)	LN(FIN)	LN(FDI)	L(NTR)
LN(GR)	1				
LN(ICT)	−0.124	1			
LN(FIN)	0.018	0.244	1		
LN(FDI)	0.147	0.042	0.121	1	
LN(TR)	0.137	0.049	0.616	0.496	1

Source: Author’s calculation

ICT information and communication technology index, *FIN* financial development, *GR* growth rate, *FDI* foreign direct investment, *Std* standard deviation, *TR* trade

The time-series nature of our data collection makes our variables vulnerable to the root phase of units. Therefore, we use the Im, Pesaran, and Shin (IPS) and ADF-Fisher chi-square measures to verify the unit-root presence in the panel data and determine the order of integrating the sequence seen in Table 6. The null hypothesis of Im, Pesaran, and Shin (IPS) and ADF-Fisher chi-square tests are that the unit root (non-stationary) is the underlying series. The results revealed that GR, ICT index, and FDI do not possess unit root, i.e., stationary at the *I*(0) stage, Whereas, FIN and TR are stationary at the level *I*(1).

Table 4 Results of unit root test

Variables	Im, Pesaran, and Shin W-stat				ADF-Fisher chi-square				Results
	Level		First difference		Level		First difference		
	T-stat	P-value	T-stat	P-value	T-stat	P-value	T-stat	P-value	
LN(GR)	-5.149	0.000	-10.123	0.000	64.607	0.000	116.090	0.000	I(0)
LN(ICT)	-4.849	0.000	-3.898	0.000	74.533	0.000	52.976	0.000	I(0)
LN(FIN)	1.985	0.976	-5.412	0.000	13.918	0.904	67.358	0.000	I(1)
LN(FDI)	-2.519	0.006	-9.314	0.000	120.577	0.006	115.635	0.000	I(0)
LN(TR)	-0.045	0.482	-6.518	0.000	27.258	0.202	78.652	0.000	I(1)

Source: Author’s calculation

ICT information and communication technology index, *FIN* financial development, *GR* growth rate, *Std* standard deviation, *FDI* foreign direct investment, *TR* trade

Hausman test has been employed for model specification in this study; results are presented in Table 5. It confirmed that the panel fixed effects regression technique is the desirable model specification compared to the panel random effects regression technique, as the null hypothesis. Random effects test is accepted at the *P*-value of 9.4%. Therefore, we have employed random effects regression. These data are compatible with one body of literature, which we refer to as those of Pohjola (2002). One possible explanation for this is that technological advancements and innovations drive unskilled and low-wage workers out of the labor market, which is a major cause of higher income inequality in any economy (see Freeman & Soete, 1997). For more information on similar results, see O’Mahony and Bechky (2008), and Ceccobelli et al. (2012). However, we serve that ICT investment led by imports has a statistically significant impact on Pakistan’s economic growth ($2 = 1.73$; $p 0.05$) when ICT imports (as a percentage of total imports) reach the threshold level of 4.13, allowing Pakistan to enter a different regime.

Table 5 Results of Hausman test

Test summary	Chi-sq. statistic	Chi-sq. <i>d.f</i>	Prob
Period random	0.714	4.000	0.094

Source: Author’s calculation

After validation of the Hausman test model specification, the study proceeded with the panel random effects regression and presented the results in Table 6. The results indicated a negative and significant impact of the ICT development on selected sample countries’ economic growth; if there is a 1% increase in GDP growth, the ICT Index’s proxy variables decreases by -0.379 .

Table 6 Results of panel random-effects regression

Variable	Coefficient	Std. error	t-Statistic	Prob
C	4.234	0.432	9.790	0.000
ICT	−0.379	0.263	−1.439	0.151
FIN	−0.002	0.007	−0.355	0.722
FDI	0.676	0.617	1.096	0.274
TR	0.009	0.008	1.148	0.251
R-squared	0.0410	Dependent variable = LN _{GR}		
Adjusted R-squared	0.0222			
F-statistic	2.1828			
Prob (F-statistic)	0.0721			

Source: Author's calculation

ICT information and communication technology index, FIN financial development, GR growth rate, Std standard deviation, TR trade

The selection of the appropriate lag and optimum lag selection criteria is used. It is essential to use advanced econometric techniques such as the co-integration, ARDL, and Granger causality test. The five lag order selection criteria were used to select the optimal lag. For choosing the optimum lag, shown by the asterisks, each parameter's lowest value is used. The lag order chosen for our analysis, based on the below analysis, is 2.

Table 7 Optimum lag order selection criterion

Lag	Log L	LR	FPE	AIC	SC	HQ
0	−1430.83	NA	149,727.70	26.11	26.23	26.16
1	−996.34	821.58	87.52	18.66	19.397*	18.96
2	−953.81	76.536*	63.822*	18.342*	19.69	18.889*

Source: Author's calculation

AIC Akaike information criterion, FPE final prediction error, HQ Hannan–Quinn information criterion LR sequentially modified LR test statistic (each test at 5% level), SC Schwarz information criterion

*Lag order selected by the criterion)

We applied the ARDL method to estimate the long-run and short-run coefficients. Table 7 presents the results of the long-run and short-run ARDL estimation. The short-run estimates indicate the presence of a short-run relationship as the cointegrating equation is significant at -0.703 . The results demonstrate that the expansion of ICT has a significant negative effect on economic growth in the long run. But it does not impact economic growth in the short run, which hinders economic growth by 2.825 points throughout the selected countries in the long run.

Furthermore, the results suggest that short- and long-run financial development slows down growth in N11 countries. The results of Ductor and Grechyna (2012), Adusei (2014), Samargandi et al. (2015) validate this outcome. Foreign direct investment

and trade coefficients suggest a positive and significant relationship with economic growth in the long run. These results confirm the benefits of trade and foreign investment for the growth of selected economies, according to Rafindadi and Yusof (2015).

Table 8 Long-run and short-run results using the ARDL approach

Variable	Coefficient	Std. error	t-Statistic	Prob.*
Long-run equation				
ICT	−2.825	0.253	−11.175	0.000***
FIN	0.078	0.010	7.967	0.000***
FDI	0.793	0.368	2.154	0.034**
TR	0.036	0.012	2.905	0.005***
Short-run equation				
COINTEQ01	−0.703	0.181	−3.876	0.000**
D(ICT)	0.031	0.582	0.054	0.957
D(FIN)	0.043	0.127	0.343	0.732
D(FDI)	−2.030	1.211	−1.676	0.097*
D(TR)	−0.014	0.085	−0.164	0.870
C	−0.298	1.203	−0.247	0.805

(i) Respectively, the signs ***, **, and * describe the significance levels at 1%, 5%, and 10%. (ii) Estimated results of the long-run and short-run ARDL approach

Conclusion

The paper analyzed and evaluated the finance–growth nexus and the role of ICT expansion in the context of N11 countries using panel data from 2000 to 2018. One of the critical findings emanating from this study aligns with a group of earlier studies that financial development negatively affects N11 economic growth. The results suggest that the N11 countries' policies to improve the financial sector are not well placed to accomplish the expected objectives. We follow the several theoretical and methodological innovations to improve on the limitation. Theoretically, in pursuing the economic growth objective, the impacts of ICTs play in complementing financial policies. Methodologically, a robust estimation approach provides a better long-run and short-run estimations. We concluded that ICT, FIN, and TR have a significant long-run relationship with economic growth. The problem of the N11 countries is that it attempts to grow the financial sector which needs to be reinforced through ICT infrastructure, improved internet access, and greater integration of electronic finance policies. The findings of the study reveal that ICT infrastructure, along with other macroeconomic factors, is an important driver of economic growth in the EU countries.

This research also revealed that policy-related economic instability has a significant impact on N11 countries. The N11 countries employ to validate the expected

outcome as well as to evaluate the response levels of many other countries with different uncertainties. Moreover, our results are distinguished by the breadth and depth with which it covers all current political discussions (particularly from the perspective of the N11) about the future of the USMCA. Because of the large and persistently unfavorable trade relations among N11 countries, there has been a steadily rising amount of discussion and critique about USMCA on the US side. Furthermore, the traditional variables related to economic factors, the EPU index, as an additional independent variable, should be included in hospitality demand models. This concern is more crucial than ever in today's complex and uncertain global economy. The empirical studies of Işık et al. (2020) involved other countries, and different methodologies and data sets may be required for growth. The benefits of this study are insightful in terms of harmonizing the financial sector and innovative research reforms. The study's significant finding revealed that financial development by itself inhibits N11 countries' prosperity; furthermore, its association with ICT expansion encourages regional economic growth.

We recommend that the N11 countries target enhanced investment, penetration, and affordability of ICTs to complement their efforts to develop the financial sector through increased ICT infrastructure investment, improved internet penetration, and further integration of electronic finance systems. These ICT policy decisions would function as an alternative to the adverse effects on the study region's economic growth of the financial stability indicators. This research emphasized, in order to promote economic growth, ICT infrastructure development (by encouraging increased investment in ICT so as to provide easy access to these technologies) should be a priority in government policies. A drawback of our study is limiting the investigation to the EU countries only. Therefore, as a future research direction, we aim to extend the analysis with data for other European non-EU countries, as well as to analyze the impact of ICT use on groups of countries, depending on their level of development, including the assessment of the impact of economic growth on ICT development.

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Author Contribution Dr. Agha contributed on the analysis section. Dr. Tunio contributed on the central theme of the study and worked on the abstract and introduction parts. Mr. Magsi and Dr. Shah worked on the literature review section and in writing the review and Dr. Zia was responsible for the data collection and organizing. Overall, all the authors have distributed the work as per their expertise and finally sat down to the compilation and submission of the paper.

Data Availability This is confirmed that this research article's data is available on world development indicators on the World Bank website, and a copy of the data set is also with the authors. <https://datatopics.worldbank.org/world-development-indicators/>.

Declarations

Competing Interests The authors declare no competing interests.

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