System GMM-based Model for Monitoring Joint Impact of ICT-infrastructure, Financial Development, and Trade-openness on Economic-growth

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Abstract

This study has analyzed the joint impact of information communications technology (ICT) Infrastructure, financial development (FD), and trade openness (TO) on economic growth (EG). We have used the data from 85 countries (including 27 low-income and 58 high-income countries). In this sample, we have collected the data from the year 2000-2019. We have framed hypotheses for samples and applied OLS, fixed effect regression (FER), and GMM method. Our results provide evidence that (a) ICT infrastructure is a significant and positive interpreter of economic growth, (b) Individual consideration of trade openness and financial development is insignificant and negative for both groups of countries, ICT infrastructure requires more financial development and trade openness in low-income countries (LICs) in comparison to high-income countries(HICs), (c) ICT infrastructure-financial development-trade openness nexus differ significantly for both groups of countries. Our study acquiesces that variables are grave drivers of any economy and comprehensive growth in low-income countries. In this work, we have also discussed policy implications.

1. Introduction

The economic growth of any country depends on the various determinants, financial development (FD), foreign direct investment (FDI), financial development, and trade openness (TO) are most important among these (Adom *et al.,* 2019; Boamah, 2017; Dunne & Masiyandima, 2017). However, information and communication technology (ICT) is a modern driver of growth as compared to TO and FDI (Donou-Adonsou, 2019; Myovella *et al.,* 2020). Furthermore, a wide range of studies is an emphasis on different channels of ICT; mainly here discussed about telecommunication infrastructure because telecommunication infrastructures contribute to EG like: reducing transaction time period and cost, increasing efficiency, growth in trade, enlarge innovation and development, increasing job opportunities, etc. (Pradhan, Arvin, Hall, & Bennett, 2018; Pradhan, Arvin, & Norman, 2015; Datta & Agarwal, 2004; Shahiduzzaman & Alam, 2014). According to United Nations, (2019), ICT Infrastructure directly affects job creation, GDP, increasing rate of return, profitability by using skilled persons, and income in the IT sectors, especially in developing countries. Similarly, World Bank (2012) argues that ICT is a driving force in encouraging EG in developing countries. However, developing countries are gradually using more developed ICT Infrastructure. Therefore, it shows that the number of internet and mobile users is increasing significantly in developing countries (including low-income & middle-income countries). To improve ICT infrastructure, we are still requiring funds, and it is possible when investing in new technologies, including artificial intelligence, robotics, and AR/VR[1]. ICT is increasingly associated with more positive economic growth. Nowadays, ICT plays a vital role in all the sectors with extensive ICT applications. With the help of new ICT technologies, cost-reducing, innovative behaviour, economic reconstruction, and increased performance in all sectors make possible (Sharafat and Lehr, 2017). **ICT** connects the customers, suppliers, and manufacturers through the ease of doing the business. Moreover, it helps in developing new knowledge and spread through the more efficient process of easy transformation of all types of information without any geographical and demographical barriers.

Even though the ICT plays a significant role in economic growth, it requires more financial support for further investment in new ICT projects and adaptation of more trade openness policies of particular countries. For the making of good ICT infrastructure required high speed of internet, costly installation & operation charges, consume more electricity, etc. The rapid growth of ICT requires more financial development and trade openness. Previous studies regarding the nexus between ICT and EG are discussed exclusively without looking at the impact of financial development and trade openness. Therefore, it is necessary to continue research and analysis on this issue, including these two most significant variables which affect EG.

The potential contributions of our study are in four aspects: First, this study empirically tested the joint impact of ICT infrastructure, financial development, and trade openness on EG. Second, our study analyzes the different mechanisms of ICT infrastructure's influence on the economic growth of LICs and HICs. Third, this study research has enhanced the research literature between ICT infrastructure, financial development, and trade openness moreover provided the possibility of reference for subsequent analysis in this field. Fourth, the variables financial development and trade openness removes previous deficiencies to examine the collaborative relationship among ICT infrastructure, financial development, trade openness and EG.

This study is structured in the following way: a related study discussed in section 2. How collects and chooses the data for this study is explained in section 3. Econometric results and discussion are described in section 4. The final section 5 offers a conclusion and policy implications based on the findings.

[1] AR-Augmented reality and VR- Virtual reality

2. Literature Review

As we have studied in previous papers (S.H. Lee, Levendis, and Gutierrez, 2012; Deloitte, 2012; Vu, 2011; Gruber and Koutroumpis, 2011; Lam and Shiu, 2010; Antonopoulos and Sakellaris, 2009; Waverman, Meschi, and Fuss, 2005) that ICT represents as an ICT infrastructure, ICT diffusion, telecommunication, telephone penetration, mobile users, digitalization, digitization, etc. Different proxies are used to measure ICT infrastructure/ICT diffusion/ ICT expansion like the mobile telephone, internet users, broadband user's internet servers, etc. Whereas, the impact of ICT on EG is well discussed in the previous studies (Appiah-Otoo and Song, 2021; Habibi and Zabardast, 2020; Parwantoa and Wulansari, 2020; Adeleye and Eboagu, 2019; Albiman and Sulong, 2016; Bertschek and Niebel, 2016; Ghosh, 2016; Das, Khan, and Chowdhury, 2016; Ahmed and Ridzuan 2013; Chavula, 2013) and they have found a positive association between ICT and EG. Most of the studies considered the developed countries for the empirical analysis of ICT infrastructure. Only a few studies (Yousefi, 2011) have been done on underdeveloped countries because of the lack of data availability of ICT variables.

Appiah-Otoo and Song, (2021) examined the countries that have high ICT revolution among the high, middle, and low-income countries. They have used panel data of forty-eight high, fifty-eight middle, and twenty low-income countries for this examination. Therefore, this analysis included 123 countries, and the time frame was from 2002 to 2017. They have taken the independent variable as ICT index measured by internet, mobile, and fixed broadband users, and the dependent variable was EG. Finally, they concluded that the ICT index encouraged EG in these countries.

Similarly, Ghosh (2016) used Indian states and, using data from 2001–2012, analyzed the impact of a mobile telephone on EG. The results of panel data analysis revealed a positive association between the mobile telephone and EG. Moreover, Habibi and Zabardast (2020) examined the effects of education and ICT on EG in the Middle East countries (17) and the Organization for Economic Cooperation and Development (OECD) economies (24). Further, they have also compared the impact of the variables between these selected two groups of countries. To compare the effects of ICT and education on EG, they have used two kinds of countries; most and least developed. They took 18 years of data from 2000 to 2017 and used it as panel data. They have applied OLS, fixed-effect, and GMM methods. Results of panel analysis show that ICT is positively affecting the EG in both countries (the Middle East countries and OECD).

Parwantoa and Wulansari (2020) analyzed the impact of ICT on EG in Asian countries, including lower, middle, and high-income countries. They used the period 2010–2018 and applied panel data regression. The panel analysis results found that middle-income countries (MICs) used more ICT facilities than LICs and HICs countries. Similarly, Lam and Shiu (2010) used lower-middle-income countries (LMICs) (59 countries) and used panel data analysis for the causal relationship between ICT diffusion and EG (real GDP per capita). This analysis used the data from1980 to 2006, and the results show a unidirectional causality between ICT diffusion and real GDP per capita. Pohjola (2000) explored the impact of ICT on EG in the 39 countries and data used from 1980–1990 by applying an explicit model of EG. Here, it can be observed that the countries that have invested in ICT sectors/ICT infrastructure/technology encourage the EG. But they have found those countries that have not invested; they found a negative and insignificant relationship between ICT and EG. Yousefi (2011) analyzed the effect of ICT capital on EG in developed and developing countries for 2000–2006. It is indicated that ICT capital played a significant role in the EG of upper, middle, and low-income countries.

On the other hand, studies related to financial development and EG are well explained in the literature. De Gregorio and Guidotti (1995) examined the relationship between financial development and economic growth. They found that financial development has a positive relation with EG in the cross-country sample, but in the panel data (Latin American countries) found a negative impact of financial development on EG. Arestis and Demetriades (1997) found empirical proof related to the relationship between financial development and EG in two ways: how and to what extent the FD can contribute to upgrading EG. So, firstly, find out the causal relationship between FD and EG. Secondly, the financial liberal policy can stimulate investment and EG. However, Shaw (1973) and McKinnon (1973b) have justified policies related to financial liberalisation in their research work separately. Sassi and Goaied (2013) examined the combined impact of ICT and financial development on EG in the Middle East and North Africa (MENA) regions. They have applied the GMM approach on the sample of 17 MENA regions for 1960–2009. GMM method results concluded that ICT positively affects EG, but financial development negatively relates to EG. On the other hand, they found the joint effect of ICT and financial development is significantly positive with EG in the MENA regions.

Similarly, Dimelis and Papaioannou (2010) examined the effect of ICT and financial development on EG in developed and developing countries from 1993–2001. In this paper, FDI was used as a proxy of financial development and applied the GMM Model. They found various results based on the GMM Model; firstly, ICT positively affects developing countries. Secondly, FDI has contributed to the

overall, but it positively affects developed countries. Thirdly, FDI does not have a significant impact in developing countries. Although Dimelis and Papaioannou (2010) and Pradhan, Arvin, and Norman (2015) studies included financial development and ICT diffusion in empirical estimation, they were ignored the joint effects of ICT and financial development on EG. In the same way, Pradhan, Arvin, and Norman (2015) analyzed the relationship between ICT infrastructure, financial development, and EG in Asian countries from 2001 to 2012. They have applied panel co-integration techniques with the results of short and long-term causal relationships among the ICT infrastructure, financial development, and EG.

The relationship between trade openness and EG is discussed in previous studies (Fetahi-Vehapi, Sadiku, and Petkovski 2015; Chatterji, Mohan, and Dastidar 2014; Kaushal and Pathak, 2015). The study of Fetahi-Vehapi, Sadiku, and Petkovski (2015) analyzed the impact of trade openness on EG in South-Eastern European (SEE) nations. They have included time spam from 1996-to 2012 and applied the GMM Model. Outcomes indicate that they have not found any robust association between trade openness and EG. On the other hand, Chatterji, Mohan, and Dastidar (2014) proved that trade growth encouraged EG in India from 1970 to 2010 and applied the Vector Autoregression (VAR) method. Moreover, they have also concluded that there is no evidence of a significant relationship between trade barriers and rates.

Kumari et al. (2021) examined the long-term and causal relationship among foreign direct investment (FDI) inflows, trade openness, and EG from India. They have applied the Johansen co-integration and vector autoregression (VAR) Model. They have found no long-term co-integration but present the causality between FDI inflow and EG in India for the period of 1991–2013. Further, the results of the VAR Model are bi-directional causality between FDI and EG. Still, in contrast, they found no bi-directional relationship between trade openness and EG in India. Bangake and Eggoh (2011) used panel data for the empirical analysis, and these panel countries were classified into low, middle & high-income countries. They concluded bidirectional long-run causality between financial development and EG in LICs, MICs, and HICs but no found short-run causality in LICs & MICs. Only in HICs found a significant short-run causal relationship between financial development and EG. Hence, the impact of ICT, financial development, trade openness on EG in the existing studies is mixed (positive, negative, and insignificant), a summarized information is shown in Table 1.

Table 1
Literature Summary

S. No	Authors & Year	Countries & Year	Dependent Variable	Independent Variable	Methodologies/Approach/ Techniques	Effects (Positive/ Negative/ Insignificant)
1.	Adeleye and Eboagu (2019)	2005 to 2015 54 countries from Africa	ICT development	EG	GMM technique	+VE
2.	Parwanto and Wulansari (2020)	2010–2018 35 Asian countries in (lower-middle, upper-middle, and high-income countries)	ICT	EG	Fixed and random effect method	More + VE in Low-income countries as comparison of high-income countries
3.	Ntonopoulos and Sakellaris (2009)	1988–2003	ICT Investments	Total Factor Productivity	neoclassical growth accounting model	+VE
4.	Albimanand Sulong (2016)	1990–2014 Sub Saharan African (SSA) region	ICTs	EG	system generalist method of moment	+VE
5.	Das, Chowdhury, and Seaborn (2018)	2000 to 2014 Developing countries	ICT and FD	EG	GMM technique	+VE
6.	Vu (2011)	1996 to 2005 102 Countries	ICT penetration	EG	GMM technique	+VE
7.	Deloitte (2012)	1995 to 2000 and 2008 to 2011 developed and developing markets	Mobile phone penetration & 3G penetration rates	EG		+VE
8.	Lee et al. (2012)	1975 to 2006 Sub-Saharan African countries	ICT	EG	GMM approach	+VE
9.	Chavula (2013)	1990 to 2007 Sub-Saharan Africa (upper-middle, upper-low and low-income countries)	ICT Diffusion	EG	OLS	+VE
10.	Ahmed and Ridzuan (2013)	1975 to 2006 eight Asian countries	ICT	EG	GLS estimation	+VE
11.	Appiah-Otoo and song (2021)	2002 to 2017 123 countries 45 HIC, 58 MIC, and 20 LIC	ICT index (Mobile, internet, and fixed broadband)	EG	Principal component analysis (PCA) and Co-integration analysis	+VE
12.	Bertschek, et al. (2016)	2002 to 2007 22 OECD countries	Broadband adoption	Factor productivity growth and GDP growth.	OLS, fixed and random effect method and GMM method	+VE

Source: Authors Compiled

S. No	Authors & Year	Countries & Year	Dependent Variable	Independent Variable	Methodologies/Approach/ Techniques	Effects (Positive/ Negative/ Insignificant)
13.	Ghosh (2016)	2001–2012 MENA countries	Mobile Telephony	EG	OLS and System GMM estimator	+VE
14.	Gruber and Koutroumpis (2011)	1990–2007 192 countries	Mobile penetration	GDP per Capita	OLS and GMM Model	+VE
15.	Habibi and Zabardast (2020)	2000–2017 Middle East countries & OECD	ICT	EG	OLS fixed-effect and GMM methods	+VE
16.	Waverman *et al.* (2005)	1980 and 2003 OECD nations	Mobile Penetration	EG	Fixed effects Model	+VE
17.	Lam and Shiu (2010)	1980 to 2006 Low and lower-middle-income groups (59 Developing countries)	ICT diffusion	Real GDP	GMM weights and Covariance	Tele density growth → GDP growth Mobile telecommunications growth ↔ GDP growth.

Source: Authors Compiled

3. Data Collection, Hypothesis And Methodology

3.1 Data collection and assessment issues

Panel data analysis is becoming more popular among the researchers because panel data provide multiple benefits compared to cross-section and time-series data set. In this work, we have used the panel data considering LICs and HICs and the time frame from 2000 to 2019. All the variables data is collected since 2000 because data related to the ICT variables for the underdeveloped countries is available from 2000. The variables data were collected from the World Bank Indicators (WDI, 2019) except ICT infrastructure variables. ICT infrastructure variables data are collected from Worldwide Telecommunications Union (WTU 2019).

We have applied the generalize method of moments (system GMM approach) to estimate the framed hypotheses. This approach has various benefits: firstly, not find biased behaviour. Secondly, this method is capable of controlling the country or sector-specific effects. Thirdly, and most importantly, controls the endogeneity problem which is not possible in OLS and Fixed Effect Regression (FER) method. Therefore, our study applied the Generalized method of moments (GMM) approach. This technique is widely used when incorporating panel data includes a couple of periods with an enormous number of observations (Roodman, 2006). As suggested by Hoeffler, (2002) and Das and Paul, (2011), the GMM approach is utilized in both situations where variables are lagged and differenced versions of the regressors as instruments in obtaining coefficient estimates. In this method, Arellano- bond shows that there is no serial correlation along with the hypothesis and error terms. This is supported by the selection of instrumental variables in the GMM model. In these studies, it is suggested that why the GMM approach is preferred over OLS and FER.

3.2 Hypothesis framed

Based on the above literature review, we have framed the hypotheses to analyze the impact of ICT infrastructure, financial development, and trade openness on EG in LICs and HICs. The formulated hypotheses are as follows.

Hypothesis 1

Good ICT infrastructure has a significantly positive impact on EG in LICs and HICs.

The ICT infrastructure should accelerate EG by providing the development and adaptation of innovation processes. The new EG theories suggest the growth effects of modern communication processes in countries. The EG theories suggest that the ICT arrival of internet technology may have different qualities. Good ICT infrastructure may accelerate the foster competition and new ideas to develop products, processes, business models & how it circulates from one place to another, facilitating economic growth. Therefore, we also support the previous studies (Parwanto and Wulansari, 2020; Adeleye and Eboagu, 2019; Albimanand Sulong, 2016) and expected ICT infrastructure significantly impacts EG in LICs and HICs.

Hypothesis

(a): Financial development encourages EG in both countries (LICs and HICs countries).

Financial development is the most prominent independent variable that highly impacts the EG of any economy. Firstly, Goldsmith (1969) and Shaw (1973) included FD and EG to find out the kind of relationship. Before, EG theory did not include financial development as an endogenous variable in the regression model. However, a growing number of previous studies shows how allocated resources, diversified risks, and intermediation savings is important contributor to EG (Greenwood and Jovanovic, 1990; Jibili et al. 1997). Thus, we also support these studies and expect that FD encourages EG in both countries (LICs and HICs countries).

Hypothesis

(b): Jointly, ICT infrastructure and FD positively correlate with EG in both countries (LICs and HICs countries).

The above hypothesis supports the ICT and FD to encourage the EG, but it is checked individually only in the previous studies. Now we expect ICT infrastructure and FD jointly more effective to encourage the EG in both sample. We support Ghosh, (2016); Habibi and Zabardast, (2020); Appiah-Otoo and song, (2021) and expect jointly ICT infrastructure and FD to positively correlate with EG in LICs and HICs. Because jointly ICT infrastructure and FD are most significant factors affect to the economic growth.

Hypothesis 3

(a): Joint effects of FD, and TO encourages EG in LICs and HICs.

Previous studies found mixed results regarding the relationship between EG and trade openness. As a few examples, Shahbaz and lean (2012) argue that TO promotes the EG of Pakistan's economy. Similarly, Eris and Ulasan (2013) found no direct relationship between TO and EG in cross-country data. On the other hand, Kumari, et al., (2021) found that TO has a positive and long-run with EG in India. Thus, we also expect the joint effects of FD and TO will encourage EG in both LICs and HICs.

Hypothesis 3

(b): Joint effect of ICT infrastructure, FD, and TO promote to EG in LICs and HICs.

Salahuddin and Gow (2015) applied the unit root test, Johansen, and ARDL co-integration tests to analyze the effects of internet usage, financial development, and TO on economic growth. This study was based on the time-series data for South Africa from 1991 to 2013. They have strongly supported a positive relationship between internet usage and EG in South Africa. Similarly, they found the same results regarding financial development and economic growth. But, in this study, TO is not disused to encourage economic growth. As we expect more TO economy attracts financial development and improve ICT infrastructure, these three variables promote EG in LICs and HICs (Salahuddin and Gow, 2015).

Hypothesis 3

(c) Joint effects of ICT infrastructure, FD, and TO encourage EG to vary between two groups of countries (LICs and HICs).

Joint effects of ICT infrastructure and FD on EG and ICT infrastructure and TO on EG encourage EG. It may also vary from country to country because past studies' results were mixed (positive, negative, and insignificant) (Ghosh, 2016; Habibi and Zabardast, 2020; Appiah-Otoo and song, 2021; Salahuddin and Gow, 2015; Shahbaz and lean, 2012). Thus, we also expect the joint effects of ICT infrastructure, FD, and TO encourage EG, and it may vary between two groups of countries (LICs and HICs). The framed hypothesis is represented in Fig. 1 to show the impact of ICT infrastructure, financial development, and trade openness on EG.

3.3 Econometric Model

In this study, we have applied a standard estimation for the EG Model where the EG is determined by (Das, Khan, and Chowdhury 2016; Kumari et al., 2021; Myovella, Karacuka, and Haucap, 2020), financial development, trade openness, and ICT as suggested by Barro et al. (1991). Secure internet servers, broadband servers, mobile users, and individual internet users are used as proxies of ICT infrastructure. From the following (Myovella, Karacuka, and Haucap, 2020; Sassi and Goaied, 2013) literature, we have used government consumption, capital formation, population growth as control variables. Therefore, the proposed model is framed as mentioned in Eq. (1).

$$\boldsymbol{EG_{it}} = f(\, ICT\ infrastrucutr_{it}, FD_{it}, TO_{it}) \tag{1}$$

$$\boldsymbol{EG_{it}} = \beta_0 + \beta_1 EG_{it-1} + \beta_2\, ICT\ infrastructure_{it} + \beta_3\, FD_{it} + \beta_4\, TO_{it} + \beta_5 ICT\ infrastructure_{it} * FD_{it} + \beta_6\, FD_{it} * TO_{it} + \beta_7\, ICT\ infrastructure_{it} * FD_{it} * TO + IVE + \delta_{it} + \epsilon_{it} \tag{2}$$

Where,

β_0 represents the coefficient of the parameters.

EG_{it} is represented by GDP per capita (Constant in US$), *telephone* is represented by the [fixed telephone subscriptions (per 100s people) [individuals using the Internet (% of the population)], *secinternet* is represented by [Secure Internet servers (per 1 million people)], *broadband* is represents by [fixed broadband subscriptions (per 100 people)]. FD is represents by the total credit provided to the private sectors (% of GDP). *TO* is represents by total sum of imports and exports divided by GDP per capita, *capfor* is represented by capital formation (the gross domestic investment as a share of GDP), *consum* is represented by general government final consumption expenditure (%1 of GDP), *popugr* is represented by total population growth rate. i implies no of observations (total countries considered) and t is period. ϵ_{it} is represented by error term.

Total ten variables included for the empirical analysis, one variable taken as a dependent, and the other nine variables are considered as explanatory variables, including three control variables. We have applied the system GMM approach on normalized values of the variables. After converting all variables into the normalized form, we have applied the system GMM method. All the framed hypotheses 1, 2 (a, b), and 3 (a, b, c) shown in Eq. (2) are well explained in sub-section 3.2. We have described the variables, measured proxies, and data sources in Table 2.

Table 2
Name of variables, proxies, measured and data source

Variables Names	Proxy	Measured	Data Sources
Economic Growth	*EG*	GDP per capita	World Bank Indicators *(WBI)*
Fixed Telephone Subscriptions	*telephone*	Fixed telephone subscriptions (per 100 people)	Worldwide Telecommunications Union (ITU)
Individual Internet Users	*internet*	Individuals using the Internet (% of the population)	Worldwide Telecommunications Union (ITU)
Secure Internet Servers	*secinternet*	Secure Internet servers (per 1 million people)	Worldwide Telecommunications Union (ITU)
Fixed Broadband Subscription	*broadband*	Fixed broadband subscriptions (per 100 people)	Worldwide Telecommunications Union (ITU)
Trade openness	*TO*	Total sum of imports and exports divided by GDP per capita	World Bank Indicators *(WBI)*
Financial development	*FD*	Total credit provided to the private sectors (% of GDP)	World Bank Indicators *(WBI)*
Capital formation	*capfor*	Capital formation (the gross domestic investment as a share of GDP)	World Bank Indicators *(WBI)*
Government consumption expenditure	*consum*	General government final consumption expenditure (%1 of GDP)	World Bank Indicators *(WBI)*
Population Growth	*popugr*	Total population growth rate	World Bank Indicators *(WBI)*

Source: Authors estimations

3.4 Descriptive statistics and correlation analysis

Tables 3 and 4 show the descriptive analysis of LICs and HICs. The average EG for the sample of LICs is 625.856, and Std.Dev. is 371.990. The average and std. dev of *internet, secinternet, broadband* and *telephone* is 9.741, 0.558, 0.793, 1.528 and 14.468, 0.860, 1.070, 3.302, respectively. In HICs (Table 4), the average and std. dev of EG is 31773.85 and 21389.4, including min 1659.908, and max is 118823.6. For HICs, we have observed an average of *internet, secinternet, broadband, and telephone* is 60.731, 7194.66, 16.007, and 37.49, respectively.

Table 3
Descriptive Analysis of LICs

Variable	Obs	Mean	Std. Dev.	Min	Max
EG	540	625.845	371.990	111.927	2032.623
TO	540	13.543	12.471	1.000	126.672
telephone	540	1.528	3.302	0	22.620
capfor	540	18.831	8.229	0.145	60.156
consum	540	14.658	6.972	-2.681	54.796
popugr	540	8.313	11.317	0.004	78.180
internet	540	9.741	14.468	0	89.532
secinternet	540	.558	.860	0.014	8.730
broadband	540	.793	1.070	0.119	8.730
FD	540	11.131	7.243	0.015	41.156
Source: Authors' estimations					

Table 4
Descriptive Analysis of HICs

Variable	Obs	Mean	Std. Dev.	Min	Max
EG	1,160	31773.85	21389.4	1659.908	118823.6
TO	1,160	.581	.533	.051	3.365
telephone	1,160	37.49	14.941	4.862	74.987
capfor	1,160	23.163	4.622	9.307	44.308
consum	1,160	18.023	4.017	0	30.003
popugr	1,160	14.838	355.36	-99.999	11916.13
internet	1,160	60.731	19.182	.693	99.7015
secinternet	1,160	7194.66	12398.2	13.091	277133.7
broadband	1,160	16.007	11.919	.001	45.693
FD	1,160	83.226	43.743	.186	308.978
Source: Authors' estimations					

4. Results And Discussion

Tables 5 and 6 show the correlation results of LICs and HICs. There is a positive association between the secinternet and telephone in LICs with a value of 0.375, which is quite good. It specifies that people who have a telephone subscription are more likely to use the secure internet in LICs. It also shows that these countries are still facing a lack of ICT infrastructure.

Similarly, from Table 6, we can see that the correlation between the secinternet and broadband is 0.146 in HICs which is relatively high compared to LICs. So, it shows that internet and broadband services are good in HICs. Most people who do not even use broadband and phone subscription also rely on broadband. Therefore, we can say that developed countries are more updated and well-structured in ICT infrastructure than LICs.

Table 5
Correlation matrix (LICs)

	EG	*TO*	*telephone*	*capfor*	*consum*	*popugr*	*internet*	*secinternet*	*broadband*	*FD*
EG	1.000									
TO	-0.512	1.000								
Telephone	0.504	-0.145**	1.000							
Capfor	0.143**	-0.087**	0.033**	1.000						
Consum	0.036**	-0.059**	0.120**	0.019	1.000					
Popugr	0.400**	-0.120**	0.185**	0.065**	-0.008**	1.000				
Internet	0.208**	-0.085**	0.142**	0.024**	-0.140*	0.286*	1.000			
secinternet	0.032**	0.097**	0.375**	-0.100**	-0.042	0.034*	0.007	1.000		
broadband	-0.059**	0.157**	0.264**	-0.135**	-0.071	-0.065*	-0.073	0.9012**	1.000	
FD	-0.049**	0.020**	0.087**	0.143**	0.560**	0.067**	0.151**	-0.144	-0.220	-1.000

Source: Authors estimation, **Note**: ** 5% and *1 level of significance

Table 6
Correlation Matrix of HICs

	EG	*TO*	*telephone*	*capfor*	*consum*	*popugr*	*internet*	*secinternet*	*broadband*	*FD*
EG	1.000									
TO	-0.618**	1.000								
Telephone	0.163**	0.246**	1.000							
Capfor	-0.077**	0.127** -	0.131**	1.000						
Consum	0.035	-0.155**	0.032**	-0.134**	1.000					
Popugr	-0.035**	0.062**	-0.022**	-0.002	0.053**	1.000				
Internet	0.384**	-0.342**	-0.031**	-0.067**	0.025**	0.009**	1.000			
secinternet	0.103**	-0.029**	-0.0468	0.002**	0.092**	-0.002**	0.049*	1.000		
Broadband	0.173**	-0.173**	0.0740	-0.091**	0.099**	-0.001**	0.528*	0.146**	1.000	
FD	0.361**	-0.287**	0.4864	-0.066**	-0.035**	-0.053**	0.191**	0.065**	0.239**	1.000

Source: Authors estimation, **Note**: ** 5% and *1 level of significance

Table 7 shows the results of OLS, FER, and system GMM. Initially, we have applied the OLS method and FE regression method, but we found that the results were biased in terms of endogenous. Therefore further, we have applied the GMM method to overcome the endogeneity problem. So, here we discussed only the results of GMM and showed 12 different models related to the framed hypothesis. In the GMM Model, we found TO, *secinternet* and *FD* negatively related to EG in LICs so these findings did not support hypotheses 2 (a) and (b). For the HICs, we found almost all results were the same but ICT infrastructure proxy sign (+/-) changes according to the Model. In the case of HICs, TO, *broadband*, and FD have a negative relation with EG which is also not supported by hypotheses 2 (a) and (b). But, the majority of the ICT infrastructure variables have a positive relation with EG along with FD and TO, therefore we can conclude that ICT infrastructure has a positive relation with EG in LICs and HICs.

Table 7
Comparative Models impact of ICT infrastructure, FD and TO on EG

	LICs			HICs		
Dependent variable: EG	**OLS**	**FE**	**GMM**	**OLS**	**FE**	**GMM**
GDP per capita (1st diff)	-	-	0.900***	-	-	0.925***
			(0.212)			(0.025)
TO	-0.043**	-0.019*	-0.006**	-0.319***	-0.088**	-0.034**
	(0.003)	(0.003)	(0.009)	(0.018)	(0.014)	(0.011)
telephone	0.033**	0.002**	0.004*	0.010*	-0.347**	0.036**
	(0.003)	(0.006)	(0.007)	(0.027)	(0.027)	(0.013)
capfor	0.007**	0.003*	0.000*	0.002*	0.075**	0.016*
	(0.002)	(0.002)	(0.002)	(0.030)	(0.019)	(0.014)
consum	0.006**	-0.001*	0.003**	-0.012	-0.167***	-0.046**
	(0.003)	(0.003)	(0.002)	(0.030)	(0.037)	(0.021)
popugr	0.025**	0.009***	0.001**	0.267***	0.092**	0.025**
	(0.003)	(0.003)	(0.005)	(0.029)	(0.021)	(0.015)
internet	0.005**	0.018***	0.001**	0.125***	0.054**	0.006*
	(0.002)	(0.004)	(0.001)	(0.016)	(0.009)	(0.007)
secinternet	-0.043***	0.072***	-0.020**	0.199***	-0.032**	0.041***
	(0.064)	(0.041)	(0.037)	(0.054)	(0.027)	(0.025)
broadband	-0.012***	-0.146***	0.007**	-0.033**	0.041**	-0.003***
	(0.060)	(0.040)	(0.038)	(0.015)	(0.011)	(0.008)
FD	-0.011**	0.007**	-0.003**	0.172***	0.180***	-0.014
	(0.002)	(0.003)	(0.003)	(0.020)	(0.019)	(0.012)
Constant	0.015**	0.014**	0.002**	0.030***	0.199***	0.018**
	(0.001)	(0.001)	(0.003)	(0.024)	(0.021)	(0.013)
		-	-	.479	-	-
R-squared	0.558					
		-	-	0.493	-	-
Adj R-squared	0.551					
Within	-	0.529	-	-	0.481	-
Between	-	0.056	-	-	0.067	-
Overall	-	0.199	-	-	0.145	-
Arellano- Bond Test for AR(1)	-	-	-1.89	-	-	-3.670**
Arellano- Bond Test for AR (2)	-	-	0.08	-	-	-4.210

Source: Authors' estimations,

Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance

	LICs			HICs		
Saragan test H_0: Not robust, but not some instruments are weak	-	-	75.81	-	-	543.160
Hansen test H_0: robust, but some instruments are weak	-	-	21.56	-	-	34.860
No of observations	**540**	**540**	**513**	**1,160**	**1,160**	**1,160**
No of countries	**27**	**27**	**27**	**58**	**58**	**58**
Source: Authors' estimations,						
Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance						

Table 8 shows the individual and joint effect of ICT infrastructure and FD on EG. When we check the individual effect of ICT infrastructure (*internet, secinternet, broadband, and telephone*) on EG, we found that *internet* and *telephone* have a positive impact on EG and are statistically significant at the level of 5%. On the other hand, *secinternet and broadband* have a negative impact on EG but are statistically significant at 10% and 5% level. AR (1) and AR (2) prove that all estimated versions of this model meet Areellono bond criteria for the valid estimations, so do not reject the hypothesis of the GMM Model, and it supports hypothesis 1. Moreover, Table 8 also revealed that the joint impact of *internet*FD* (0.025), *secinternet*FD* (0.101), *broadband*FD* (0.056) found a positive impact on EG and significant at 5% and 1% level of significance. Only *telephone*FD* (-0.023) have a negative effect on EG. Our findings support Sassi and Goaied (2013) for MENA countries. On the other hand, in the individual analysis, *the internet* (0.002), *secinternet* (0.05), and *telephone* (0.003) have found positive relation with EG and significant at 5% level of significance. In contrast, *broadband* (-0.006) has a negative relation with EG in LICs but is significant at a 5% level of significance. Hypothesis 2 (a) has been failed to prove that FD encourages EG in LICs. When we check the individual impact of FD than found that it has a negative impact on EG. But on the other hand, we proved hypothesis 2 (b) because jointly ICT infrastructure and FD positively correlate with EG in both countries. *TO, capfor*, and positively affect EG in the entire models. These findings support Sassi and Goaied, (2013) and Das, Khan, and Chowdhury, (2016). As we thought interaction of FD and ICT infrastructure is always positive and significant. FD motivates economic growth through the ICT infrastructure in LICs. When FD is considered, the marginal effects of the internet, broadband, and secured internet are more potent than that of the telephone in LICs. Similarly, this finding was found in the study of Sassi and Goaied (2013), but they support more telephone use than the internet and mobile.

Table 9 shows the joint impact of ICT infrastructure, *FD*, and *TO* on EG in LICs. Jointly impact of *FD*internet*TO* (.638), *FD* secinternet* *TO* (0.103), *FD* broadband* TO* (0.096) and *FD* telephone* TO* (0.031) is positive relation with EG in LICs and statistical significance at 1% and 10% level of significance, respectively. But, when we analyzed the individual impact of FD and TO on EG then found a negative relationship with EG in LICs but statistically significant at 5% & 1% levels of significance. Our study proved hypothesis 3 (b) and supported the joint effects of ICT infrastructure, FD, and TO encouraging EG in LICs (Sassi and Goaied, 2013).

Table 8
Individual and jointly effect of **ICT infrastructure and FD** on EG (LICs)

EG (dependent Variable)	$Model_1$	{Model}_{2}	{Model}_{3}	{Model}_{4}	{Model}_{5}	{Model}_{6}	{Model}_{7}	{Model}_{8}
L1. EG	0.946	.929 (.134)	0.930	0.908	0.968	.926	0.923	0.930
	(-0.198)		(-0.145)	(0.205)	(0.170)	(0.157)	(0.169)	(0.169)
internet	0.002**	-	-	-	-0.009**	-	-	-
	(0.001)				(0.012)			
*FD*internet*	-	-	-	-	0.025**	-	-	-
					(0.029)			
secinternet	-	0.05***	-	-	-	-0.037	-	-
		(.010)				(0.028)		
FD secinternet*	-	-	-	-	-	0.101***	-	-
						(0.091)		
broadband	-	-	-0.006**	-	-	-	-0.023	-
			(0.008)				(0.031)	
FD broadband*	-	-	-	-	-	-	0.056***	-
							(0.100)	
telephone	-	-	-	0.003**	-	-	-	.983
				(0.006)				(0.011)
FD telephone*	-	-	-	-	-	-	-	-0.023***
								(0.019)
TO	-0.006***	– .005*** (.004)	-0.006***	-0.007***	-0.004***	-0.005***	-0.006***	-0.006***
	(0.010)		(0.004)	(0.008)	(0.007)	(0.009)	(0.008)	(0.008)
FD	-0.003***	– .002**	-0.002**	-0.002**	-0.005**	-0.004**	-0.004**	-0.001**
	(0.002)	(.002)	(0.002)	(0.003)	(0.002)	(0.003)	(0.003)	(0.002)
capfor	0.001*	.006**	0.001*	0.002*	0.001*	0.001*	0.001*	0.001*
	(0.002)	(.003)	(0.002)	(0.002)	(0.001)	(0.001)	(0.002)	(0.001)
consum	0.003***	.003*	0.003*	0.004*	0.007*	0.009*	0.008*	0.008*
	(0.003)	(.002)	(0.003)	(0.003)	(0.002)	(0.002)	(0.003)	(0.002)
popugr	0.000*	.007**	0.001*	0.001*	0.000*	0.001*	0.001*	0.000*
	(0.007)	(.003)	(0.004)	(0.006)	(0.005)	(0.005)	(0.006)	(0.005)
_cons	0.001*	.0028*	0.002*	0.002*	0.002*	0.002*	0.002*	0.001*
	(0.003)	(.003)	(0.0020	(0.003)	(0.0020	(0.003)	(0.003)	(0.002)
No of observations	540	540	540	540	540	540	540	540

Source: Authors, estimations based on data set.

Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance

EG (dependent Variable)	$Model_1$	{Model}_{2}	{Model}_{3}	{Model}_{4}	{Model}_{5}	{Model}_{6}	{Model}_{7}	{Model}_{8}
No of country	27	27	27	27	27	27	27	27
AR (1)	-1.91**	-2.00***	-1.99***	-1.89**	-1.91**	-1.98***	-1.96**	-1.95**
AR (2)	0.04	0.06	0.06	0.05	0	0	0.05	0.07
Sargan test	70.99	71.92	72.24	72.46	68.13	71.62	71.91	70.63
Hansen test	23.44	23.74	23.45	24.26	21.92	24.12	24.99	24.02
Source: Authors, estimations based on data set.								
Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance								

Table 9
Joint effect of **ICT infrastructure, FD and TO** on EG (LICs)

Dependent variable: EG	**{Model}_{9}**	**{Model}_{10}**	**{Model}_{11}**	**{Model}_{12}**
L1. EG	0.952***	0.929***	0.930***	.907***
	(0.196)	(0.143)	(0.155)	(0.206)
internet	0.001*	-	-	-
	(0.001)			
secinternet	-	-0.008***	-	-
		(0.010)		
broadband	-		-0.009***	-
			(0.009)	
telephone	-	-	-	0.002**
				(0.006)
FD	-0.003**	-0.003**	-0.003**	-0.003**
	(0.002)	(0.002)	(0.003)	(0.0030
*FD*internet*TO*	.638***	-	-	-
	(0.015)			
FD secinternet* TO*	-	0.103***	-	-
		(0.205)		
FD broadband* TO*	-	-	0.096***	-
			(0.164)	
FD telephone* TO*	-	-	-	0.031*
				(0.074)
TO	-0.005**	-0.006*	-0.006**	-0.007**
	(0.009)	(0.006)	(0.006)	(0.008)
capfor	0.001*	0.001*	0.001*	0.001*
	(0.002)	(0.024)	(0.029)	(0.031)
consum	0.003**	0.023***	0.043**	0.063**
	(0.003)	(0.003)	(0.003)	(0.003)
popugr	-0.001**	0.011*	0.031*	0.071**
	(0.007)	(0.004)	(0.005)	(0.006)
_cons	0.001*	0.002*	0.012*	0.022*
	(0.013)	(0.012)	(0.102)	(0.113)

Source: Authors' estimations based on the dataset

Note: Std. dev shown in bracket and *10%, ** 5% and *** 1 level of significance

Dependent variable: EG	{Model}_{9}	{Model}_{10}	{Model}_{11}	{Model}_{12}
AR (1)	-1.920**	-1.990**	-1.980**	-1.890**
AR (2)	0.030	0.050	0.060	0.050
Sargan test	70.760**	72.150**	72.580**	72.520**
Hansen test	23.220	23.780	23.420	24.220
Source: Authors' estimations based on the dataset				
Note: Std. dev shown in bracket and *10%, ** 5% and *** 1 level of significance				

Table 10 shows the individual and joint impact of ICT infrastructure and *FD* on *EG* in HICs. The results of the GMM Model shows that AR (1) and AR (2) proved that there is no serial correlation under the predetermined variable and error terms of the different period. This helps to choose the set of lags that is used as instrumental variables in the GMM method. Moreover, Table 10 also revealed that the joint impact of *internet*FD* (0.003), *secinternet*FD* (0.015), *telephone*FD* (0.083) found a positive impact on EG and significant at 5% and 1% level of significance. Only *broadband*FD* (-0.035) has a negative relation with EG. On the other hand, in the individual analysis, *internet* (0.002), *secineternet* (0.040), *broadband* (0.001), *telephone* (0.034), *and FD* (0.001) have found positive relation with EG and significant at 5% level of significance in HICs. In contrast, *broadband* (-0.006) and *secinternet* (-0.037) have a negative relationship with EG in LICs but significant at 5% and 1% levels of significance, respectively as shown in Table 9. Therefore, we failed to prove hypothesis 2(a) in the case of LICs but in the case of HICs we did not reject hypothesis 2 (a) so our results are considered for the ICT infrastructure and FD more encouraged in HICs as comparison of LICs. When we check the individual impact of FD, we found it's a positive impact on EG in and we found FD has a negative relationship with EG only in model 8. So, the majority of the different Models found *FD* have a positive relationship with EG in HICs. Moreover, *TO* has a negative impact on EG in HICs. More trade openness in any country is negatively affected to the business activities because liberal legal rules and regulations increase FDI inflow which is harmful at the point of view ownership transfer (Kumari and Sharma, 2017). Apart from TO, control variables (capital formation, consumption, and population growth) positively correlate with EG in all Models. These findings were also found in the study of (Sassi and Goaied, 2013) and (Das, Khan, and Chowdhury, 2016). As we expected, ICT infrastructure and FD have a positive relationship with EG, but in HICs jointly *broadband* and *FD* have a negative relationship with EG. Therefore, we can conclude that the marginal effect of the *internet, secinternet, telephone* with FD is stronger than the joint effect of *broadband* and *FD.* Our study proved hypothesis 3 (a) and supported the joint impacts of FD and TO encouraging EG in HICs (Sassi and Goaied, 2013).

Table 11 presents the joint effect of ICT infrastructure, FD, and TO on EG in HICs. Jointly impact of *FD*internet*TO (-0.116), FD*secinternet*TO (-0.225)*, FD**broadband*TO (-0.160)* and *FD* telephone* TO (-0.194)* are negative relations with EG in HICs and statistical significance at 1% and 10% level of significance, respectively. But, the Joint impact of *FD*Internet*TO (0.638), FD*secinternet*TO (0.103), FD* broadband* TO (0.096) and FD* telephone* TO (0.031)* are positive relations with EG in LICs and statistical significance at 1% and 10% level of significance, respectively as shown in Table 10. Therefore, we can conclude that ICT infrastructure plays a significant role in improving the EG of LICs.

Yousefi (2011) study argues that there is no significant effect of ICT infrastructure on EG in LMICs. It may be due to the improper use of available human capital or labour; maybe they feel an extra burden with new technologies. Thus, people need higher salaries with higher ICT use and require a stronger financial sector. Without further enhancement in ICT uses, the country's overall development is not possible. Most of the financial intermediaries (including banks and stock markets) adopted ICT facilities like AI, machine learning, data mining, etc. If the banking sector and the stock market do not accept ICT, the number of changes to increase labour productivity will be minimal. Based on a comparison of LICs and HICs ICT infrastructure, we found that LIC will immediately require vital support of R&D, ICT infrastructure, IT skill enhancement program, human resource, more trade openness, reconstructive manual process, and new IT business Model (S.-Y.T. Lee, Gholami, and Tong, 2005). Although, few LICs adopted mobilization due to the down price in mobile but still internet and broadband penetration facilities remain unequal between developed and developing countries.

On the other hand, LMICs like Bolivia and Ghana have taken IT projects for the developed ICT infrastructure in their education sector, financial institutions (including bank and stock/share market), and industries that help to encourage EG (Das, Khan, and Chowdhury, 2016; Rodas and Lopez, 2007). Similarly, with the help of ICT facilities, developed countries benefit from high-speed internet, free Wi-Fi (selected places), developed e-Commerce channels, sales distribution channels, etc. It also helps to create new job opportunities for the people. In contrast, LICs are still struggling for ICT infrastructure, FD, and more TO because these countries only enjoy ICT

infrastructure's as initial benefits (Das, Khan, and Chowdhury, 2016). Nevertheless, policymakers should pay attention to the growth in ICT infrastructure because after the situation of covid-19 without adaptation of ICT survival will be difficult.

Table 10
Individual and Joint effect of ICT infrastructure and FD on EG (HICs)

Dependent variable: EG	{Model}_{1}	{Model}_{2}	{Model}_{3}	{Model}_{4}	{Model}_{5}	{Model}_{6}	{Model}_{7}	{Model}_{8}
L1. EG	0.915***	0.911***	0.918***	0.942***	0.915***	0.912***	0.918***	0.947***
	(0.025)	(0.018)	(0.021)	(0.017)	(0.025)	(0.018)	(0.021)	(0.016)
internet	0.002**	-	-	-	0.003**	-	-	-
	(0.006)				(0.012)			
FD	0.001**	0.031**	0.051**	-0.015***	0.002**	0.001**	0.010***	-0.040***
	(0.014)	(0.014)	(0.013)	(0.012)	(0.038)	(0.018)	(0.017)	(0.028)
*FD*internet*					- 0.003***	-	-	-
					(0.289)			
Secinternet	-	0.040**	-	-	-	0.029***	-	-
		(0.027)				(0.054)		
FD secinternet*					-	0.015***	-	-
						(0.162)		
Broadband	-	-	0.001**	-	-	-	0.104**	-
			(0.007)				(0.015)	
FD broadband*					-	-	-0.035	-
							(0.052)	
Telephone	-	-	-	0.034**	-	-	-	0.014**
				(0.012)				(0.023)
FD* telephone					-0.032**	-	-	0.083***
					(0.057)			(0.082)
TO	-0.042**	-0.044**	-0.042**	-0.030**	-0.042**	-0.044**	-0.041**	-0.028**
	(0.012)	(0.011)	(0.012)	(0.010)	(0.012)	(0.012)	(0.011)	(0.010)
Capfor	0.013*	0.012*	0.012*	0.015**	0.013**	0.010**	0.011**	0.016**
	(0.015)	(0.015)	0.015	0.013	0.015	0.015	0.014	0.013
Consum	-0.043**	-0.045**	-0.044**	-0.043**	-0.043**	-0.046**	-0.044**	-0.044**
	(0.023)	(0.023)	(0.023)	(0.019)	(0.023)	(0.023)	(0.022)	(0.019)
Popugr	0.020**	0.021**	0.019***	0.023***	0.020***	0.022***	0.020**	0.021**
	(0.016)	(0.015)	(0.015)	(0.013)	(0.016)	(0.015)	(0.015)	(0.012)
_cons	0.030***	0.031*	0.031**	0.019**	0.029**	0.032**	0.029**	0.024**
	(0.015)	(0.014)	(0.014)	(0.012)	(0.016)	(0.015)	(0.013)	(0.013)
No of observations	1102	1102	1102	1102	1102	1102	1102	1102
No of country	58	58	58	58	58	58	58	58

Source: Authors' estimations based on dataset

Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance.

Dependent variable: EG	{Model}_{1}	{Model}_{2}	{Model}_{3}	{Model}_{4}	{Model}_{5}	{Model}_{6}	{Model}_{7}	{Model}_{8}
AR (1)	-3.65	-3.67	-3.67	-3.7	-3.68	-3.71	-3.68	-3.71
AR (2)	-4.2	-4.22	-4.2	-4.22	-4.21	-4.22	-4.21	-4.22
Sargan test	569.41	566.88	567.11	542.37	566.9	537.1	566.9	537.1
Hansen test	36.69	35.55	36.67	36.23	36.07	36.05	36.08	36.06
Source: Authors' estimations based on dataset								
Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance.								

Table 11
Joint effect of ICT infrastructure, FD, and TO on EG (HICs)

Dependent variable: EG	{Model}_{9}	{Model}_{10}	{Model}_{11}	{Model}_{12}
L1. EG	0.899***	0.911***	0.909***	0.937***
	(0.028)	0.018	0.023	0.019
internet	0.009*	-	-	-
	(0.009)			
secinternet	-	.457**	-	-
		(0.034)		
broadband	-	-	0.007*	-
			(0.010)	
telephone	-	-	-	0.041*
				0.014
FD	0.014*	0.002**	0.007**	-0.007***
	(0.019)	(0.015)	(0.014)	(0.015)
FD**internet**TO	-0.116***	-	-	-
	(0.151)			
FD* *secinternet** TO	-	-0.225***	-	-
		(0.618)		
FD* broadband* TO	-	-	-0.160***	-
			(0.215)	
FD* *telephone** TO	-	-	-	-0.194****
				(0.235)
TO	-0.033***	-0.043***	-0.039***	-0.022**
	(0.015)	(0.012)	(0.011)	(0.012)
capfor	0.011*	0.012*	0.010**	0.014**
	(0.0160	(0.015)	(0.015)	(0.013)
consum	-0.050**	-0.045**	-0.050**	-0.045**
	(0.025)	(0.023)	(0.024)	(0.020)
popugr	0.025**	0.021**	0.022**	0.025**
	(0.018)	(0.015)	(0.016)	(0.013)
Cons	0.027**	0.031**	0.032**	0.017**
	(0.015)	(0.015)	(0.014)	(0.012)

Source: Authors' estimations based on dataset

Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance.

Dependent variable: EG	{Model}_{9}	{Model}_{10}	{Model}_{11}	{Model}_{12}
AR (1)	-3.65**	-3.67**	-3.66**	-3.7**
AR (2)	-4.2	-4.22	-4.2	-4.22
Sargan test	577.11	567.14	570.52	542.66
Hansen test	36.83	35.53	36.64	36.16
No of observations	1102	1102	1102	1102
No of country	58	58	58	58
Source: Authors' estimations based on dataset				
Note: Std. Dev shown in bracket and *10%, ** 5% and *** 1 level of significance.				

The impact of ICT infrastructure and its joint implications are summarized in Figures 2, 3, and 4 using tables 8, 9, 10, and 11.

Figure 2 shows the individual impact of ICT infrastructure. We can see that the internet positively affects economic growth, and its influence is almost the same in low-income and high-income countries. Secure internet and broadband negatively influence the GDP per capita (EG) of LICs while the positive influence on HICs. Telephone lines are positively influencing the EG of LICs and HICs. From figure 2, it can be concluded that secure internet and telephone lines significantly impact the high-income countries' EG.

Figures 3 and 4 show the joint effects of ICT infrastructure with FD and FD*TO, respectively. Observations from Fig. 3 show that the joint effect of the Internet and secure internet is favourable on both LICs and HICs. When we look at the broadband and telephone lines, both are having a reverse correlation with EG in LICs and HICs. Observations from Fig. 4 show that when we look at the joint impact of ICT infrastructure with FD and TO, EG of LICs are positively influenced while HICs are negatively affected. Overall observation drawn from Figs. 2, 3, and 4 shows that individual ICT infrastructure and jointly ICT infrastructure along with FD can play a crucial role in improving the GDP per capita of HICs when we invest in it. However, in the case of LICs, it can be observed that ICT infrastructure, FD, and TO show a positive relationship with GDP per capita. Therefore, to improve the GDP per capita of LICs, it is recommended to invest in ICT infrastructure along with FD and TO.

5. Conclusion And Policy Implication

Our study analyses the joint impact of ICT Infrastructure, financial development, trade openness on EG for the sample of 85 countries (including 27 low-income and 58 high-income countries) from 2000 to 2019. Our results reveal that individual (ICT infrastructure, *FD*, and *TO* on EG), and joint impact ICT infrastructure, FD (including different models like *internet*FD, secinternet*FD, broadband*FD*, and *telephone*FD*) on EG in LICs and HICs. And, another combination has been analyzed to observe the joint impact of *ICT*FD*TO* on EG in LICs and HICs.

Based on the analysis of this paper, we contributed to the literature review related to ICT infrastructure and financial development in two different samples (LICs and HICs). In HICs, FD does not have a positive relationship with economic growth; so, our hypothesis 2 (b) failed to prove. But when we estimate the combined effect of ICT infrastructure and FD, we found that internet*FD, secinternet*FD, broadband*FD have a positive relationship with economic growth. Only telephone*FD has a negative impact on EG in LICs. Therefore, financial development works as a harmonizing for the ICT infrastructure. ICT infrastructure, financial development, and trade openness have joint effects on both economies, but results vary in both countries' context. Thus, we have framed the number of policies and suggestions for both countries (LICs and HICs). With the help of these policies, both countries increase potential output capital gains and maintain sustained GDP per capita.

Given the above results, broadband has a positive relation with economic growth, although broadband (or high-speed) internet access is not lavish, but is a basic need to encourage human and economic development in low and high-income countries (World Bank, 2021). Till now, only around 35% of the population in low-income countries has access to the internet compared to high-income countries (85% access to the internet). It may be due to poor infrastructure in low-income countries. Broadband networks and services play a significant role in making smart ICT infrastructures like Intelligent Transport Systems and Smart Electric grids. Therefore, the government of developing countries should focus on access to the internet and broadband because it creates jobs in the ICT sector, develops skills, helps to reduce poverty, bridges the digital gap, and helps in making the international connections.

Moreover, broadband and the internet can help expand task-based work by the online platforms, which is provide millions of opportunities and billions of dollars return over the upcoming years. In developing countries, rising mobile penetration 75% as comparison of the previous condition approximately 35% increased would add as much as US$2 trillion to their collective GDP and create 143 new jobs around the globe.

Declarations

Statements and Declarations The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

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Appendix

Appendix 1: Name of sampled countries

Low-Income Economies ($1,034 or less)	High-Income Economies ($12.536 or More)	
Afghanistan	Antigua and Barbuda	Lithuania
Burkina Faso	Aruba	Luxembourg
Burundi	Australia	Macao SAR, China
The central African Republic	Austria	Malta
Chad	Bahamas, The	Mauritius
Congo, Dem. Rep	Bahrain	Netherlands
Eritrea	Barbados	New Zealand
Ethiopia	Belgium	Norway
Gambia, The	Brunei Darussalam	Oman
Guinea	Canada	Panama
Guinea-Bissau	Chile	Poland
Haiti	Croatia	Portugal
Liberia	Cyprus	**Romania**
Madagascar	Czech Republic	Qatar
Malawi	Denmark	Saudi Arabia
Mali	Estonia	Seychelles
Mozambique	Finland	Singapore
Niger	France	Slovak Republic
Rwanda	Germany	Slovenia
Sierra Leone	Greece	Spain
South Sudan	Hong Kong SAR, China	St. Kitts and Nevis
Sudan	Hungary	Sweden
Syrian Arab Republic	Iceland	Switzerland
Syrian Arab Republic	Ireland	Trinidad and Tobago
Tajikistan	Israel	United Arab Emirates
Togo	Italy	United Kingdom
Uganda	Japan	United States
Yemen, Rep.	Korea, Rep.	Uruguay
	Kuwait	
	Latvia	

Figures

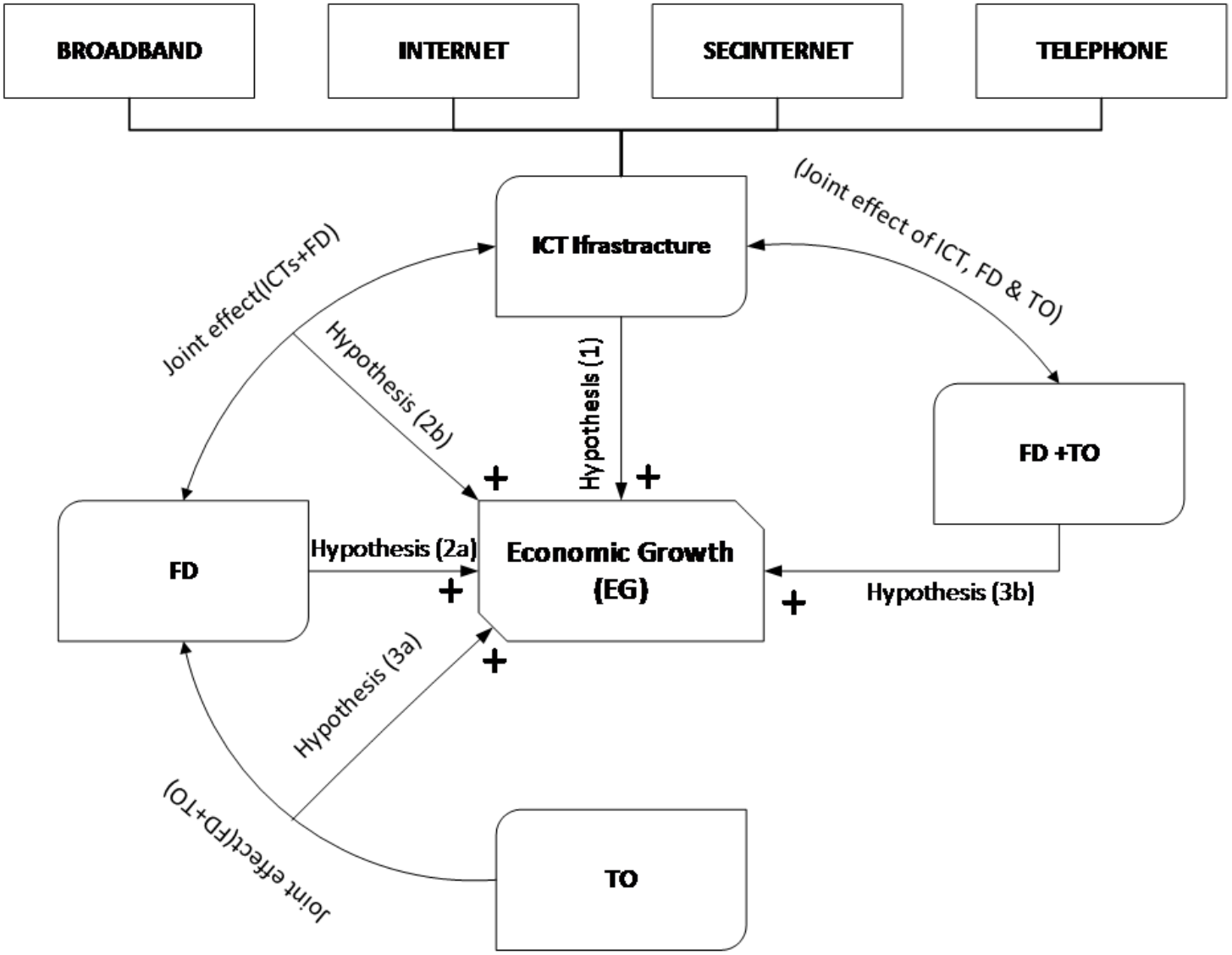

Figure 1

Framed Hypothesis

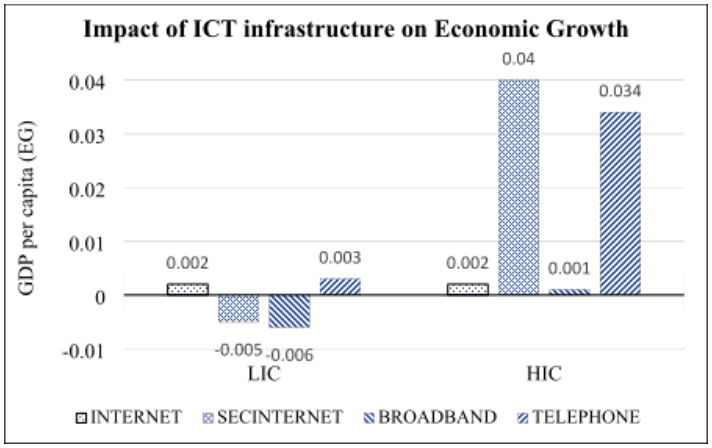

Figure 2

Impact of ICT infrastructure on EG

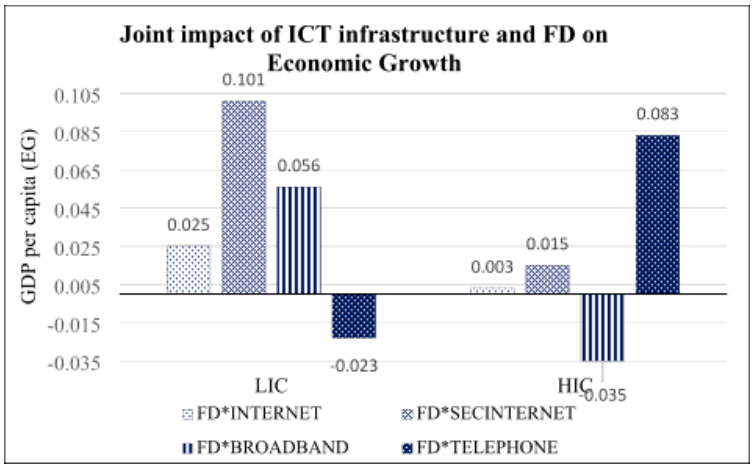

Figure 3

Joint impact of ICT infrastructure and FD on EG

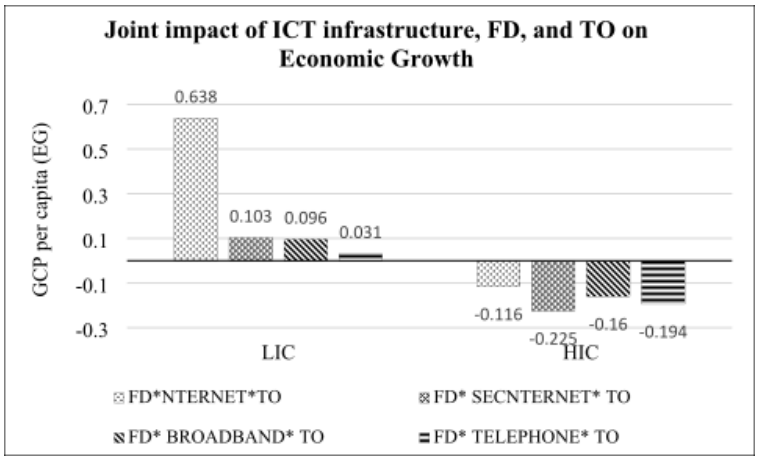

Figure 4

Joint impact of ICT infrastructure, FD, TO on EG