ICT Development Index and Its Role in the FDI – Growth Nexus: Evidence from G20 Economies

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Abstract

The collective GDP of the G20 nations constitutes over 80% of the global GDP, making them pivotal recipients of significant economic investments in various forms including foreign direct investments. This study delves into the dynamic interplay of ICT development and foreign direct investment (FDI) and GDP nexus among the G20 economies. A comprehensive index is constructed using PCA to gauge ICT development across economies. The study further examines the relationships among FDI, ICT development, and GDP using panel data spanning from 2000 to 2019. The study finds that in the absence of interaction, FDI alone does not exhibit a statistically significant impact on GDP. However, considering the interaction between FDI and ICT, a nuanced pattern emerges. The study discerns that the influence of FDI on GDP is contingent upon the maturity of a country's ICT sector. This suggests the need for policymakers to adopt a more focused approach, tailoring strategies to leverage the interdependence of FDI and ICT for optimal economic growth.

Keywords	***DOI***	***JEL code***
FDI, ICT, G20, Growth	*https://doi.org/10.54694/stat.2023.59*	*O10, O49, O50*

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INTRODUCTION

As per UNESCO Institute for Statistics (2009), ICT refers to "a diverse set of technological tools and resources used to transmit, store, create, share or exchange information. These technological tools and resources include computers, the Internet, live broadcasting technologies, recorded broadcasting technologies and telephony". Information and communication technology (ICT) and IT-enabled services are considered as a revolution which involves the creation, codification, and dissemination of knowledge (Kirkman et al., 2002), with its effective use having a positive impact on economic growth and competitiveness (Hanna, 2009).

ICT has the potential to enhance productivity and catalyse human development. Accordingly, it has been suggested that policy makers use ICT penetration as a target instrument to achieve higher levels of development (Asongu and Roux, 2017). ICT, as highlighted by the Digital Opportunity Initiative (2001)[6] significantly enhances sustainable environmental management, improves monitoring, and addresses issues like aging, poverty, health, and education. World Bank Group (2012) envisages that governments employ ICT to revolutionize public service delivery at the national and local levels in the areas of health, education, social protection, justice, agriculture, energy, and transportation. The extension of choices available to society with respect to health, education and other components of living standards made possible due to the widespread use of ICT are considered as key parameters of human development (Yakunina and Bychkov, 2015). The participatory aspect of ICT establishes new relationships that stimulate and support innovation, allowing new ideas and beliefs to be integrated. It is capable of unleashing a social transformation and modernizing the economy (Saith and Vijayabaskar, 2005).

The advancement of ICT expands human freedom in numerous ways which according to Sen's human capability approach leads to an improvement in the quality of life (Sen, 2010). Also, increasingly ICT use is no longer a matter of choice, rather it is an essential element in the daily lives of the active populations of countries across the development spectrum. It commands this power due to its ability to facilitate the optimization of limited resources. ICT development has tremendous scope as it influences social behaviour, democratic processes, and innovation.

For the reasons mentioned above, active and effective cooperation for the promotion of ICT enabled digital global economy is high on the G20[7] agenda. The consideration of the G20 economies stems from the substantial role this group plays in global economic dynamics. The G20 is a platform where the leaders commit to working with developing countries, particularly those with low incomes, to help them implement policies and priorities that are based on their national needs in order to achieve international development goals, particularly the Millennium Development Goals (MDGs), and to reaffirm their commitment to standstill. In order to support growth and development, the G20 provides policy coherence, analysis, and practical tools with a broad objective to ensure financial stability and promote growth. Further, as developing countries are getting more integrated into the global economy, the phenomenon contributes to the G20's objective of strong, sustainable, balanced and inclusive global growth. The 2030 Agenda for Sustainable Development too sets an ambitious, transformative and universal agenda for sustainable development efforts.

The Digital Economy Working Group (DEWG), currently chaired by India, is deliberating on plans to foster cooperation among the member countries for the equitable progress of digitalization. The GDP

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[6] Digital Opportunity Initiative is a unique public-private partnership between Accenture, the Markle Foundation and the United Nations Development Programme (UNDP).

[7] G20 is a strategic forum which brings together the world's major developed and developing economies. The members of the G20 are: Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union.

of the G20 countries cumulatively exceeds 80% of the global GDP, 75% of global commerce, and 60% of the global population.[8] Therefore, the G20 can play a crucial role, strategically, in the path towards future global prosperity and economic progress. The widespread use of the ICT infrastructure and the consequent digitalization is essential to create conditions that can potentially allow developing countries to leapfrog their way into economic prosperity. Due to the digital economy's expanding influence on the G20 economies and its ability to impact both the levels and rates of change of employment and production, there is a pressing need for new data, indicators, and measuring tools.

The objective of the paper is twofold. Firstly, we construct an ICT Development Index (IDI) using data for selected G20 economies over the period 2000–2019 using the technique of Principal Components Analysis (PCA). The variables have been carefully chosen to cover the three broad dimensions of ICT identified in the literature i.e. access, usage and capability. The index aims to quantify and then compare the ICT performance of these countries vis-a-vis each other and suggest recommendations based on learnings from leading countries. This index is an important tool to quantify the ICT development in a comprehensive manner. Secondly, the paper seeks to empirically verify the hypothesis that the ICT development may catalyse the association between FDI and economic growth. A certain amount of the ICT development may be a prerequisite for FDI to make an impact on economic growth. It enhances a country's readiness to harness technology spillovers and speed up human capital formation and thereby contribute to greater economic growth. Using the constructed ICT Development Index, the study evaluates if the ICT development augments the impact of FDI on economic growth.

1 REVIEW OF LITERATURE

The relationship between FDI and economic growth has been extensively examined in the extant literature (Li and Liu, 2005) and provides mixed evidence on the relationship between FDI and economic growth. Although some studies have identified a positive association between foreign direct investment (FDI) and economic growth (Sunde, 2017), there are others that have empirically established the impact of FDI on growth to be negative (Benzaim et al., 2023) and also those that have reported no causal impact of FDI on economic growth (Shimul, 2009; Tabassum and Ahmed, 2014). Hudea and Stancu (2012) for instance, reports a significant and positive impact of FDI on economic growth, both in the short and long terms, thereby reducing the technological disparity. The study also uncovered a bidirectional relationship, demonstrating causality not solely from FDI to economic growth but also in the converse direction, suggesting that FDI precipitates a chain reaction effect.

Alfaro (2003) challenges the commonly held notion that foreign direct investment (FDI) generates significant benefits uniformly for host countries. A closer examination makes it evident that there are significant sectoral effects. Moreover, the study finds that the overall impact of total FDI on growth remains inconclusive.

In this context, a relevant argument stems from an understanding of how FDI would influence the growth. While FDI is primarily a source of external capital for the host country and in that capacity relieves the resource constraint on growth and development, there is another indirect channel that reinforces this effect. FDI is an important channel for the transfer of technology and the host country needs to be equipped to fully tap its potential. A certain level of absorptive capacity may in fact be considered essential. So, when a company decides to set up a factory in a foreign land, it relies for some inputs on the host country, most important being the labour. For the investment to be productive and hence profitable the labour needs to be efficient. There can be little opposition to the proposition that the higher the digital literacy and more extensive the ICT use in the host country the more productive its labour and

[8] Source: OECD.

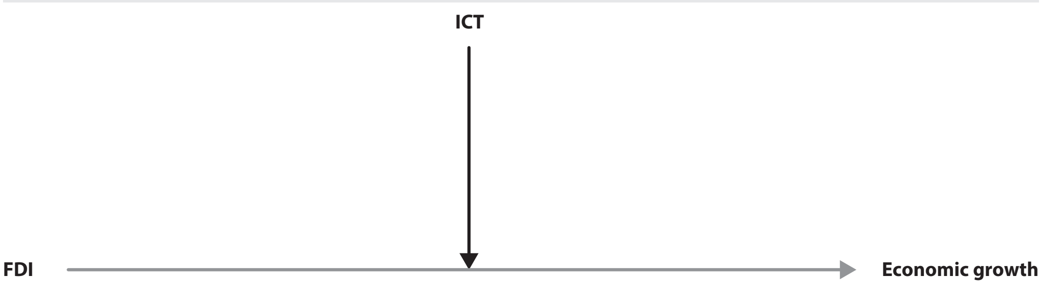
the more conducive the environment to generate profits. It may then be argued that a positive impact of FDI on economic growth may be conditional on the extent of the ICT use in the economy.

Similar findings have been reported by Gholami et al. (2010) who argue that the effects of ICT are not automatic and can vary depending on factors such as sector-specific implementation. Alfaro et al. (2004) asserted that FDI constituted a substantial determinant of economic growth across 20 countries belonging to the Organization for Economic Cooperation and Development (OECD). Dinh et al. (2019) reports significant role of FDI in stimulating long-term economic growth but found a negative impact in the short run. Similarly, Kallal et al. (2021) find empirical evidence supporting the positive long-term impact of ICT on Tunisia's economic growth, while attributing the observed negative short-run effect to the presence of investment bias.

Numerous studies have extensively explored the relationship between ICT and economic growth (Pohjola, 2001; Oulton, 2002; Kim et al., 2008; Toader et al., 2018). The potential consequences of ICT are diverse, making it a critical factor in promoting social development and economic advancement (Dimelis and Papaioannou, 2011). Notably, several studies emphasize the particular significance of ICT in fostering economic growth in developed countries (Nair et al., 2020; Kurniawati, 2020; Myovella et al., 2020).

Dewan and Kraemer (2000) contribute to the discourse by uncovering a statistically significant positive impact of ICT investment in West African Economic and Monetary Union (WAEMU) countries. Pohjola (2001) highlights the substantial role of ICT in driving economic activities and growth within developed countries. Kim et al. (2008) employs a knowledge management and resource-based perspective to analyse the influence of hardware, software, and internal spending as dimensions of IT investment on GDP. The study provides empirical evidence that supports the inconclusive nature of the relationship between the value of IT investment and GDP. Kurniawati (2020) highlights the potential of well-established ICT infrastructure to enhance economic growth in OECD economies. Myovella et al. (2020) provides empirical evidence demonstrating the positive impact of digitalization on economic growth in two distinct groups of countries, namely OECD (Organization for Economic Cooperation and Development) and SSA (Sub-Saharan Africa). Nair et al. (2020) highlights that in order to achieve sustained economic growth, policymakers in the OECD economies should implement an integrated framework that incorporates co-development policies related to R&D investment, ICT diffusion, and initiatives that enhance economic growth. However, despite the extensive body of research, the findings regarding the impact of ICT on economic growth have presented a complex picture, with studies yielding mixed results.

Figure 1 Proposed model



Source: Authors' compilation

It is widely acknowledged that the impact of FDI on economic growth is contingent upon various complementary factors. A holistic understanding of the interplay among FDI, and such factors is crucial for analysing the FDI-growth nexus (Benetrix et al., 2023). Gönel and Aksoy (2016) emphasizes the significance of considering additional mechanisms, such as technology-upgrading progress, among other factors implemented by the host country, in order to assess the potential positive impact of foreign direct investment (FDI) on economic growth. Similarly, Silajdzic and Mehic (2016) suggests that FDI has a positive impact on economic growth, particularly in technologically advanced transition economies. However, these studies emphasize that the relationship between FDI and economic growth is contingent upon various contextual factors and mechanisms adopted by the host country, or the presence of sufficient absorptive capacity within the host countries, suggesting that a comprehensive analysis incorporating these factors is crucial for an understanding of the FDI-growth nexus.

On the basis of literature reviewed, the current study aims to study the impact of the ICT development on the relationship between FDI and economic growth using a PCA constructed the ICT Index as displayed in Figure 1. The role of ICT in the growth FDI nexus is far from settled. This paper contributes to the literature by providing evidence based on the experience of the G20 nations, an economic grouping that represents a significant amount of global economic activity. It also contributes by constructing an index that provides a means to numerically evaluate the spread of ICT and digitalisation.

2 DATA AND METHODOLOGY

Given the importance and relevance of the G20 countries, it is imperative to have a dedicated index of ICT development of the member countries in order to analyse the performance of these countries vis-a-vis each other and how learnings from each other can help them perform better. In this regard, the next section discusses the relevant data sources and methodology adopted for constructing the IDI index for the G20 countries.

2.1 Variables and data sources

An ICT Development Index (IDI) for the G20 countries is constructed and used to rank them on the basis of their mean index score. Table 1(a) lists the six variables that are used to capture the three broad dimensions of ICT i.e., access, usage and capability. Table 1(b) lists the other variables taken for the study. The data used covers the G20 economies[9] over the period 2000–2019.

Table 1(a) Variable description and data sources for IDI construction

Dimensions	Description	Variables	Source
ICT access	Measures the readiness of network infrastructure and access to ICT	Mobile cellular subscription (per 100 people)	International Telecommunication Union (ITU) World Telecommunication/ ICT Indicators Database (26th Edition)
		Fixed telephonic subscription (per 100 people)	
ICT usage	Captures the extent to which ICTs are used in society, as well as the intensity with which they are used	Fixed broadband subscription (per 100 people)	
		Individuals using the internet (% of population)	
ICT capability	Identifies the competence or skills of efficient and effective ICT use as important input indicators	ICT service exports (% of service exports, BoP)	
		Research and development expenditure (% of GDP)	

Source: Author's compilation

[9] South Korea has been excluded from analysis owing to data unavailability.

Table 1(b) Variable description and data sources

Variables		Description	Source
GDP	Gross Domestic Product	Annual percentage growth rate of GDP at market prices based on constant local currency	World Development Indicators, the World Bank
FDI	Foreign Direct Investment as a % of GDP	The sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments	
GFCF	Government Final Consumption Expenditure as a % of GDP	Includes all government current expenditures for purchases of goods and services (including compensation of employees	
Trade	Trade as a % of GDP	The sum of exports and imports of goods and services measured as a share of gross domestic product	
GFCE	Gross Fixed Capital Expenditure as a % of GDP	Includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings	
EDU	Education Index	Component of the Human Development Index, measuring the educational attainment	UNDP's Human Development Report

Source: Author's compilation

2.2 Empirical methodology

This section is divided into two parts: the first part explains the methodology used to construct the ICT development index (IDI) while the second explains the panel data models employed to empirically understand the role of ICT development in explaining the FDI- growth relation. After the first step of compiling the data for the several variables to be used (explained in Section 2.1), the next step is to construct an ICT Development Index for the G20 economies. This is followed by a panel data analysis for assessing the role of ICT in FDI – Growth nexus. The following two subsections explain each of these steps in requisite detail.

2.2.1 ICT index construction

The study uses Principal Component Analysis (PCA) for constructing the IDI index. PCA is a widely used dimension reduction technique and recommended as the appropriate methodology for constructing composite indices (Asongu et al., 2018; Malik and Kaur, 2020). It merges standardized variable values and extracts vital information by reducing dimensionality, enhancing interpretability, and minimizing information loss (Abdi and Williams, 2019; Jolliffe and Cadima, 2016). Besides, utilizing this approach for constructing a composite index can be advocated as it is well-suited for highly correlated datasets (Asongu et al., 2018).

Before applying PCA to construct an index, the variables are standardized using Cumulative Distribution Functions (CDFs), where ranks are assigned to individual observations after organizing the dataset in ascending order such that $x_{[1]} \leq x_{[2]} \leq x_{[3]} \leq ..... x_{[n]}$. The transformed data is represented by z_t such that:

$$z_t = \begin{cases} {}^{r}/_{n} \, for \; x_{[n]} \leq x_t, \; r = 1, 2, ..., n-1, \\ 1 \; for \; x_t \geq x_{[n]} \end{cases} \tag{1}$$

where: x_t, z_t, r, and n represent original series, transformed series, the assigned rank of x_t and the total observations respectively.

Bartlett's test of sphericity and Kaiser Meyer Olkin (KMO) test of sampling adequacy are applied to test for the suitability of the dataset for PCA. To enhance the orthogonality of sub-indicators and reveal a distinct loading pattern, the obtained components are subjected to varimax rotation (Issah and Antwi, 2017). Varimax rotation serves to simplify the representation of a specific sub-space by emphasizing only the major items within it. It is important to note that the actual coordinate system remains unchanged; instead, it's the orthogonal basis that undergoes rotation to align with those coordinates. Factors having the highest eigenvalues are chosen as PCs. Kaiser (1960) recommends considering PCs which have eigenvalues higher than one. Using the weights derived by the weighted average of eigenvalue with indicator loadings of each variable, the final index is constructed using the following equation.

Assignment of weights using PCA:

$$W_i = \sum_{i=1}^{n} |L_{ij}| E_j \, , \tag{2}$$

where: W_i is the weight of the i^{th} indicator; E_j is the eigenvalue of the j^{th} factor; L_{ij} is the loading value of the i^{th} unit of grouping on j^{th} factor; i and j represents indicators and PCs respectively.

After obtaining the weights, Index (I) is created as:

$$I = \frac{\sum_{i=1}^{n} z_i W_i}{\sum_{i=1}^{n} W_i} \, , \tag{3}$$

where: z_i and W_i represent the normalized value and the weight of the i^{th} indicator respectively.

2.2.2 Panel data analysis

The dataset used for the study is a panel spanning nineteen countries over the period 2000–2020, hence the need to employ the appropriate panel data model.

Consider the following equation that may be used to model the dataset available:

$$Y_{it} = \beta_1 + \sum_{j=2}^{k} \beta_j X_{jit} + \alpha_i + \varepsilon_{it} \, , \tag{4}$$

where: Y_{it} is the dependent variable for the ith cross-sectional unit for the time period t, X_{jit} is the jth independent variable for the same observation, α_i is the individual specific unobserved effect for the ith cross-sectional unit and ε_{it} is the error term. The study uses flow chart provided by Dougherty (2011) that summarizes the decision-making process for the choice of the appropriate panel data model. To check for the random effects for individual heterogeneity i.e., the presence of random effects, the study uses the Breusch–Pagan test. The Hausman test is then used to choose between the Random and Fixed effects models. In this study, Hausman test indicates that a fixed effects model is appropriate. In Fixed effects model, variables are expressed as mean-corrected values, and Ordinary Least Squares on this de-meaned equation is applied (Gujarati et al., 2019). The final equation estimated for fixed effects model is as below:

$$y_{it} = \sum_{j=2}^{k} \beta_j x_{jit} + u_{it} \, , \tag{4a}$$

where: the dependent, independent and the error terms represent the de-meaned values.

The IDI index constructed using the methodology described earlier is then used to examine empirically whether ICT can serve as a catalyst in the FDI growth relation. A static panel data analysis for G20 countries using data over the period 2000 to 2020 is conducted. The specification of the estimated model, Model 1 is given as:

$$GDP_{it} = \alpha_0 + \alpha_1 FDI_{it} + \alpha_2 IDI_{it} + \alpha_3 GFCE_{it} + \alpha_4 Trade_{it} + \alpha_5 GFCF_{it} + \alpha_6 EDU_{it} + \mu_i + \epsilon_{it}, \tag{5}$$

where: *GDP* is GDP growth; *FDI* is Foreign Direct Investment as a % of GDP; *IDI* is the ICT Development Index (IDI) constructed using PCA; *GFCE* is the Government Final Consumption Expenditure as a % of GDP; *Trade* has been taken as a % of GDP; $GFCF_{it}$ is the Gross Fixed Capital Expenditure as a % of GDP; *EDU* is Education Index.

We start the analysis by estimating the regression in Model 1. This model assesses the marginal impact of FDI on GDP after controlling for ICT and other factors. In line with the objective of the study, i.e., whether the role of FDI on GDP is conditional on the ICT index, we introduce an explanatory variable, FDIIDI, which is an interaction of FDI and the IDI. The same is represented in Model 2 as:

$$GDP_{it} = \alpha_{i0} + \alpha_1 FDI_{it} + \alpha_2 ICT_{it} + \alpha_3 GFCE_{it} + \alpha_4 Trade_{it} + \alpha_5 GFCF_{it} + \alpha_6 EDU_{it} + \alpha_7 FDIICT_{it} + \varepsilon_{it}. \tag{6}$$

The coefficient term α_7 measures the significance of the interaction term on the GDP growth. It signifies whether the interaction term of FDI and ICT amplifies or distorts the impact of FDI. Therefore, the conditional effect of FDI on growth can be calculated as:

$$\frac{\partial GDP}{\partial FDI} \; \alpha_1 + \alpha_7. \tag{7}$$

If $\alpha_1 < 0$ and $\alpha_7 > 0$, then it denotes that ICT reduces/ increases the impact of FDI on GDP growth.

3 RESULTS

After applying PCA to construct the index, the G20 economies have been ranked on the basis of the mean index score calculated in the process. Table 2 gives an overview of the index scores of the G20 countries along with their mean index score values. This is followed by ranking of countries based on their mean index score.

While most of the extant literature on determinants of GDP have concluded a positive relation between FDI and growth (Abbes et al., 2015; Soylu et al., 2023, for instance), some have also established the reasons for a negative impact (Susilo, 2018; Dinh et al., 2019, for instance). FDI slows down growth especially at the initial stages but shows a positive effect in the long run (Dinh et al., 2019). The authors believe that to negate the initial effect and to make FDI enable growth, it's important to interact it with other significant variables like ICT index. The empirical results in this study conform to the results in the vast literature on the nexus between FDI and growth.

The results of the panel data analysis are discussed below. Both Bruesch Pagan test and the Hausmann test give results in favour of the Fixed Effects model. We can see from Table 3 that the coefficient of variable FDI is negative, which implies that a percentage increase in FDI leads to a .04% decrease in the growth of GDP. However, the coefficient is insignificant. However, in the model with interaction, see Table 4, both FDI variable and the interaction term become significant. This calls for increasing FDI in the ICT sector to increase the conditional effect on growth.

The conditional effect of FDI can be written as:

$$\frac{\partial GDP}{\partial FDI} \; -.39 + .67.$$

Table 2 Estimated Mean Index Score based on PCA

Year	Indonesia	Mexico	India	South Africa	Turkey	Saudi Arabia	Brazil	China	Argentina	Russia	Australia	Italy	Japan	United States	Canada	European Union	UK	France	Germany
2000	0.03	0.19	0.21	0.11	0.16	0.08	0.15	0.12	0.2	0.2	0.44	0.39	0.45	0.51	0.57	0.41	0.45	0.47	0.5
2001	0.03	0.17	0.21	0.13	0.17	0.09	0.21	0.12	0.23	0.23	0.44	0.46	0.48	0.54	0.61	0.45	0.47	0.52	0.56
2002	0.06	0.17	0.22	0.14	0.18	0.1	0.21	0.16	0.23	0.24	0.49	0.44	0.5	0.55	0.61	0.48	0.52	0.57	0.59
2003	0.1	0.17	0.22	0.15	0.19	0.12	0.27	0.23	0.24	0.27	0.51	0.49	0.5	0.57	0.63	0.51	0.57	0.58	0.62
2004	0.15	0.19	0.23	0.17	0.22	0.13	0.26	0.27	0.27	0.29	0.54	0.51	0.52	0.58	0.62	0.53	0.61	0.59	0.65
2012	0.31	0.29	0.31	0.36	0.34	0.48	0.46	0.49	0.59	0.58	0.65	0.66	0.68	0.66	0.71	0.75	0.74	0.76	0.84
2013	0.32	0.28	0.31	0.39	0.36	0.47	0.49	0.52	0.61	0.6	0.66	0.67	0.71	0.66	0.69	0.76	0.75	0.76	0.85
2014	0.33	0.27	0.32	0.4	0.36	0.48	0.53	0.54	0.6	0.62	0.65	0.67	0.73	0.68	0.68	0.77	0.76	0.78	0.83
2015	0.33	0.31	0.32	0.42	0.36	0.48	0.53	0.57	0.61	0.64	0.64	0.67	0.74	0.7	0.68	0.76	0.77	0.77	0.83
2016	0.35	0.31	0.34	0.41	0.38	0.47	0.52	0.58	0.62	0.64	0.65	0.67	0.76	0.74	0.68	0.77	0.77	0.77	0.86
2017	0.37	0.32	0.34	0.43	0.39	0.48	0.51	0.6	0.62	0.66	0.65	0.67	0.77	0.75	0.69	0.78	0.76	0.77	0.87
2018	0.31	0.33	0.34	0.43	0.42	0.56	0.53	0.63	0.63	0.65	0.67	0.69	0.78	0.76	0.7	0.79	0.75	0.79	0.87
2019	0.35	0.35	0.36	0.45	0.42	0.56	0.52	0.66	0.6	0.66	0.67	0.69	0.8	0.77	0.71	0.8	0.75	0.78	0.86
Mean Index Score	0.25	0.26	0.29	0.3	0.32	0.35	0.38	0.42	0.47	0.5	0.6	0.61	0.64	0.65	0.67	0.67	0.68	0.69	0.77
Rank based on Mean Index Score	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1

Source: The authors

Table 3 Fixed-Effects Model

GDP growth	Coefficients	S.E.	t-value	p-value	[95% conf. interval]		Significance
FDI	–.044	.087	–0.51	.61	–.216	.127	
ICT	–5.3	2.102	–2.52	.012	–9.435	–1.164	**
GFCE	–.609	.134	–4.55	0	–.872	–.345	***
Trade	.072	.021	3.49	.001	.031	.113	***
EDU	.154	4.684	0.03	.974	–9.06	9.368	
GFCF	.256	.066	3.87	0	.126	.386	***
Constant	6.495	3.689	1.76	.079	–.762	13.751	*
Model statistics							
Mean dependent var		3.097		**SD dependent var**		3.401	
R-squared		0.216		**Number of obs.**		359	
F-test		15.421		**Prob > F**		0.000	
Akaike crit. (AIC)		1 651.466		**Bayesian crit. (BIC)**		1 678.650	

Note: *** p<.01, ** p<.05, * p<.1.
Source: Authors' compilation

Table 4 Interaction Model

GDP growth	Coefficients	S.E.	t-value	p-value	[95% conf. interval]		Significance
FDI	–.393	.221	–1.78	.077	–.828	.043	*
ICT	–6.336	2.182	–2.90	.004	–10.628	–2.044	***
GFCE	–.623	.134	–4.66	0	–.886	–.36	***
Trade	.074	.021	3.61	0	.034	.115	***
EDU	–.411	4.682	–0.09	.93	–9.621	8.8	
GFCF	.278	.067	4.15	0	.146	.411	***
FDIICT	.674	.394	1.71	.088	–.101	1.449	*
Constant	7.052	3.693	1.91	.057	–.212	14.316	*
Model statistics							
R-squared		0.223		**Observations**		359	
F-test		13.713		**Prob > F**		0.000	
Akaike crit. (AIC)		1 650.332		**Bayesian crit. (BIC)**		1 681.399	

Note: *** p<.01, ** p<.05, * p<.1.
Source: Authors' compilation

The results are robust by amplifying the significance of ICT index on FDI in its effect on growth. The interaction has a positive effect on growth i.e., effect of FDI on growth is conditional on the magnitude of the interaction term.

We expect all coefficients to be positive. i.e., FDI, ICT, Trade, Expenditures, Investment, Education to boost economic growth. Even though several studies have exhibited a positive relation between FDI and growth, a negative relation is also a potential outcome (Abbes et al., 2015).

DISCUSSION AND CONCLUSION

The study attempts to assess the dynamic nature of the FDI-GDP growth nexus, emphasizing the role of ICT as a contextual determinant. In terms of the mean IDI score values, Germany has the highest mean score of 0.77 among all the G20 nations. Germany is a leading force in innovation, demonstrated by its top ranking in the World Economic Forum's 2018 Global Competitiveness Report. The country's emphasis on ICT is evident through the government's prioritization of this sector in the BMWi's Digital Agenda. Germany boasts one of Europe's largest ICT industries, with a significant software market and a substantial number of IT businesses and workers. With the mean IDI score of 0.69, the digital divide in France is closing as more households acquire computers and internet connections. The ICT market in France reached US$112.07 billion in 2021 and is projected to grow at a CAGR of 7.3% to US$159.25 billion by 2026.[10] France's strong ICT usage is recognized in the Global Innovation Index 2021, where it ranks 10th. The French government is fully committed to the ICT growth, exemplified by the strategic implementation of the French National Plan for Digital Inclusion (September 2018), promoting digital transformation in businesses and the establishment of a secure, people-centric digital society. UK retains its position as one of the world's largest ICT markets, ranking second in ICT spending per capita.[11] With a digital technology turnover of over $240 billion in 2018, the UK houses approximately 100 000 software companies and serves as the top destination for U.S. ICT businesses in Europe.

The EU and Canada both have a mean index score of 0.67. In the past four years, the EU has experienced significant growth in various aspects of the ICT infrastructure, access, and usage, leading globally in terms of internet access, with an estimated 85% of households having access in 2019, compared to the global average of 57.4%.[12] Similarly, Canada's technology sector serves as a major economic driver, surpassing much of the country's overall economy. In recent years, Canada has become a hub for tech entrepreneurship, laying the foundation for the ICT expansion. The United States, with a mean IDI score of 0.65, has the most advanced software and IT services industry in the world. The industry accounts for $1.8 trillion of U.S. value-added GDP (more than 10% of the national economy) and 11.8 million jobs.

Next is Japan with a mean IDI score of 0.64. Japan's ICT market, which has developed through the spread of telecommunications services and the advancement of telecommunications networks, holds a 6.4% share of the global market.[13] The ICT sector is playing an increasingly strategic role in Italy, which has the mean IDI score of 0.61, as it now provides fundamental contributions to all other sectors of the economy. R&D spending by Italian ICT companies reached $2.29 billion in 2017, 7.5% more than in 2016 and amounting to 10.6% of total R&D spending across all sectors. With a mean IDI score of 0.60, Australia serves as a strategic site for various ICT activities, attracting global and regional attention due to its robust research infrastructure, skilled workforce, and technology-driven clientele. It has seen notable examples of renowned companies viz. Avaya, Canon, and IBM leveraging Australia's ICT resources. While Russia aims to control internet content, its government is also attempting to improve the use of modern technologies. The ICT regulatory framework has shown significant development with the adoption of various laws, adoption of the Telemedicine Law (2018), the Law on Critical Infrastructure (2017), the Online Cash Register Law (2017), amendments to the Public-Private Partnerships Law (2018).

Argentina, China, Brazil, Saudi Arabia, Turkey, South Africa, India, Mexico and Indonesia have mean IDI scores less than 0.50. Argentina's long-term growth performance remained susceptible to macro-fiscal crises. Inadequate human capital, difficulty in obtaining financing for innovation, particularly for start-ups, weak links between relevant players, and insufficient incentives for public research and technology

[10] Source: Global Data – France ICT Market Size and Forecast (by IT Solution Area, Size Band and Vertical), 2022–2026.
[11] Source: International Trade Administration – United Kingdom Information and Communications Technology.
[12] Source: ITU, Based on ITU WTI Database.
[13] Source: Japan External Trade Organization, Digitalization of society brought about by 5G and Beyond 5G, based on data from Statista.

institutions have been additional barriers to innovation. The landscape of the ICT policy in China is not easy. China's approach to the issue balances on concerns of commerce and national social security. Furthermore, although the protection of intellectual property has improved over time, piracy remains a major issue. Brazil has been recently making progress in the right direction. The Brazilian Information and Communication Technology market (ICT) was valued at US$ 49.5 billion in 2020. It has implemented the Brazil More Digital (Brasil Mais Digital), an online education initiative. Saudi Arabia is just as keen as the other nations to use IT to reap larger benefits. Saudi Arabia's transition to an informational society, however, is being hampered by a lack of knowledge, time, and trust in new systems. Regulations in Turkey on social media platforms, a new tax on digital services, and requirements for local content make it more challenging for foreign businesses to operate there. The economy has, nevertheless, exhibited developments recently. South Africa has demonstrated technological superiority in the areas of mobile software, security software, and online banking services in the past decade and has shown a tremendous growth. Using ICT to promote socioeconomic fairness and inclusion, boosting competitiveness and preparing the country for the digital industrial revolution (fourth industrial revolution) is at the core of the priorities of the South African government. The bold ICT vision of India is constantly articulated and persuasively outlined in Rebooting India. India has shown a consistent growth over the years in terms of ICT development. Mexico's ICT sector has seen increased competition and investment since 2013's landmark regulatory reform, which created the Federal Institute of Telecommunications (IFT). While Mexico has advanced telecommunications regulation in Latin America according to ITU regulatory tracker, it lacks a clear roadmap for ICT public policy or a national digital strategy. Despite encouraging developments in Internet usage, Indonesia still has significant difficulties, such as an unequal population distribution.

The results of the panel data analysis carry noteworthy implications for policy development, with a specific emphasis on the interaction between ICT and FDI. In the Fixed-Effects Model without interaction terms, the non-significant coefficient of FDI suggests that, on average, FDI alone does not exert a statistically significant impact on the GDP growth. However, the unexpected negative sign introduces a new dimension – an incremental percentage increase in FDI coincides with a 0.04% reduction in the GDP growth, though this is not statistically significant. Of significance is the conspicuously important negative coefficient associated with the ICT variable, indicating a noteworthy adverse effect on the GDP growth.

The results become more intricate in the model incorporating interaction terms. The emergence of a statistically significant negative coefficient for FDI within the context of its interaction with ICT (FDIICT) introduces a paradoxical scenario – an increased FDI correlates with a 0.39% decrement in GDP growth. This apparent contradiction challenges established paradigms and underscores the conditional nature of FDI's impact contingent upon the developmental stage of ICT. Contrarily, the positive and significant coefficient affiliated with the interaction term (FDIICT) suggests that the amalgamation of FDI and ICT engenders a positive effect on the GDP growth. This provides empirical credence to the proposition that directing attention toward the ICT sector to attract FDI may amplify its constructive repercussions on economic growth.

The anticipation of positive coefficients across all variables, including FDI, ICT, Trade, Expenditures, Investment, and Education, aligns with prevailing economic theories emphasizing their favourable contributions to economic growth. However, the unique findings of this study, particularly the conditional nature of FDI's impact in the presence of ICT, emphasize the exigency for context-specific policy considerations. The ostensibly discordant negative correlation between FDI and the GDP growth serves as a poignant reminder that the influence of FDI is contingent upon a multitude of contextual factors.

In order to realize the objective of empirical analysis of the role of ICT in the economic growth-FDI nexus, the study constructs an ICT index. While the advantage of constructing the index lies in a comprehensive covering of the various facets of ICT development, it may be a matter of concern that the principal components constructed lack economic interpretability. Also, while panel data controls for any spurious relationships between ICT and growth, it might not account for all variables that vary across time for different countries. The analysis does not deal with plausible endogeneity issue and hence is a limitation of this study. Exploring other econometric techniques that overcome these limitations are suggested as avenues for future research.

In conclusion, these findings advocate for a discerningly targeted policy paradigm. Governments, in formulating strategies, should contemplate substantial investments in ICT infrastructure and the creation of an environment conducive to FDI within the ICT sector. Such an approach is poised to harness the latent synergies between FDI and ICT for optimal economic growth. This study thus challenges reductionist interpretations of the FDI-GDP growth nexus, accentuating the indispensability of bespoke policies attuned to the specific conditions characterizing individual countries. As the G20 nations continue to shape the global economic landscape, understanding and harnessing the potential of ICT development becomes imperative for sustainable and inclusive growth.

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APPENDIX

Table A1 Hausman test results

	Coefficients			
	(b) Fixed	**(B) Random**	**(b-B) Difference**	**sqrt(diag(V_b-V_B)) S.E.**
Foreigndir~i	–.0444572	.0852562	–.1297134	.0326429
ICTINDEX	–5.299693	–6.46908	1.169387	1.112262
Generalgov~p	–.6085715	–.1958342	–.4127373	.115851
TradeofGDP	.0719963	.0473668	.0246296	.0161303
Educationi~x	.1541575	3.024796	–2.870639	3.575626
Grossfixed~n	.2557294	.2290673	.0266621	.0538752
b = consistent under Ho and Ha; obtained from xtreg				
B = inconsistent under Ha, efficient under Ho; obtained from xtreg				
Test: Ho: difference in coefficients not systematic				
chi2(6) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 42.72 Prob>chi2 = 0.0000				

Source: Authors' compilation