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Nexus between information technology and economic growth: new insights from India

Asif Raihan [a,*]

[a] *Institute of Climate Change, Universiti Kebangsaan Malaysia, Bangi 43600, Selangor, Malaysia*

ABSTRACT

The objective of this research is to investigate, using time series data ranging from 1992 to 2021, the effects of information and communication technologies (ICTs) and foreign direct investment (FDI) on economic growth (GDP) in India. The stationarity of the data was examined by employing unit root tests, and an autoregressive distributed lag (ARDL) technique was used to investigate the link between the factors, taking both the long- and the short-run into consideration. According to the findings, an increase of one percent in both ICT and FDI will result in an increase of 0.56% and 0.71% in GDP over the long term, in addition to an increase of 0.11% and 0.29% over the short term. The findings of the investigation are of particular significance to policymakers because they can be utilized to establish sensible policymaking for long-term economic success, in addition to advancing the ICT sector and boosting FDI.

KEYWORDS

ICT; Economic growth; FDI; Sustainable development; ARDL

* Corresponding author: Asif Raihan
E-mail address: asifraihan666@gmail.com
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1. Introduction

Over the course of the last few decades, advances in ICT have brought about enormous change in the world in which we live (Tiwari et al., 2022). Someone brought up the fact that information and communications technology (ICT) plays a major role in the process of social change. Not only do ICTs enable people to connect with one another, but they also have the potential to optimize human development, commitment, transparency, and responsibility (Iqbal et al., 2020). It is possible for information and communications technology to increase the economic prosperity and earnings of businesses as well as to create jobs that have a significant impact (Nayak and Sahoo, 2021). This would cause nations to increase their spending on research and development actions and to implement a new information and communications technology system. This deposit has resulted in the development of novel ICT innovations and has contributed to the expansion of the global economy (Nair et al., 2020). The expansion of ICT has connected numerous different sections of the globe, which has persuaded developing nations to embrace the technology that is employed by developed countries (Raihan, 2023a). This has led to an increase in production and a more rapid expansion of the economy in former countries (Raihan and Tuspekova, 2023a). ICT has been improved and promoted in a more effective manner thanks to the new information structure that has emerged over the past few decades (Sinha and Sengupta, 2022).

Technology in the fields of information and communication has always been an important contributor to the expansion of both the economy and society (Raihan et al., 2023a). It is now generally accepted as the primary enlightenment for the communal, financial, and cultural inaction in developed nations that the inability of these countries to produce, raise, and usage the top technology in their manufacture processes is the primary cause of this stagnation. The scope and impact of this technology has emerged as one of the most pressing issues facing the world in the modern era and has attracted the attention of people everywhere (Raihan and Tuspekova, 2023b). Within the context of the overseas expansion system, the swift advancements in ICTs, as well as the growing economic globalization, provide developed countries with new opportunities to participate in global output (Begum et al., 2020; Sultana et al., 2023). This, in turn, enables developed countries to improve their level of competitiveness. International competitiveness encompasses not only the liberalization of trade but also the rising economic value of the ICT market. The ICT industries associated with developing economies face a number of challenges that must be overcome before they can fully develop and capitalize on their advantages. The characteristics of the information and communications technology sector diverge from those of the other economic sectors, particularly as the prices of goods start to fall (Haseeb et al., 2019).

ICT provides a one-of-a-kind prospect for a emerging nation like India to liberated itself from the historic and geographical burdens it has faced. This opens the door for India's commercial and economic activities to be carried out with the same level of effectiveness as they are in developed countries (Tiwari et al., 2022). The development of a more robust and reliable ICT infrastructure has had a profound impact on the character of international interactions, the availability of competitive advantages, and the prospects for economic and social progress. The widespread adoption of technologies like the internet, Laptops, broadband, and wireless phones has resulted in the formation of a globally interconnected network of individuals, companies, and governments (Sinha and Sengupta, 2022). In order for India to participate in progressively viable international markets and to entice new investments, it is necessary for the country to have a contemporary telecommunications infrastructure. This is in addition to the fact that having such an infrastructure is essential for the expansion of the Indian economy (Veeramacheneni et al., 2008). Since 2016, India has experienced a significant decline in the cost of mobile data, which has led to a massive increase in the country's mobile internet penetration and cellular data consumption (Tiwari et al., 2022). In addition, India has begun a digital initiative that is being referred to as "Digital India." This initiative will ensure that citizens of India have access to government services electronically by increasing the speed of the internet and improving the infrastructure of the internet. These initiatives will undoubtedly stimulate economic expansion in India; in

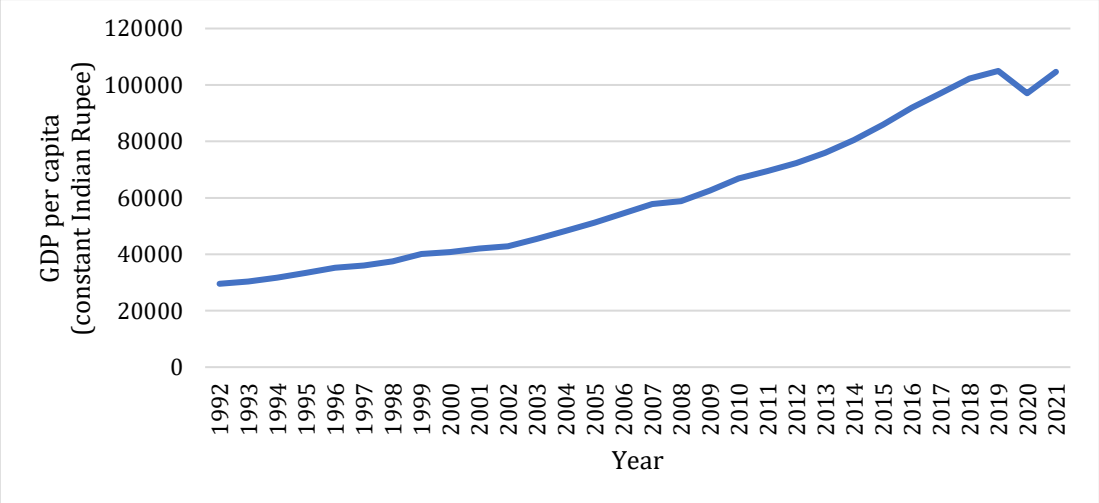
particular, the contribution of the information and communications technology (ICT) sector will determine the trajectory of the Indian economy in the years to come. The sensation of India's software manufacturing has piqued the interest of people all over the globe, including those living in India (Nayak and Sahoo, 2021). At this time, Indian companies control approximately 16% of the worldwide employees in the services segment and approximately 2 percent of the global market for services. In the near future, ICT is projected to contribute 8% of India's GDP, provide employment for 4 million people (including support services), and bring in 30% of India's foreign exchange inflows. At the present time, ICT is accountable for 14% of India's exports and 2% of the country's GDP (Tiwari et al., 2022).

In addition, as a result of increased focus on foreign direct investment (FDI), India recently surpassed both the United States of America and China in terms of FDI in greenfield projects (Veeramacheneni et al., 2008). Make in India is the name of a program that was initiated by the government of India with the intention of encouraging both domestic and international businesses to produce their goods in India. The Make in India initiative encompasses a wide variety of fields, including the field of information technology (Sinha and Sengupta, 2022). Therefore, the purpose of this study was to demonstrate the connection between advances in ICT, FDI, and rising GDP in the context of India. The stationarity and series stability of the variables was checked using three unit root tests, and their connections to long- and short-term causal dynamics were verified using the ARDL strategy. The intriguing findings of the current study could give policymakers in India new insights into measures for sustainable economic success along with advancing the ICT segment and boosting FDI. These are all areas that the study focuses on.

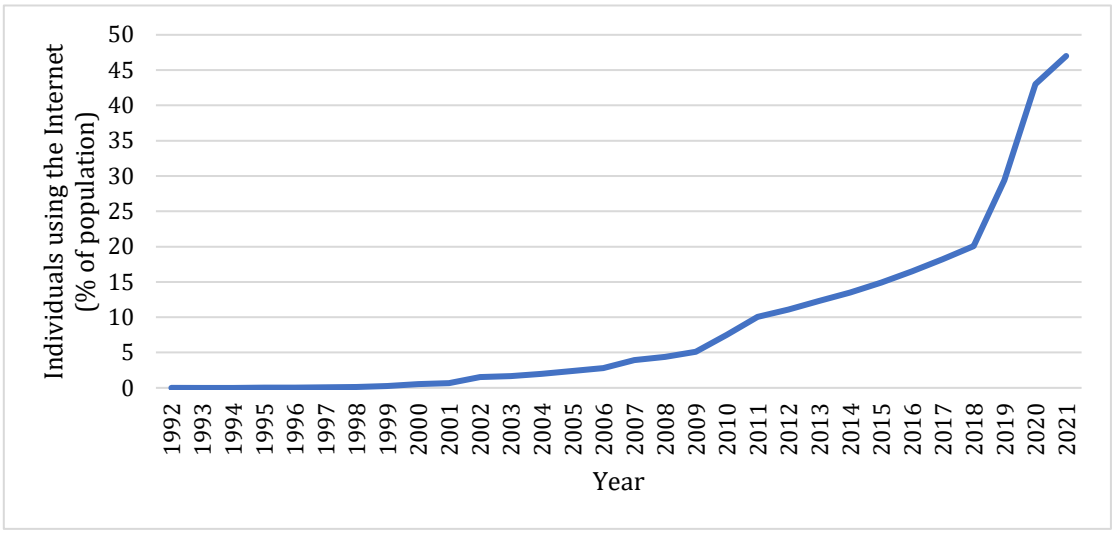
2. Methodology

2.1. Data and empirical model

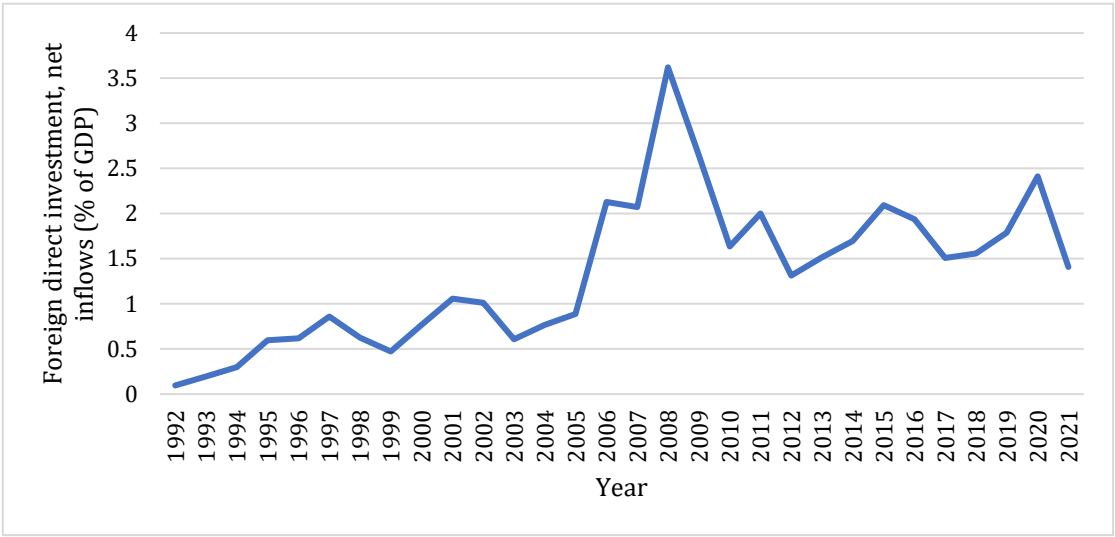
In order to validate the hypothesis regarding the relationship between the variables, the ARDL bounds analysis strategy was combined thru a cointegrating regression scrutiny. The World Development Indicators (WDI) was operated to accumulate all of the variable time series data, and the years covered by these data range from 1992 to 2021. Study variables include gross domestic product (measured in constant Indian rupees), information and communications technology (measured as percentage of population using the Internet), and foreign direct investment (measured as percentage of total GDP). Figure 1 is a plot that displays the patterns of the variables over time.



(a) GDP growth



(b) ICT



(C) FDI

Figure 1. The yearly trends of GDP, ICT, and FDI in India.

This study specified the following model at time t in order to demonstrate the association between variables.

$$GDP_t = \tau_0 + \tau_1 ICT_t + \tau_2 FDI_t + \varepsilon_t \quad (1)$$

where, τ1 and τ2 are the coefficients, whereas ε is the error term.

The variables were employed by following the logarithmic to clarify smooth data. data.

$$LGDP_t = \tau_0 + \tau_1 LICT_t + \tau_2 LFDI_t + \varepsilon_t \quad (2)$$

2.2. Stationarity check

To determine whether the dataset is unified at I(0) or I(1), this study first looks at the associations between the answer variable and its explanatory components. Second, not all regressors need to have a seasonal influence

or be included by order one (Raihan et al., 2022a; Raihan and Tuspekova, 2022a). In addition, trying to steer clear of the I(2) sequence is invalid and may produce misleading results. In addition, if any variable is nonstationary, the result may be erroneous (Raihan and Tuspekova, 2022b; Raihan et al., 2022b; Ghosh et al., 2023). However, the switch to I(2) is unparalleled and causes concern for the small sample size (Raihan and Tuspekova, 2022c; Raihan et al., 2023b; Raihan and Tuspekova, 2022d; Raihan et al., 2022c). The Augmented Dickey-Fuller (ADF), the Dickey-Fuller generalized least squares (DF-GLS), and the Phillips-Perron (P-P) unit root tests are used in this inquiry to ensure that no variables are I(2).

2.3. ARDL approach

To analyze the long-term connection between the variables, the ARDL bounds testing method of cointegration proposed by Pesaran et al. (2001) was used. With respect to the sequence of integration, this cointegration test has various advantages over more conventional methods (Raihan et al., 2022d; Raihan and Tuspekova, 2022e; Voumik et al., 2023). If the parameters are found to be unchanging at either the I(1) or I(0) level, or the I(1)/I(0) level, then this approach can be used (Raihan and Tuspekova, 2022f; Raihan, 2023b). Using a general-to-specific modeling framework, the ARDL bounds testing empirical model employs an adequate amount of lags to capture the process of data generation (Raihan and Tuspekova, 2022g; Raihan, 2023c). Under the ARDL framework, the ARDL F-statistic can be calculated to test for the presence of cointegration between variables by using a diverse ideal number of lags for each variable (Raihan and Voumik, 2022a; Raihan, 2023d). If the ARDL F-statistic is larger than a predetermined upper critical value, then it is demonstrated that the variables are cointegrated. If the ARDL F-statistic is less than the lower critical bound, then the variables do not exhibit cointegration. When the ARDL F-statistic falls in the middle of the two critical values—the upper critical bound and the lower critical value—the empirical conclusions will be unconvincing (Raihan et al., 2023c). The following is the approximate model for the ARDL bounds analysis method of examining cointegration:

$$\Delta \mathrm{LGDP}_t = \tau_0 + \tau_1 \mathrm{LGDP}_{t-1} + \tau_2 \mathrm{LICT}_{t-1} + \tau_3 \mathrm{LFDI}_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta \mathrm{LGDP}_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta \mathrm{LICT}_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta \mathrm{LFDI}_{t-i} + \varepsilon_t \quad (3)$$

where Δ stands for the first difference operator, and q indicates the length of the lag that is optimal.

ARDL bounds testing can be transformed linearly to obtain the error correction model (ECM). This method yields trustworthy empirical results even with relatively tiny samples (Raihan and Voumik, 2022b). To preserve the long-term picture, the ECM integrates the short-run subtleties with the long-term stability (Raihan, 2023e). This method isolates the cointegrating vectors that emerge from the empirical model as a consequence of the presence of several cointegrating vectors. The coefficient of ECM is shown by the symbol θ. There is almost never an ECM below 0, and it never goes over 1 (Raihan, 2023f). In instances where ECM is negative and statistically significant, it is essential that the variance be corrected to reach equilibrium. This research computed the short-run coefficients of the parameters using Equation (4) after establishing the long-term relationship between the series.

$$\Delta \mathrm{LGDP}_t = \tau_0 + \tau_1 \mathrm{LGDP}_{t-1} + \tau_2 \mathrm{LICT}_{t-1} + \tau_3 \mathrm{LFDI}_{t-1} + \sum_{i=1}^{q} \gamma_1 \Delta \mathrm{LGDP}_{t-i} + \sum_{i=1}^{q} \gamma_2 \Delta \mathrm{LICT}_{t-i} + \sum_{i=1}^{q} \gamma_3 \Delta \mathrm{LFDI}_{t-i} + \theta \mathrm{ECM}_{t-1} + \varepsilon_t \quad (4)$$

3. Results and discussion

Tabulated in Table 1 below are descriptive statistics. Based on the data collected and analyzed, it has been determined that the median and mean values of all variables are very similar. All of the variables exhibit a normal distribution, as shown by the skewness values near zero, the kurtosis values below 3, and the Jarque-Bera test statistics below their thresholds.

Table 1. Descriptive statistics.

Variables	LGDP	LICT	LFDI
Mean	10.93513	0.140057	0.052152
Median	10.93584	1.202649	0.307274
Maximum	11.56125	3.850148	1.286618
Minimum	10.29330	-9.103209	-2.344013
Std. Dev.	0.413398	3.457722	0.804675
Skewness	0.065599	-0.359899	-0.110544
Kurtosis	1.689412	2.066659	2.165168
Jarque-Bera	2.168569	1.660883	1.863558
Probability	0.338144	0.480023	0.109609

The first step is to get certain that order one, I(1), contains the entire dataset, and more specifically the response variables. This is done by analyzing the strength of correlation that exists between the response variables and the predictor parameters. Next, it is not appropriate to include all of the regressors of order one or to demonstrate temporary unit roots. Both of these approaches are flawed. To evaluate the order of the parameters and ensure compliance with the prerequisite, the ADF, DF-GLS, and P-P three-unit root tests were employed. The conclusions of the unit root tests are shown in Table 2. The data disclosed that all the tested parameters are stationary at the initial difference. The data are consequently appropriate for ARDL estimator.

Table 2. The results of unit root examinations.

Logarithmic form of the variables	ADF		DF-GLS		P-P	
	Log levels	Log first difference	Log levels	Log first difference	Log levels	Log first difference
LGDP	-0.377	-5.129***	-0.494	-5.157***	-0.378	-5.124***
LICT	-0.751	-5.188***	-0.289	-5.889***	-0.206	-5.114***
LFDI	-0.359	-5.012***	-1.456	-4.316***	-0.954	-5.182***

*Notes: *** denotes significance at 1% level.*

After establishing the reliability of the variable's unit roots, this probe devoted the ARDL bounds experiment to inspect the nature of the long-term connection that exists between the variables. The empirical conclusions of using the ARDL bounds testing approaches to cointegration are presented in Table 3. As the estimated F-statistic was higher than the values of the upper critical bound, the empirical data presented evidence that long-term cointegration did, in fact, exist among the variables in question.

Table 3. Results of ARDL bounds analysis.

F-bounds test		Null hypothesis: No degrees of relationship		
Test statistic	Estimate	Significance	I(0)	I(1)
F-statistic	13.31327	At 10%	2.63	3.35
K	2	At 5%	3.10	3.87
		At 2.5%	3.55	4.38
		At 1%	4.13	5.00

Once the long-term connection has been established, this study will proceed to estimate the long-term and short-term parameters. Tabulated in Table 4 are the findings of both the long- and short-run studies. The empirical findings from the ARDL estimation exhibit that ICT exhibits a positively significant weight on GDP over the long and short terms. A 1% upswing in ICTs precedes GDP by 0.56% (in the long run) and 0.11% (in the short run), assuming FDI remains constant. According to ARDL outcomes, FDI has both a positive and a significant influence on the GDP both in the short run and in the long run. To be more specific, an intensification of 1% in FDI results in an expansion of 0.29% in the GDP in the short-run and 0.71% in the long-run. The outcomes of the ARDL analysis demonstrated that increased ICT and FDI has a beneficial effect on India's GDP. The finding is in agreement with Veeramacheneni (2008); Nayak and Sahoo (2021); Sinha and Sengupta (2022); and Tiwari et al. (2022); who discovered that ICT and FDI enhances GDP in India.

Table 4. ARDL results over the long and short term.

Variables	Long-run			Short-run		
	Coefficient	t-Statistic	p-value	Coefficient	t-Statistic	p-value
LICT	0.564***	5.057	0.000	0.113***	4.002	0.001
LFDI	0.712***	3.099	0.000	0.291***	3.187	0.002
C	9.217	2.311	0.157	-	-	-
ECM (-1)	-	-	-	-0.592***	-3.452	0.000
R^2	0.9781					
Adjusted R^2	0.9615					

*Notes: *** denotes significance at 1% level.*

This study's evaluation of ECM is negative at the 1% level of significance. How quickly a system moves from a state of short-run disequilibrium to one of long-run equilibrium can be inferred from the magnitude and sign of the estimate of the equilibrium correlation matrix (ECM). This result demonstrates that the long-run equilibrium is reached once short-run errors are adjusted by 59 percent. Furthermore, the long-run evaluation R^2 and adjusted R^2 are 0.9781 and 0.9615, correspondingly, demonstrating that the proposed regression model fits the data remarkably well. This points out that the independent aspects can explain nearly 96% of the variability in the dependent factor. Table 5 exhibits the empirical calculations of several diagnostic statistics. To ensure uniformly distributed residuals, the Jarque-Bera test can be utilized. The Lagrange multiplier (LM) procedure was utilized in the investigation of the serial correlation issue. Model-free of serial correlation problem, as shown by the LM test result. The Breusch-Pagan-Godfrey analysis was utilized in the forecast model to investigate the heteroscedasticity issue. The conclusions of the Breusch-Pagan-Godfrey analysis designate that the predictable model does not suffer from heteroscedasticity. The model was determined to be well-founded using the Ramsey reset test.

Table 5. The findings obtained from diagnostic examinations.

Diagnostic probes	Coefficient	p-value	Decision
Jarque-Bera analysis	1.152442	0.3144	The residuals have a normal distribution.
Breusch-Godfrey LM analysis	1.239181	0.3176	There is no serial correlation
Breusch-Pagan-Godfrey analysis	1.181602	0.3648	There is no heteroscedasticity.
Ramsey RESET analysis	0.936047	0.3632	The model is precisely described

Summation cumulative of recursive residuals (CUSUM) and squares of the recursive residuals' cumulative sum (CUSUMSQ) functions were to evaluate the structural steadiness of the model in this study. The CUSUM and CUSUMQ analysis are graphically represented in Figure 2. Model parameters are stable if, for example, scatter plots don't deviate from the critical bound by more than 5%. As can be seen from the graphs, both the CUSUM and CUSUMSQ values stayed inside the allowable span of +/- 5% throughout the duration of the study.

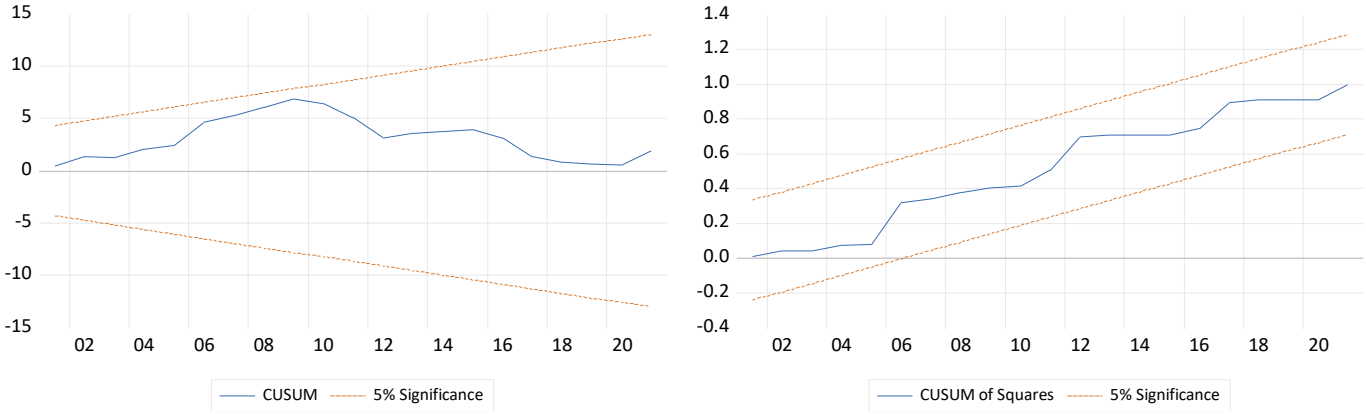


Figure 2. The findings of both the CUSUM and CUSUMQ analyses.

It is widely acknowledged that the key to generating additional employment and economic outgrowth (Raihan et al., 2022e) is the expansion of innovations connected to ICTs. It has been said that the advancement of the information and technology sector is the primary transformer of economic operation and foreign exchange (Raihan et al., 2022f; Raihan et al., 2022g). The increased use of information and communications technologies led to a reduction in the costs of correspondence, which, in turn, improved the construction of evidence and dissemination of information. The rise of information technology as a significant economic factor in developed nations is a reflection of the rapid pace at which innovations are being developed (Nayak and Sahoo, 2021; Raihan et al., 2022h). The advancement of ICTs has an impact on the progress of the economy, particularly in the areas of education, transportation, utilities, entertainment, and the dissemination of scientific information (Sinha and Sengupta 2022; Raihan et al., 2022i). The proliferation of ICT facilitates the universal exchange and distribution of concepts, and its impact can be seen in every aspect of contemporary life (Raihan et al., 2023d). Additionally, as a result of the shift in the ICT market, human development is going through a mental paradigm shift. This is the stage in the route of escalating the number of available possibilities, such as educational opportunities, safe living conditions, and high quality of life.

The advance of information technology results in an improvement in living environments and standards for the populace, a reduction in detachments, a reduction in the amount of time needed for travel and trade, the creation of opportunities for investment, and the provision of new workers (Tiwari et al., 2022; Raihan, 2023g). The liberalization of wireless carriers, the construction of information technology networks, and the authorization of major investments have all contributed to a rapid expansion of the economy (Raihan and Tuspekova, 2022h). In

addition, global warming and climate change is the burning issue of the 21st century (Raihan et al., 2018; Raihan et al., 2021a; Isfat and Raihan, 2022; Voumik et al., 2022a; Raihan and Himu, 2023) due to the atmospheric accumulation of carbon dioxide (Raihan et al., 2019; Jaafar et al., 2020; Raihan et al., 2021b; Ali et al., 2022; Raihan and Said, 2022; Raihan, 2023h). Development of ICT can help to raise awareness against environmental degradation and helps to improve the environmental quality by reducing global emissions (Raihan, 2023i).

Furthermore, the economic and social development status of the countries of Asia is currently in a very precarious state at the moment (Voumik et al., 2022b; Raihan et al., 2023e). In the past fifteen years, India has been catapulted onto the world stage as a result of the explosive growth of its ICT industry. The sector has been a driving force behind expansion across the board in the Indian financial system, consist of in the real estate, automobile, tourism and leisure industry, railroad, and credit lending commerce, to name just a few. The information and communications technology industries are swiftly mounting amid all spheres, predominantly fascinated by software expertise. It is currently responsible for the direct employment of over 2.5 million people and the indirect employment of over eight million people (Tiwari et al., 2022).

The inflow of FDI is another macroeconomic factor that shapes economic growth. Through the development of technologies and the many related fields, the accumulation of resources, and the unleashing of human ingenuity, it has a direct impact on the economy (Raihan and Tuspekova, 2022i; Raihan, 2023j). This is achieved through the financing of the current account deficit, the promotion of investment finance for multiple host markets, the creation of favorable externalities, the integration of new management capabilities across a range of sectors, and the improvement of economic performance through the creation of large numbers of jobs and government revenues (Raihan and Tuspekova, 2022j). This helps to foster the growth of the economy. It is therefore essential for consistent political and economic policies to have dynamic linkages between the expansion of industries and the influx of FDI (Sokhanvar, 2019).

India is still a popular location for foreign direct investment (FDI). The indicators of its macroeconomic environment and demographic makeup explain why it is such a desirable location for investments and why this will continue to be the case in the years to come (Raihan and Tuspekova, 2022k). In 2017, India started collecting a tax on goods and services. According to the opinions of various experts, the simplification of the indirect tax structure is a significant step towards the goal of attracting more FDI in the country. One of the most popular locations for ICT investment portfolios is India, which has become one of the most investor-friendly and attractive nations for foreign direct investment (FDI). The Indian government has liberalized foreign direct investment policies, which means that any amount can be invested in the country's ICT sector. The government has taken a variety of steps to streamline the licensing process, which has resulted in an easing of the requirements for investment.

4. Conclusions and policy implications

By utilizing data series spanning from 1992 to 2021, the objective of this analysis was to explore whether or not there is a dynamic connection between ICT and FDI and the expansion of India's GDP. The stationarity of the data was examined applying unit root tests such as ADF, DF-GLS, and P-P. Additionally, the ARDL methodology was utilized to investigate the link between the factors using both long-run and short-run scrutiny. The outcomes of the ARDL showed that an upsurge of 1% in ICT and FDI will increase GDP by 0.56 percentage points and 0.71 percentage points over the long term, in addition to 0.11% and 0.29% over the short term. The findings of the investigation can be used to establish sensible policymaking for sustainable economic development in India by advancing ICT and boosting FDI.

The findings of the study recommended that information and communications technology (ICT) should be given special emphasis for its development as a vital infrastructure of the economy. This would result in the positive effects of foreign direct investment (FDI), as well as GDP growth. To achieve the desired level of economic growth

in India, one possible solution would be to increase investments in the research and development of information and communication technologies (ICT). ICT is often referred to as the "engine of growth" and the "source of wealth creation" in the academic literature. The development of a nation's information and communications technologies (ICT) both drives and is driven by the country's overall rate of economic expansion. By adopting ICT in developing economies like India, therefore, information and communications technology policies could be formulated in such a way as to narrow the digital split that occurs between wealthy and emerging countries. If energy policies and information and communication technology policies were better coordinated, we might have a much better chance of reaching our goal.

According to the findings of the study, FDI is essential to the growth of India's GDP, and it also often sponsors to the transfer and development of cutting-edge technology in the nation that receives it. Economists are of the opinion that developing technologies and high-quality management attract domestic and foreign investment while maintaining the industry's competitiveness. In addition, external direct intervention in developing economies, in the form of labor control and opportunities for training, has brought about the introduction of substantial and positive peripheral influences to advance product manufacture. According to the findings, the government of India needs to consider taking potential actions to upgrading data technologies in order to advance economic expansion. It is crucial to enhance India's insurance and assurance policies in order to attract both domestic and international investors to the country as potential investment destinations. India has the potential to significantly boost its level of final exports while simultaneously reducing the costs of domestic production through the development of new roads, the extension of existing transport facilities, the building of new substructure, and the installation of cutting-edge machinery.

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Conflict of interest

The author claims that the manuscript is completely original. The author also declares no conflict of interest.

Author contributions

Asif Raihan: Conceptualization, methodology, data curation, visualization, formal analysis, writing

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