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Asymmetric relationships between information and communication technology (ICT), globalization, and human development in India: evidence from non-linear ARDL analysis

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Abstract

The objective of the paper is to examine the asymmetric relationships between ICT, globalization, and human development in India by analysing the annual data from 1991 to 2019 through the non-linear autoregressive distributed lag (NARDL) model. The result shows that positive (negative) change in globalization leads to a decline (increase) in human development in the long run. Further, a positive change in mobile density increases human development in the long run. A decline in internet density has a negative impact on human development in the long run. In the short run, a positive shock in globalization with one lag has a positive impact on human development. Moreover, a previous year positive shock in internet density has a positive effect on human development while the previous 2 years positive shock in internet density has a negative effect on human development in the short run. A negative shock in internet density with lag one has a negative effect on human development while with lag two it has a positive effect on human development. It is also found that the global financial crisis of 2008 has a negative impact on human development. Thus, it is suggested that India has to promote both globalization and ICT judiciously and consciously in order to improve human development.

Keywords: ICT, Globalization, Human development, NARDL

JEL Classification: O47, F00, I32, C51

1 Introduction

Since the last quarter of the twentieth century, information and communication technology (ICT) has been playing a significant role in economic development across economies in the world. It has changed the way in which people communicate with each other, how they find the required information, work, perform business activities, interact with government agencies, and how they manage their social lives (Roztocki et al. 2019). ICT also plays a major role in contributing towards the United Nations sustainable

development goals (SDGs) (Tjoa and Tjoa 2016), particularly in contributing to SDG 9.[1] Moreover, due to the big revolution in the ICT sector, a paradigm shift has been taking place in human development (Yakunina and Bychkov 2015). The revolution of ICT is considered as the main driving force for globalization (Ogunsola 2005) by promoting trade, investment, and business both domestically and internationally. It contributes to the globalization process by contributing to infrastructure for trans-world connections (Faye 2000). Globalization is important for human development because it influences its three dimensions, income, health, and education. And the interaction of globalization and ICT is considered as an important tool for human existence (Ogunsola 2005). Developing countries like India are using ICT as a powerful tool in order to eradicate poverty, reduce health hazards and mortality, and increase universal education and sustainable development (United Nations Development Programme, UNDP 2004).

India, one of the fast-growing economies in the world, is the largest exporter of ICT-related services since the 1990s. The information technology (IT) and IT-enabled services, which are the components of ICT contribute nearly eight percent to the gross domestic product (GDP) of India and provide employment opportunities to nearly four million people in 2018 (Seconded European Standardisation Expert in India, SESEI 2019). Moreover, the Government of India has launched the *Digital India* programme in 2015 to make ICTs a key policy strategy to transform the country into a digital economy by providing infrastructure, access to technology, and government services to citizens. According to a recent report of the Telecom Regulatory Authority of India (TRAI 2020), the country's total internet subscribers base and total broadband subscribers base increased to 743.19 million and 687.44 million in 2020, respectively, from 636.729 million and 563.31 million in 2019. Additionally, it is also expected that by 2025, India's core digital sectors like IT and business process management, electronics manufacturing, and digital communication services could increase the GDP level to $355–$435 billion (Kaka et al. 2019).

Despite the strong and rapid growth of the IT sector in India, people who are living in rural areas (and especially the poor people) have limited access to ICTs in terms of accessibility of internet, mobile and computer facilities for which they face the problem of incomplete/asymmetric information in their daily life (Rao 2005). Therefore, India is still lagging behind the other developed as well as developing countries in terms of ICT contribution to human development. On the other hand, there are a significant number of studies that are solely based on ICT and economic growth (Kurniawati 2021; Sahoo et al. 2021; Tripathi and Inani 2020; David and Grobler 2020; Haftu 2019; Zhang and Danish 2019; Niebel 2018; Toader et al. 2018; Ghosh 2017; Hwang and Shin 2017; Albiman and Sulong 2017; Hofman et al. 2016; Salahuddin and Alam 2016; Farhadi et al. 2012). Also, some studies like David and Grobler (2020), David (2019a, b), Asongu and Roux (2017), Gupta et al. (2019), Gholami et al. (2010), and UNDP (2004) focus on ICT and human development. Moreover, a couple of studies in literature had tried to study globalization and human development (Figueroa 2015; Cieślik 2014; Sapkota 2011; Ajija and Kusreni 2011; Tsai 2007; Sabi 2007). In India, though a large number of studies are undertaken on ICT and economic growth (Krishna et al. 2018; Erumban and Das 2016; Singh 2015; Sahoo 2012; Veeramacheneni et al. 2008) a few studies are carried out on

[1] SDG 9 includes building resilient infrastructure, promoting sustainable industrialization, and fostering innovation.

ICT and human development (Neogi 2020; Sahay and Walsham 2017; Jensen 2007). However, most of the previous studies theoretically tried to examine the relationship between ICT and socio-economic development in the process of globalization in developing countries (Simba 2004; Ogunsola 2005; Alexandru et al. 2007). A study by Simba (2004) has discussed how ICT in the wake of globalization affects the health information system (health) in developing countries. It is found that developing countries nourish their health by applying ICT with the help of globalization. Similarly, another study by Ogunsola (2005) has tried to measure how ICT affects the economies of developing countries with the help of the globalization process. In India, particularly in Bangalore, Narayana (2010) has shown the contribution of the ICT sector towards globalization and urban economic growth. But this study is limited to economic growth rather than human development.

To date, there have been no empirical studies that analyse the relationships between ICT, globalization, and human development in India. Though Narayana (2010) has undertaken a study on ICT, globalization and economic growth, it has some limitations, i.e. it takes (1) international trade and capital (FDI) to measure globalization rather KOF globalization index (which is a recent one and widely used); (2) economic growth rather human development; (3) this study is limited to one city (Bangalore) of India rather the country as a whole, and (4) time period 1980–2004 rather the latest time period. The present study has answered the relevant research questions, i.e. how does ICT through globalization affect human development in India? Does there exist any asymmetric relationships between ICT, globalization, and human development? It is also essential to know whether the increase in investment in ICT enhances the socio-economic development of India. Therefore, the objective of the paper is to examine the asymmetric relationships between ICT, globalization, and human development in India from 1991 to 2019. The originality of the paper is based on three things. Firstly, this paper has studied the relationships between ICT, globalization, and human development in India for the first time. Secondly, this paper has employed the latest method, i.e. the NARDL model which has not been adopted in the previous studies to account for the non-linear or asymmetric relationships between ICT, globalization, and human development, and thirdly, this paper has used the latest data (i.e. from 1991 to 2019) which can give an updated scenario for policymakers.

This paper is organized in the following manner: Sect. 2 analyses the stylized facts on the Indian Economy. Section 3 discusses the review of the literature on ICT, globalization, and human development. Section 4 deals with the theoretical framework. Section 5 presents the data sources and method. Section 6 includes the result and discussions while Sect. 7 concludes with some policy suggestions.

2 Some stylized facts on the Indian economy

Since the objective of the study is to examine the asymmetric relationships between ICT, globalization, and human development in India from 1991 to 2019, so it is pertinent to have some idea about the status of these variables over the period of time. Figure 1 shows the trends of mobile density (MD), internet density (ID) and KOF globalization index (KOFGI) in India. From this figure, it is clear that the MD and ID have increased at an increasing rate from 2004 onwards, but after 2011, MD has

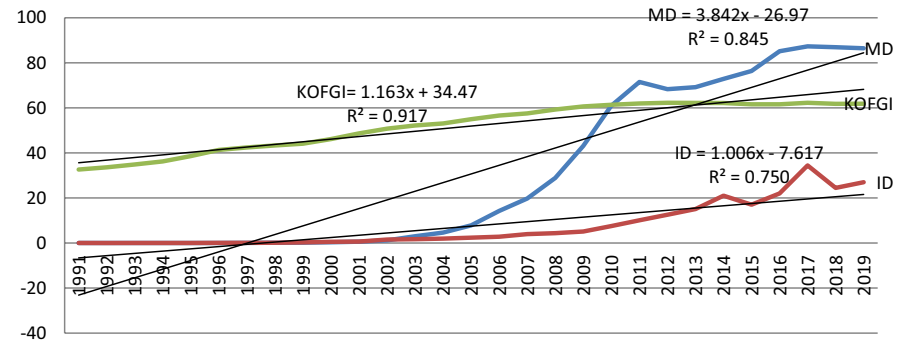

Fig. 1 Trends of mobile density, internet density, and KOF globalization index (Source: author's illustration based on WDI and ETH Zurich KOF data)

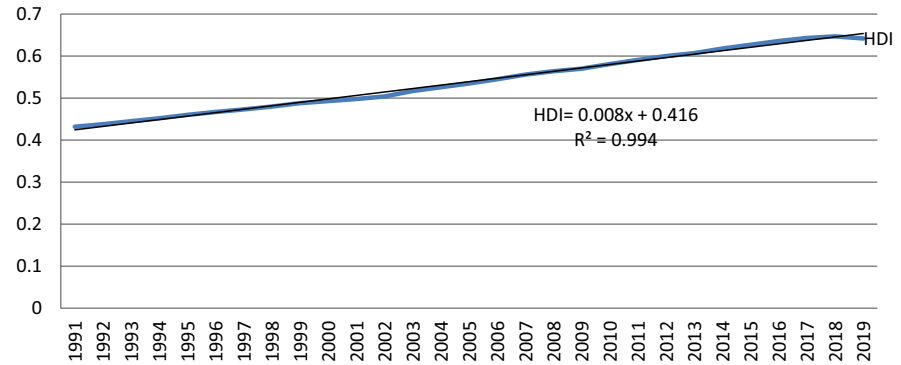

Fig. 2 Trends of human development index (Source: author's illustration based on UNDP data)

declined. It increased again from 2015 onwards. This is because of the launch of Reliance Jio SIM on 27 December 2015 which intended to provide free mobile services (cheapest data and free voice calls) to all Indians. Thus, the MD remained higher than ID. Though ID follows a fluctuating trend in recent years, i.e. from 2014 onwards, there was a sudden increase after 2015 because of the launch of the programme *Digital India* by the Government of India which provided digital infrastructure and digital empowerment to the citizens. India's performance in the globalization index has quite satisfactory but after 2008 onwards it follows a declining trend due to the 2008 global financial crisis. Figure 2 displays the trend of the human development index, and it follows an upward trend throughout the period.

The annual average growth rate (AAGR) of MD, ID, KOFGI, and HDI for certain periods, i.e. 1991–2000, 2001–2008, 2009–2019, and 1991–2019 is presented in Table 1. The AAGR of MD was negative in the period 1991–2000 which is called the new millennium period, after 2001 it was positive. But due to the global financial crisis of 2008, the AAGR of MD declined from 59.762 to 2.672 in the period 2009–2019. Similarly, the AAGR of ID has improved over the entire period 1991–2019 and subperiods. The AAGR of KOFGI was 3.945 in the period 1991–2000, and it has declined to 3.187 and 0.391, respectively, in the periods 2001–2008 and 2009–2019. Moreover, the AAGR of HDI was 1.479 from 1991 to 2000. It again increased in the period 2001–2008 and declined in the period 2009–2019.

Table 1 Average annual growth rate (AAGR) of the variables

Variables	1991–2000	2001–2008	2009–2019	1991–2019
MD	− 8.966	59.762	2.672	15.243
ID	− 21.579	− 12.494	7.965	− 7.377
KOFGI	3.945	3.187	0.391	2.332
HDI	1.479	1.697	1.187	1.427

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

3 Review of literature

As discussed earlier, India is the major hub of ICT-related services. ICTs are documented as critical tools for development because it increases productivity and economic growth by reducing transaction and communication costs (Erumban and Das 2020) and by investing in human and physical capital (Maurseth 2020). In view of this, a brief and key review of literature on ICT, globalization, and human development has been presented. The review of literature is classified into three categories, first, it has discussed the relationship between ICT and human development; second, globalization and human development, and third, ICT, globalization, and human development.

3.1 ICT and human development

Human development is a process of increasing capabilities and choices which are essential for people to lead a long and healthy life, acquire knowledge, and have access to a decent standard of living, at all levels of development (United Nations Development Programme 1990). ICT plays an important role in enhancing socio-economic development across the world (Ogunsola 2005). The use of ICT strengthens people's capabilities and their choices by enhancing access to information, communication, and network (UNDP 2005). Several studies have established the positive association of ICT with human development (Neogi 2020; Cortés and Navarro 2011; Asongu and Roux 2017; Iqbal et al. 2019; Hoz-Rosales et al. 2019; Ejemeyovwi et al. 2019; Gupta et al. 2019; Balouza 2019; Badri et al. 2019; Nosiru and Sodique 2019; Bankole et al. 2011; David and Grobler 2020). The knowledge and development report produced by World Bank (1998) has discussed the positive impact of ICT on socio-economic development. Moreover, a study by UNDP (2004) has found a positive relationship between the ICT components and HDI across all the countries of the world during two different periods (i.e. in 1991 and 2001). By taking nine countries of Asia, i.e. China, India, Indonesia, Malaysia, Mongolia, Pakistan, Sri Lanka, Thailand and Vietnam, the same result is also found by UNDP (2005). Investment in ICT enhances human development by generating employment opportunities in the service sector as well as in business and industrial activities, spreading health and health-related information, training to the medical workforce and teachers, disseminating awareness, access to education, knowledge, and training facilities. More use of television, mobile, and internet builds awareness in health, education and income (UNDP 2004). Thus, it could be concluded that ICT plays a significant role in achieving human development.

3.2 Globalization and human development

The concepts of globalization and human development are multi-dimensional. Globalization has both positive and negative impacts on human development, especially for developing countries like India. Large strands of research have found a positive relationship between globalization and human development (Sirgy et al. 2004; Sapkota 2011; Ajija and Kusreni 2011; Sabi 2007; Tsai 2007; Cieślik 2014; Badooei 2014; Kocourek et al. 2013; Tsakiri 2010; Shafeeq et al. 2019; Chhorn and Chhorn 2017; Mazlan et al. 2019; Sharma and Gani 2004; Asongu and Jacinta 2016; Figueroa 2015; Ullah and Azim 2017). On the other hand, some studies have found a negative relationship between globalization and human development (Sirgy et al. 2004; Haseeb et al. 2019; Tsakiri 2010). A recent study by Gani (2019) using exports of agricultural raw materials, fuel, ores, and high technology as the proxies for globalization, has found a positive relationship between exports of fuel, ores, and high technology and human development, but a negative relationship between exports of agricultural raw materials and human development. However, as argued by Ahmad (2005) and Haseeb et al. (2019), some factors like bad governance, corruption, and income inequality may trigger the negative relationship between globalization and human development.

3.3 ICT, globalization, and human development

Since the study on the asymmetric and dynamic relationships between ICT, globalization, and HDI is new, a conceptual analysis has been developed to analyse the relationships between the variables. The ICT affects the socio-economic development of the country through globalization. It affects globalization by influencing its three dimensions, i.e. economic, social, and political (Ogunsola 2005), i.e. an increase in trade of goods and services, investment (foreign direct investment and portfolio investment), migration, access to the internet and mobile subscriptions, human capital, international NGOs, and treaties. With the increase of globalization, there is the increase in income and employment opportunities [by working in multinational corporations (MNCs) and abroad, conducting business activities], education (by studying abroad, collaborating with foreign educational institutes, and accessing online courses), and health (by importing better medicines, health-care equipment, and medical training resulting in enhanced longevity of the population), and thereby has a positive impact on human development. This mechanism through which human development is influenced by globalization is also observed in the literature (Ogunsola 2005).

However, only some sections of the people benefit from globalization with an increase in income and employment, but it may lead to inequality (Atif et al. 2012), deprivation, massive unemployment and increase the conflicts for the other sections of people of the country. Globalization also may favour capital-intensive techniques by investing (foreign investment) more in relatively higher skill and technology-intensive sectors, which increases the demand for and wages of more skilled workers, and thereby increases their incomes, which further leads to income inequality. It is also evident from the literature that globalization leads to income inequality. By taking the period of 1995–2007 for

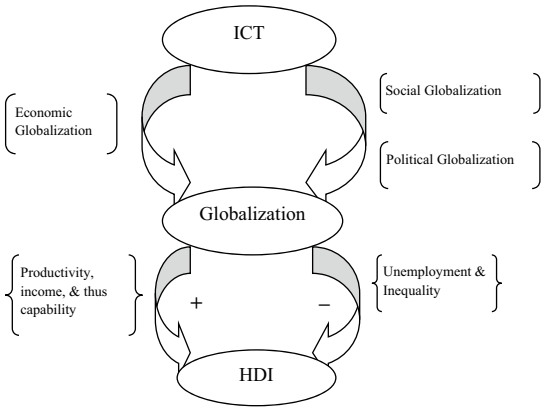

Fig. 3 Theoretical Interrelationship between the variables (Source: authors' compilation from the literature)

three different countries, i.e. developed, developing, and miracle countries, it is found that globalization leads to income inequality in developing and developed countries (Çelik and Basdas 2010). The same result is also found in the USA for the period 1980–1990 (Zhong et al. 2007) and in provinces of China (Wan 2007). On the other hand, globalization hits hard on the labour-intensive sector by saving labours through skill-biased effects that reduces employment opportunities particularly for unskilled workers. Thus, the increase in inequality and unemployment in turn reduces the human development of the country. It is also argued that the main concern in both developing and developed countries is income inequality which is related to rising globalization, and in the end it hampers the process of sustainable human development (Haseeb et al. 2019). Another study by Bjørnstad and Skjerpen (2006) which is based on Norwegian countries for the period 1972–1997 has found that globalization (measured by foreign direct investment) produces more unemployment which in turn leads to inequality and thereby hampers human development.

4 Theoretical framework

The capability approach developed by Sen (1985) is based on two normative approaches. Firstly, the freedom to achieve well-being is of utmost moral importance and, secondly, that well-being should be measured in terms of people's capabilities and functionings. Capabilities are the various combinations of functionings (i.e. beings and doings) that a person can achieve. Functionings are the various things that the person can do or be, such as beings well-nourished, getting married, being educated, and travelling. Nussbaum (2011) has given the general capability approach which consists of two clusters, i.e. first, focussing on the comparative quality of life and second, on theorizing about justice. Both clusters would be concerned with what people are able to do and be, and would hold to five principles: treating each person as an end; emphasizing choice and freedom over achievements; pluralism about values; addressing social injustices; and assigning government with responsibilities.

Table 2 Data sources and variables description

Quantitative variables	Description	Sources
HDI	Human Development Index	UNDP
KOFGI	KOF Globalization Index	ETH Zurich KOF
MD	Mobile density (mobile cellular subscription per 100 people)	WDI, World Bank
ID	Internet density—Individuals using the internet (percentage of population)	WDI, World Bank
Qualitative variables	**Description**	
TRAI	Dummy, TRAI = 1, for post-TRAI act 1997 period, and '0' otherwise	
FC	Dummy, FC = 1, for post-financial crisis period, and '0' otherwise	

Source: authors' compilation from different sources

The term human development is conceptually based on the capability approach and focuses on application. Human development denotes both the process of widening people's choices and the level of their achieved well-being. According to Sen (2010), for the expansion of human freedoms and capabilities, ICT plays an important role because it helps people to be more efficient in their work. The theoretical interrelationship between the variables which is discussed in the literature review section is expressed in Fig. 3.

5 Data sources and method

The data used for the study are secondary in nature and are collected for the period 1991–2019. The starting year for the data is 1991 because mobile density and internet density data are not available before 1991. Further, the globalization data are not available for the years 2018 and 2019, so these missing values are addressed by adopting the 3-year moving average method. The data for the independent variables such as KOF globalization index, mobile density, and internet density are collected from ETH Zurich KOF, and World Development Indicators (WDI), World Bank, respectively. The data for the dependent variable, i.e. human development index are collected from United Nations Development Programme (UNDP). During the study period, there is a major transformation of the Indian economy with the introduction of TRAI which was established in 1997 in pursuance of TRAI (Ordinance) 1997, to regulate telecommunication services (Department of Telecommunications 2020). This is considered as the period of new economy, and it affects the Indian economy. Therefore, to account for ICT policy changes, the dummy variable TRAI is introduced. Further, India was integrated with the world economy with much vigour since 1991 through its Structural Adjustment Programme (SAP) and macroeconomic stabilization policies. Therefore, India had to go through global financial crisis (FC) in 2008. To account for the effect of the global financial crisis of 2008 on the Indian economy, the dummy variable FC is introduced. The variables used for the study are described in Table 2.

5.1 Method

The variables selected for the study are based on the review of the literature. Both internet density and mobile density are used in the present study to represent the ICT, while to measure globalization and human development, Konjunkturforschungsstelle globalization index (KOFGI) and human development index (HDI) are used, respectively. Moreover, the period (1997 and after) when TRAI was introduced and the period (2008 and after) when the financial crisis (FC) took place has a significant impact on the Indian economy. Therefore, the two dummy variables with the values 1 for 'post-TRAI act 1997 period' and 0 'otherwise', and 1 for 'post-financial crisis 2008 period' and 0 for 'otherwise' are taken to capture the impact of post-TRAI act as well as the financial crisis on HDI. All the variables (except the dummy variables, i.e. TRAI and FC) are transformed into the natural logarithmic to examine the relationships between the variables. The estimation of the data is carried out by econometric software Eviews version 9.

The relationship between KOFGI, MD, ID, and HDI is expressed in the following functional form:

$$\mathrm{HDI} = f(\mathrm{KOFGI},\ \mathrm{MD},\ \mathrm{ID}) \tag{1}$$

The above functional form can be converted into a linear equation in the following form:

$$\mathrm{LnHDI}_t = \alpha + \alpha_1 \mathrm{LnKOFGI}_t + \alpha_2 \mathrm{LnMD}_t + \alpha_3 \mathrm{LnID}_t + \varepsilon_t, \tag{2}$$

where LnHDI is the outcome variable and LnKOFGI, LnMD, and LnID are the explanatory variables. In Eq. 2, the linear association is assumed between the explanatory variables and explained variables. The above equation can be converted into the following autoregressive distributed lag model (ARDL) form for estimation purpose:

$$\begin{aligned}\Delta \mathrm{LnHDI}_t = {} & \alpha + \rho \mathrm{LnHDI}_{t-1} + \beta_1 \mathrm{LnKOFGI}_{t-1} + \beta_2 \mathrm{LnMD}_{t-1} \\ & + \beta_3 \mathrm{LnID}_{t-1} + \sum_{j=1}^{p} \gamma_{1j} \Delta \mathrm{LnHDI}_{t-j} \\ & + \sum_{j=0}^{q} \gamma_{2j} \Delta \mathrm{LnKOFGI}_{t-j} + \sum_{j=0}^{r} \gamma_{3j} \Delta \mathrm{LnMD}_{t-j} \\ & + \sum_{j=0}^{s} \gamma_{4j} \Delta \mathrm{LnID}_{t-j} + \varepsilon_t.\end{aligned} \tag{3}$$

The ARDL model presented in Eq. 3 can be represented in an error correction form, which is expressed as follows:

$$\begin{aligned}\Delta \mathrm{LnHDI}_t = {} & \eta + \rho \mathrm{ECT}_{t-1} + \sum_{j=1}^{p} \gamma_{1j} \Delta \mathrm{LnHDI}_{t-j} + \sum_{j=0}^{q} \gamma_{2j} \Delta \mathrm{LnKOFGI}_{t-j} \\ & + \sum_{j=0}^{r} \gamma_{3j} \Delta \mathrm{LnMD}_{t-j} + \sum_{j=0}^{s} \gamma_{4j} \Delta \mathrm{LnID}_{t-j} + \varepsilon_t,\end{aligned} \tag{4}$$

where $\mathrm{ECT}_{t-1} = \mathrm{LnHDI}_{t-1} - \phi_1 \mathrm{LnKOFGI}_{t-1} - \phi_2 \mathrm{LnMD}_{t-1} - \phi_3 \mathrm{LnID}_{t-1}$ is the error correction term and ρ is the coefficient of error correction term. It indicates the speed of adjustment that measures how long the system would take to converge to long-run equilibrium after any shock in explanatory variables in short run (given that the estimated value is between -1 and 0). Statistical significance of ρ ensures the existence of long-run cointegration between the studied variable.

The ARDL model estimates the symmetric cointegration relationships between the variables. But in the real field or in actual situation the relationship is something different, i.e. there exists non-linear association between KOFGI, MD, ID, and HDI. In addition, in real situation, the rate or magnitude at which the response of HDI to positive change of ICT and KOFGI (increase) is different from the rate at which the response of HDI to negative change of ICT and KOFGI (decrease). In other words, there is no symmetric, i.e. asymmetric relationships exist between the explanatory variables and explained variable. Moreover, most of the variables like ICT (MD and ID), KOFGI, and HDI are non-linear in nature. Thus, the linear model may not reveal the appropriate relationship between ICT, KOFGI, and HDI. Thus, the non-linear autoregressive distributed lag (NARDL) model, which was introduced by Shin et al. (2014), is used for examining the asymmetric relationships between the ICT, KOFGI, and HDI.

The NARDL model is an extended version of the linear ARDL model (Pesaran et al. 2001). This method analyses the long-run and short-run asymmetric impact of both positive and negative components of ICT and globalization on human development. In addition, it captures the asymmetric effect of the explanatory variables on explained variable. The model can be adopted when the variables are stationary at level, i.e. I(0) or at the first difference i.e. I(1), or a mix of the two except stationary at the second difference I(2). Besides, the NARDL model allows the ARDL bounds tests approach for computing the asymmetric short-run and long-run coefficients in a cointegration framework. When there is the analysis of the cointegration relations in small samples, the NARDL model performs better (Romilly et al. 2001).

Thus, first the asymmetric long-run regression can be expressed in the following form before going into the full representation of the NARDL model:

$$\mathrm{HDI}_t = \alpha + \beta^+ \mathrm{KOFGI}_t^+ + \beta^- \mathrm{KOFGI}_t^- + \delta^+ \mathrm{MD}_t^+ + \delta^- \mathrm{MD}_t^- + \vartheta^+ \mathrm{ID}_t^+ + \vartheta^- \mathrm{ID}_t^- + e_t, \tag{5}$$

where the coefficients β^+, β^-, δ^+, δ^-, ϑ^+, and ϑ^- are the asymmetric long-run coefficients. To capture the asymmetric effect, the explanatory variables are decomposed in the following forms:

$$\left.\begin{aligned} \mathrm{KOFGI}_t &= \mathrm{KOFGI}_0 + \mathrm{KOFGI}_t^+ + \mathrm{KOFGI}_t^- \\ \mathrm{MD}_t &= \mathrm{MD}_0 + \mathrm{MD}_t^+ + \mathrm{MD}_t^- \\ \mathrm{ID}_t &= \mathrm{ID}_0 + \mathrm{ID}_t^+ + \mathrm{ID}_t^- \end{aligned}\right\}, \tag{6}$$

where KOFGI^+, KOFGI^-, MD^+, MD^-, ID^+, and ID^- are partial sum process of positive and negative changes in KOFGI, MD, and ID as follows:

$$\left.\begin{aligned}
\mathrm{KOFGI}_t^+ &= \sum_{j=1}^{t} \Delta\mathrm{KOFGI}_j^+ = \sum_{j=1}^{t} \max\left(\Delta\mathrm{KOFGI}_j, 0\right)\\
\mathrm{KOFGI}_t^- &= \sum_{j=1}^{t} \Delta\mathrm{KOFGI}_j^- = \sum_{j=1}^{t} \min\left(\Delta\mathrm{KOFGI}_j, 0\right)\\
\mathrm{MD}_t^+ &= \sum_{j=1}^{t} \Delta\mathrm{MD}_j^+ = \sum_{j=1}^{t} \max\left(\Delta\mathrm{MD}_j, 0\right)\\
\mathrm{MD}_t^- &= \sum_{j=1}^{t} \Delta\mathrm{MD}_j^- = \sum_{j=1}^{t} \min\left(\Delta\mathrm{MD}_j, 0\right)\\
\mathrm{ID}_t^+ &= \sum_{j=1}^{t} \Delta\mathrm{ID}_j^+ = \sum_{j=1}^{t} \max\left(\Delta\mathrm{ID}_j, 0\right)\\
\mathrm{ID}_t^- &= \sum_{j=1}^{t} \Delta\mathrm{ID}_j^- = \sum_{j=1}^{t} \min\left(\Delta\mathrm{ID}_j, 0\right)
\end{aligned}\right\}. \tag{7}$$

Therefore, following Shin et al. (2014) the NARDL model, which uses the positive and negative partial sum decompositions is given as follows:

$$\begin{aligned}
\Delta\mathrm{LnHDI}_t = {} & \gamma + \tau\mathrm{LnHDI}_{t-1} + \theta_1^+\mathrm{LnKOFGI}_{t-1}^+\\
& + \theta_1^-\mathrm{LnKOFGI}_{t-1}^- + \theta_2^+\mathrm{LnMD}_{t-1}^+\\
& + \theta_2^-\mathrm{LnMD}_{t-1}^- + \theta_3^+\mathrm{LnID}_{t-1}^+ + \theta_3^-\mathrm{LnID}_{t-1}^-\\
& + \sum_{j=1}^{p-1} \pi_j \Delta\mathrm{LnHDI}_{t-j}\\
& + \sum_{j=0}^{q-1} \left(\varphi_{1j}^+ \Delta\mathrm{LnKOFGI}_{t-j}^+ + \varphi_{1j}^- \Delta\mathrm{LnKOFGI}_{t-j}^-\right)\\
& + \sum_{j=0}^{q-1} \left(\varphi_{2j}^+ \Delta\mathrm{LnMD}_{t-j}^+ + \varphi_{2j}^- \Delta\mathrm{LnMD}_{t-j}^-\right)\\
& + \sum_{j=0}^{q-1} \left(\varphi_{3j}^+ \Delta\mathrm{LnID}_{t-j}^+ + \varphi_{3j}^- \Delta\mathrm{LnID}_{t-j}^-\right) + \mu_t.
\end{aligned} \tag{8}$$

The NARDL model can be represented in an error correction form, which is expressed as follows:

$$\begin{aligned}\Delta \mathrm{LnHDI}_t = {} & \gamma + \tau \mathrm{ECT}_{t-1} \\ & + \sum_{j=0}^{q-1} \left(\varphi_{1j}^{+} \Delta \mathrm{LnKOFGI}_{t-j}^{+} + \varphi_{1j}^{-} \Delta \mathrm{LnKOFGI}_{t-j}^{-} \right) \\ & + \sum_{j=0}^{q-1} \left(\varphi_{2j}^{+} \Delta \mathrm{LnMD}_{t-j}^{+} + \varphi_{2j}^{-} \Delta \mathrm{LnMD}_{t-j}^{-} \right) \\ & + \sum_{j=0}^{q-1} \left(\varphi_{3j}^{+} \Delta \mathrm{LnID}_{t-j}^{+} + \varphi_{3j}^{-} \Delta \mathrm{LnID}_{t-j}^{-} \right) + \mu_t,\end{aligned} \tag{9}$$

where

$$\begin{aligned}\mathrm{ECT}_{t-1} = {} & \mathrm{LnHDI}_{t-1} - \sigma_1^{+} \mathrm{LnKOFGI}_{t-1}^{+} - \sigma_1^{-} \mathrm{LnKOFGI}_{t-1}^{-} \\ & - \sigma_2^{+} \mathrm{LnMD}_{t-1}^{+} - \sigma_2^{-} \mathrm{LnMD}_{t-1}^{-} - \sigma_3^{+} \mathrm{LnID}_{t-1}^{+} - \sigma_3^{-} \mathrm{LnID}_{t-1}^{-}.\end{aligned}$$

μ represents the error term which independently and identically distributed with zero mean and constant variance. Similarly, p and q represent the lag orders. The long-run asymmetric effects of the explanatory variables on explained variable can be estimated by $\sigma_1^{+} = -\frac{\theta_1^{+}}{\tau}$, $\sigma_1^{-} = -\frac{\theta_1^{-}}{\tau}$, $\sigma_2^{+} = -\frac{\theta_2^{+}}{\tau}$, $\sigma_2^{-} = -\frac{\theta_2^{-}}{\tau}$, $\sigma_3^{+} = -\frac{\theta_3^{+}}{\tau}$, and $\sigma_3^{-} = -\frac{\theta_3^{-}}{\tau}$ while the short-run asymmetric effects can be estimated by $\sum_{j=0}^{q-1} \varphi_j^{+}$ and $\sum_{j=0}^{q-1} \varphi_j^{-}$. By incorporating the dummy variables into the NARDL model can be expressed as follows:

$$\begin{aligned}\Delta \mathrm{LnHDI}_t = {} & \gamma + \tau \mathrm{ECT}_{t-1} + \sum_{j=0}^{q-1} \left(\varphi_{1j}^{+} \Delta \mathrm{LnKOFGI}_{t-j}^{+} + \varphi_{1j}^{-} \Delta \mathrm{LnKOFGI}_{t-j}^{-} \right) \\ & + \sum_{j=0}^{q-1} \left(\varphi_{2j}^{+} \Delta \mathrm{LnMD}_{t-j}^{+} + \varphi_{2j}^{-} \Delta \mathrm{LnMD}_{t-j}^{-} \right) \\ & + \sum_{j=0}^{q-1} \left(\varphi_{3j}^{+} \Delta \mathrm{LnID}_{t-j}^{+} + \varphi_{3j}^{-} \Delta \mathrm{LnID}_{t-j}^{-} \right) + \rho_1 \mathrm{TRAI} + \rho_2 \mathrm{FC} + \mu_t.\end{aligned} \tag{10}$$

Some steps need to be followed before and after applying the NARDL model: first the stationary of variables should be checked through different unit root tests, and the variables must be either stationary at level or first difference or both. Second, estimate the NARDL model. Third, after estimation of NARDL model, there is a need to test the cointegration between the variables, i.e. to test the existence of long-run relations through the NARDL bounds test and NARDL cointegration approach. Fourth, after confirmation of the cointegration between the variables, then the long-run and short-run asymmetric relationship need to be tested through Wald test. The Wald test measures whether the difference between the coefficients of positive and negative variations is significant in the long run and short run and is given as follows:

Null hypothesis (H_0): $\sigma_i^{+} = \sigma_i^{-}$ (no long-run asymmetric relationship).
Alternative hypothesis (H_1): $\sigma_i^{+} \neq \sigma_i^{-}$ (long-run asymmetric relationship exists).
Null hypothesis (H_0): $\sum_{j=0}^{q-1} \varphi_j^{+} = \sum_{j=0}^{q-1} \varphi_j^{-}$ (no short-run asymmetric relationship).

Alternative hypothesis (H_1): $\sum_{j=0}^{q-1} \varphi_j^+ \neq \sum_{j=0}^{q-1} \varphi_j^-$ (short-run asymmetric relationship), where i and $j = 1, 2, \ldots, n$.

Fifth, NARDL dynamic multiplier graph can be used to examine the pattern of adjustment of the explained variable to its new long-run equilibrium following the positive and negative shocks, as follows:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{KOFGI}_t^+},\ m_h^- = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{KOFGI}_t^-},\ m_h^+ = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{MD}_t^+},\ m_h^- = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{MD}_t^-},$$

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{ID}_t^+}, m_h^- = \sum_{j=0}^{h} \frac{\partial \mathrm{HDI}_{t+j}}{\partial \mathrm{ID}_t^-},\ \text{for } h = 0, 1, 2, \ldots,$$

where if $h \to \infty$, then $m_h^+ = \sigma_i^+$, and $m_h^- = \sigma_i^-$.

Lastly, the residual tests should be carried out to test the validity of the model before the results are finally interpreted to draw any relevant conclusion.

For the purpose of robustness check, the present paper has used the Gregory–Hansen test for cointegration with regime shifts. Since there may exist structural breaks in the variables, the use of bounds testing method for cointegration may give inconsistent results. Therefore, in order to address the issue, this paper uses the technique developed by Gregory–Hansen (1996) test for cointegration. This model is now widely used in the literature (Amarasekara et al. 2022; Udeagha and Ngepah 2021; Hassoun et al. 2021).

6 Results and discussion

Before examining the asymmetric relationship between the variables, it is essential to describe the characteristics of the variables and their correlation which are shown in Table 3. The mean per capita of HDI, KOFGI, MD, and ID in India during 1991–2019 are −0.626, 3.928, 1.072, and −0.315, respectively. Besides this, KOFGI and HDI are highly and positively correlated with each other with a correlation coefficient 0.949. Similarly, MD and ID are also highly and positively correlated with HDI at the coefficients 0.963 and 0.915, respectively.

The unit root tests like Augmented Dicky–Fuller (ADF) (1981), Philips–Perron (PP) (1988), Kwiatkowski–Phillips–Schmidt–Shin (KPSS) (1992), and Ng–Perron (2001) are presented in Tables 4 and 5. A perusal of the tables reveals that KOFGI, MD and ID are stationary at first difference as per the ADF and PP tests while all the variables are stationary at level by KPSS test. But according to Ng–Perron test, HDI is stationary at first difference while other variables are stationary at level. One of the limitations of the conventional tests is that they neglect the existence of structural breaks in the variables. Since it is expected that the time series data may contain structural breaks, this paper uses Lee and Strazicich (2003) LM unit root test and Zivot–Andrews (ZA) (1992) unit root test with single structural break. The results of these two tests are shown in Table 6. It is found in Table 6 that all the variables are stationary at level by Lee and Strazicich test. According to ZA test, KOFGI and ID are stationary at first difference while HDI is

Table 3 Descriptive statistics and correlation between the variables

Variables	Mean	Standard deviation	Minimum	Maximum	Skewness	Kurtosis	Correlation with HDI
HDI	−0.626	0.130	−0.839	−0.435	−0.039	1.689	
KOFGI	3.928	0.216	3.485	4.131	−0.734	2.161	0.949[a]
MD	1.072	3.278	−4.834	4.470	−0.399	1.562	0.963[a]
ID	−0.315	3.711	−9.103	3.540	−1.140	3.203	0.915[a]

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

[a] Implies correlation is significant at 1% level

Table 4 Unit root test results

Variables	ADF			PP			KPSS		
	Level	1st difference	Inferences	Level	1st difference	Inferences	Level	1st difference	Inferences
LnHDI	0.060	−1.442		0.357	−1.441		0.110	0.178	I(0)
LnKOFGI	−0.050	−4.755*	I(1)	2.600	−3.883**	I(1)	0.186	0.500*	I(0)
LnMD	−0.863	−5.472*	I(1)	−1.075	−5.472*	I(1)	0.192	0.138	I(0)
LnID	−1.132	−5.199*	I(1)	−0.211	−5.821*	I(1)	0.190	0.178	I(0)

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

The value of ADF for 1%, 5% and 10% are −4.339, −3.588, and −3.229, respectively

The value of PP for 1%, 5% and 10% are −4.324, 3.581, and −3.225, respectively

The value of KPSS for 1%, 5% and 10% are 0.216, 0.146, and 0.119, respectively

* and ** imply significant at 1% and 5%, level, respectively

stationary at level. This implies that none of the variables are stationary at second difference, so the NARDL model can be estimated.

The result of the NARDL model with and without dummy variables is shown in Table 7. By taking without dummy variables, it is found that the previous year shocks in HDI have a positive impact on HDI. By taking with dummy variables, it is found that the previous 2-year shocks in HDI have a positive impact on HDI. A positive (negative) shock in globalization leads to a decline (increase) in human development by 0.342 percent (5.678 percent) in the long run. The result is consistent while incorporating the dummy variables. The negative effect of globalization on human development is supported by the literature (Sirgy et al. 2004; Haseeb et al. 2019; Tsakiri 2010). This may be due to the fact that globalization favours capital-intensive techniques by investing more in relatively higher skill and technology-intensive sectors, which increases the demand for and wages of more skilled workers, which leads to income inequality (Dreher and Gaston 2008; Zhu and Trefler 2005; Çelik and Basdas 2010; Zhong et al. 2007), and thereby reduces human development (Haseeb et al. 2019; Wicaksono et al. 2017). It is also argued in the literature that the main concern in both developing and developed countries is income inequality which is due to rising globalization and it impedes the human development (Haseeb et al. 2019).

Moreover, a positive shock in mobile density increases human development (with the coefficient 0.013 and 0.015) by taking without and with dummy variables. In other words, an increase in mobile density increases human development. A negative shock in internet density reduces human development in the long run by taking without dummy

Table 5 Ng–Perron test results

Variables	MZa		MZt		MSB		MPT		Inference
	Level	1st difference	Level	1st difference	Level	1st difference	Level	1st difference	
LnHDI	−214.459	−8.906*	−10.167	−1.585*	0.047	0.178*	0.914	11.866*	I(1)
LnKOFGI	−11.812*	−26.400	−2.260*	−3.632	0.191*	0.138	8.567*	3.457	I(0)
LnMD	−3.024*	−13.053*	−1.038*	−2.547*	0.343*	0.195*	25.488*	7.023*	I(0)/ I(1)
LnID	−4.174*	−9.505*	−1.320*	−2.178	0.316*	0.229*	20.539*	9.595*	I(0)/ I(1)
Critical values:	1%	−23.800	−3.420		0.143		4.030		
	5%	−17.300	−2.910		0.168		5.480		
	10%	−14.200	−2.620		0.185		6.670		

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

* implies significant at 1% level, respectively

Table 6 Lee and Strazicich (2003) LM unit root test (one-break) and Zivot–Andrews structural break unit root test results

Variables	Lee and Strazicich LM unit root test				Zivot–Andrews unit root test		
	t-statistic	Break points	Lags	Inferences	Level	1st difference	Inferences
LnHDI	−6.392**	2009	8	I(0)	−10.470*	−4.746	I(0)
LnKOFGI	−9.226**	2003	8	I(0)	−3.707	−8.722*	I(1)
LnMD	−15.078**	2009	7	I(0)	−1.435	−3.379	
LnID	−7.815**	2004	7	I(0)	−2.730	−5.581*	I(1)

Source: author's calculations

The value of Zivot–Andrews for 1%, 5% and 10% are −5.57, −5.08, and −4.82, respectively

* and ** imply significant at 1% and 5% level, respectively

variables. This is because in recent years the internet has become the major driver of human development by connecting people in remote locations to markets, increasing access to education and health care facilities, enhancing productivity through innovation, enabling access to information, and increasing citizens' participation in the democratic process (Guerriero 2015). Therefore, a reduction in internet density is detrimental to human progress. Aksentijević et al. (2021) found that ICT enhances human development in lower-middle-income and low-income countries through giving access to information to the individuals, facilitating access to education and health care, and creating business opportunities. Ejemeyovwi et al. (2019) argued that internet usage plays a significant role in improving human development in 15 Economic Community of West African States (ECOWAS). However, the ICT penetration has both positive and negative societal effect as evident from the literature (Forte et al. 2021; UNCTAD 2011; Gunduz 2007; Quaglio and Millar 2020) and a summary of the details is reported in Appendix.

In the short run, a previous year negative shock in globalization has a positive impact on human development, whereas the previous 2 years negative shocks in globalization have a negative impact on human development by taking without dummy variables. A positive shock in globalization with one lag has a positive impact on human development

Table 7 Results of NARDL model

Variables	Without dummy variables		With dummy variables	
	Coefficients	Probability	Coefficients	Probability
LnHDI (− 1)	0.479* (0.153)	0.017	0.314 (0.178)	0.137
LnHDI (− 2)	0.247 (0.144)	0.129	0.514** (0.205)	0.054
Long run				
LnKOFGI_POS	− 0.342* (0.065)	0.001	− 0.423* (0.082)	0.004
LnKOFGI_NEG	− 5.678** (2.220)	0.038	− 1.862 (2.922)	0.552
LnMD_POS	0.013** (0.006)	0.058	0.015** (0.005)	0.037
LnMD_NEG	0.001 (0.005)	0.907	0.001 (0.005)	0.843
LnID_POS	0.004 (0.004)	0.282	0.005 (0.003)	0.135
LnID_NEG	0.137** (0.048)	0.023	0.061 (0.061)	0.361
Short run				
LnKOFGI_POS (− 1)	0.148 (0.086)	0.131	0.153*** (0.077)	0.104
LnKOFGI_NEG (− 1)	− 5.741** (2.093)	0.029	− 2.141 (2.757)	0.473
LnKOFGI_NEG (− 2)	47.662*** (22.563)	0.073	8.919 (29.698)	0.776
LnMD_POS (− 1)	0.009 (0.006)	0.203	0.009 (0.005)	0.148
LnMD_POS (− 2)	− 0.003 (0.003)	0.416	− 0.005 (0.003)	0.164
LnMD_NEG (− 1)	0.008 (0.005)	0.159	0.007 (0.004)	0.138
LnID_POS (− 1)	0.008** (0.003)	0.043	0.007** (0.003)	0.052
LnID_POS (− 2)	− 0.010* (0.002)	0.004	− 0.008** (0.003)	0.054
LnID_NEG (− 1)	0.151* (0.046)	0.013	0.080 (0.056)	0.208
LnID_NEG (− 2)	− 2.234*** (1.061)	0.073	− 0.410 (1.396)	0.781
C	− 2.984*** (1.427)	0.075	− 0.490 (1.890)	0.806
TRAI dummy			− 0.008 (0.010)	0.462
FC dummy			− 0.005*** (0.002)	0.077
Diagnostics result	R^2		0.99	0.99
	F statistics		6095.052	7811.157
	Probability		0.000	0.000
	Durbin–Watson test statistic		2.311	2.476
NARDL bounds test (null hypothesis: no long-run relationships exist)				
F statistics	7.814*			
Critical value bounds	Significance		I 0 Bound	I 1 Bound
	1%		3.15	4.43
	2.5%		2.75	3.99
	5%		2.45	3.61
	10%		2.12	3.23

NARDL cointegration and long-run form

Variables	Coefficients	Probability
Coint Eq (− 1)	− 0.274* (0.053)	0.001
Long run		
LnKOFGI_POS	− 0.709 (0.448)	0.158
LnKOFGI_NEG	132.312** (55.265)	0.048
LnMD_POS	0.068** (0.023)	0.022
LnMD_NEG	0.031 (0.020)	0.172
LnID_POS	0.009 (0.009)	0.336
LnID_NEG	− 7.104** (2.896)	0.044
C	− 10.894** (4.160)	0.035

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

*, **, and *** imply significant at 1%, 5%, and 10% level, respectively

Table 8 Long-run and short-run asymmetric test (Wald test)

Variables	Long-run asymmetry		Short-run asymmetry	
	χ^2	Probability	χ^2	Probability
LnKOFGI	3.251***	0.071	4.155**	0.042
LnMD	3.080***	0.079	0.044	0.833
LnID	3.955**	0.047	4.175**	0.041

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

** and *** imply significant at 5% and 10% level, respectively

with a coefficient of 0.153 by taking with dummy variables. Similarly, a short-run previous year positive shock in internet density has a positive effect on human development while the previous 2 years positive shocks in internet density have a negative impact on human development by taking with and without dummy variables. The reason behind the negative relationship between the previous 2 years positive shocks in internet density and human development may be due to the high initial cost in the development of infrastructure for providing internet services (Tripathi and Inani 2016). A negative shock in internet density with lag one has a negative effect on human development while with lag two it has a positive effect on human development by taking without dummy variables. It is also found that the post-global financial crisis 2008 has a negative impact on the human development. Moreover, there exist the long-run relationships between MD, ID, KOFGI, and HDI confirmed by the NARDL bounds test.[2] The cointegration equation coefficient (−0.274) is also negative and significant, this implies that there are long-run relationships between the variables.

The long-run and short-run asymmetric relationships are evaluated in Table 8 by using Wald test. The result reveals the long-run asymmetric relations between positive shocks and negative shocks in KOFGI, MD, and ID. In addition, there exist short-run asymmetric relationships between positive and negative shocks of KOFGI and ID. But, in the case of MD, it shows short-run symmetric relationship between positive and negative shocks.

The NARDL dynamic multiplier graph is illustrated for KOFGI, MD, and ID in the respective diagrams. Figure 4 reveals that the negative globalization shocks are high in comparison to positive globalization shocks on human development. Similarly, the positive shocks in mobile density and internet density are high on human development compared to the negative shocks in mobile density and internet density and are shown in Figs. 5 and 6.

Some residual tests like Breusch–Pagan–Godfrey (BPG) test for heteroscedasticity, LM test for serial correlation, Jarque–Bera (JB) test for normality, and the correlogram residual squared are conducted to validate the results of the NARDL model. As

[2] If the calculated F-statistic of the model exceeds the upper bound critical value, then the null hypothesis of long-run cointegration relationship between the variables will be rejected. Alternatively, if it falls below the lower bound critical value, then the null hypothesis will be failed for rejection. And, if the calculated F-statistic value falls within the bounds, the test is inconclusive.

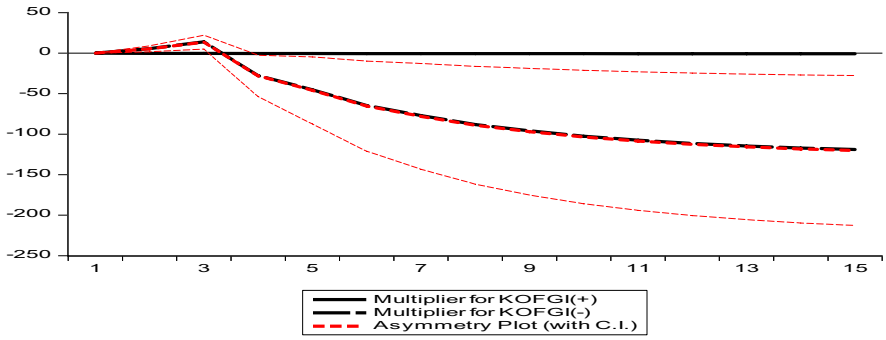

Fig. 4 NARDL dynamic multiplier graph for KOFGI (Source: authors' illustration from UNDP, WDI, and ETH Zurich KOF data)

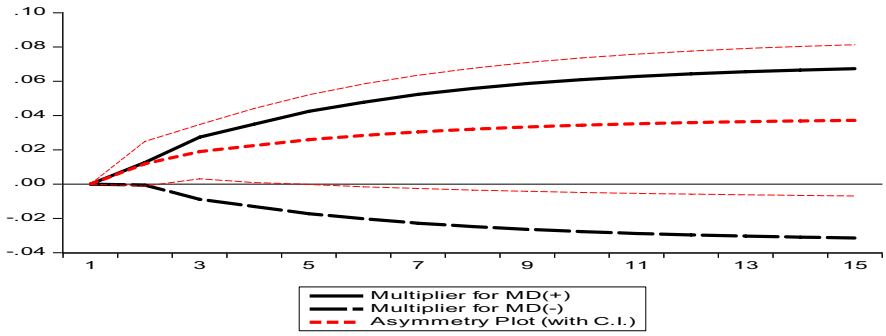

Fig. 5 NARDL dynamic multiplier graph for MD (Source: authors' illustration from UNDP, WDI, and ETH Zurich KOF data)

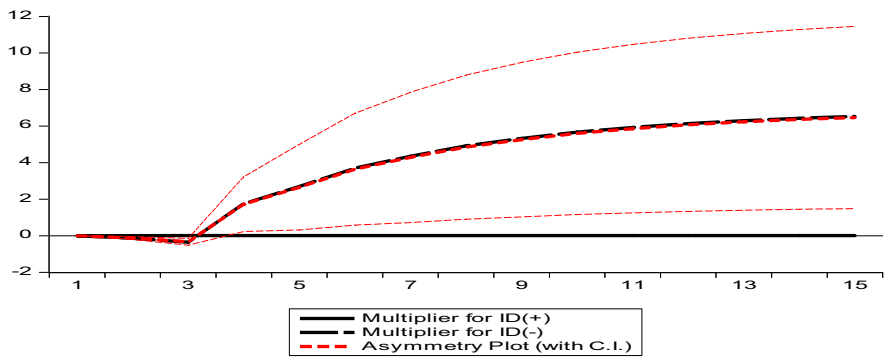

Fig. 6 NARDL dynamic multiplier graph for ID (Source: authors' illustration from UNDP, WDI, and ETH Zurich KOF data)

Table 9 Residual tests

Test	Test-statistics	Probability
BPG test for heteroscedasticity	0.334	0.971
LM test for serial correlation	0.116	0.893
Jarque–Bera test for normality	12.755	0.002

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

Table 10 Residual tests (correlogram)

Autocorrelation	Partial correlation		AC	PAC	Q-Stat	Prob*
. | . |	| . |	1	−0.057	−0.057	0.0941	0.759
. *| . |	. *| . |	2	−0.136	−0.139	0.6524	0.722
. |**. |	. |**. |	3	0.336	0.326	4.2203	0.239
. |* . |	. |* . |	4	0.120	0.148	4.6980	0.320

Source: authors' estimation from UNDP, WDI, and ETH Zurich KOF data

*Probabilities may not be valid for this equation specification

Table 11 Results of Gregory–Hansen test for cointegration with regime shifts

Test	Test statistics	Breakpoint	Date	Asymptotic critical values		
				1%	5%	10%
ADF	−7.03[a]	14	2004	−6.51	−6.00	−5.75
Zt	−5.74	11	2001	−6.51	−6.00	−5.75
Za	−30.92	11	2001	−80.15	−68.94	−63.42

[a] Implies significant at 1% level

Source: author's calculations

shown in Table 9, the model is free from the problem of heteroscedasticity and serial correlation but is not normally distributed and the correlogram residual squared confirms no autocorrelation and partial correlation problems (Table 10).

6.1 Robustness check

As mentioned earlier, there exists structural breaks in the variables which is confirmed by the Lee and Strazicich and Zivot–Andrews unit root tests. Further, the Chow test[3] is conducted to confirm the evidence of structural breaks in the model and the timing of the structural break is found at 2003. Since the presence of structural break in the variables has been established, the present study conducts a cointegration test to confirm whether these variables have a long-run relationship. Therefore, the Gregory–Hansen test for cointegration with regime shifts is used in the study and is presented in Table 11. The table shows that the variables under investigation are cointegrated at the breakpoint. This implies that the result is robust and consistent with the cointegrating relationship established earlier assuming no structural break.

7 Conclusion and policy suggestions

This paper investigates the asymmetric relationships between ICT, globalization, and human development in India from 1991 to 2019 by using the NARDL model. It is found that in the long run the positive (negative) changes in globalization have a negative (positive) effect on human development, consistent with the literature. In the

[3] The Chow test result can be provided upon request.

long run, a positive change in mobile density has a positive impact on human development. Moreover, a decline in internet density has a negative impact on human development in the long run. In the short run, a negative change in globalization with one lag has a positive effect on human development whereas with lag two it has a negative effect on human development. A positive change in globalization with one lag has a positive impact on human development. In addition, the positive change in internet density with lag one has a positive impact on human development while with lag two it has a negative impact on human development in the short run. The reason behind the negative relationship between the previous 2 years positive shocks in internet density and human development may be due to the high initial cost in the development of infrastructure for providing internet services (Tripathi and Inani 2016). A negative shock in internet density with lag one has a negative effect on human development while with lag two it has a positive effect on human development.

However, the global financial crisis has a negative impact on human development in the study. Since the effect of the global financial crisis is realised due to the integration of the Indian economy with the world economy, India needs to promote globalization judiciously and cautiously.

From the cointegration equation, it is also confirmed that there exists a long-run relationships between ICT, globalization, and human development. The robustness of the result is also verified by the Gregory–Hansen test for cointegration with regime shifts which found the cointegrating relationship between the variables in the presence of structural breaks. On the other hand, it is also found that there is both short-run and long-run asymmetric relationships between the variables except mobile density in the short run through the Wald test. In addition, the result also shows that the effect of positive components of mobile density and internet density is high than the effect of negative components of mobile density and internet density on human development. Similarly, the effect of negative components of globalization is high on human development than the effect of positive components of globalization.

It is suggested from the above findings that the Government of India needs to promote ICT, particularly internet use and globalization more cautiously in order to improve the human development of the country.

Appendix

See Table 12.

Table 12 Summary table on positive and negative societal impacts of ICT penetration

Positive impacts	Negative impacts
ICT enhances the educational benefits of the students by offering resources for the teaching and learning process as well as the skills required in a society (UNCTAD 2011)	ICT causes stress, anxiety, depression, sleeping disorder, internet addiction, and modern diseases (obesity, diabetes, and cardiovascular disease) (Gunduz 2007; Quaglio and Millar 2020; Johnson 2020)
ICT in forms of electronic health records (e-health), m-health (use of mobile phones for health purposes), telemedicine, e-learning, and e-journals improves health care facilities for the people (UNCTAD 2011)	Recycling e-waste which is produced from e-health-related activities has adverse health impacts (UNCTAD 2011)
ICT in terms of e-government facilitates democratic processes and increases the participation of citizens (e-voting) through the use of e-mail, social networking sites, and mobile phones (UNCTAD 2011)	Overuse of the internet such as engaging in online games, watching and spreading images of pornography, cyberbullying, hacking, e-fraud, e-crime, copyright infringement, and security and privacy concerns negatively affect individuals and communities (Ogbuabor 2017; UNCTAD 2011)
ICT saves time and money through online shopping, e-banking, e-tourism, social media, and e-government (UNCTAD 2011)	ICT in the form of e-commerce removes the unskilled workers from the e-commerce economy and gives more preference for an expert system like robots in some industries (the automobile manufacturing industry) (Ogbuabor 2017)
ICT has a potential impact on the empowerment of women, minorities, and socially disadvantaged groups through their electronic access to relevant public information on rights and benefits (World Bank 2009)	More use of the internet also gives rise to the risk of isolation from society (Gunduz 2007; Quaglio and Millar 2020)
It makes transportation easier for the people through online booking of tickets, online payment, detailed information about travel, communication with travel patterns, and safety and security	It becomes difficult for people who are digitally illiterate and not skilled in booking tickets and making payments online. In other words, it widens the digital divide
ICT in the forms of the internet, remote sensing, geographical information system (GIS), and satellite-based communication systems prevents and mitigates natural calamities through forecasting (Rao 2020)	It leads to loss of privacy (Ing and Rodrik 2022)
ICT in the form of mobile applications prevents suicide through monitoring depressive symptoms and suicidal ideation through the use of text messages, social media posts and telepsychiatry (Forte et al. 2021)	Social media increases suicide risk factors and suicide-related behaviours

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