Leapfrogging into knowledge economy: Information and communication technology for human development

Anushka Verma
Birla Institute of Technology and Science, India
p20190069@pilani.bits-pilani.ac.in

Arun Kumar Giri
Birla Institute of Technology and Science, India

Byomakesh Debata
Birla Institute of Technology and Science, India

Abstract

Modern-day economic growth is focused on productivity and innovation, which puts information and technology integral to economic policy issues. In this context, ICT has a significant position as it increases efficiency, promotes information dissemination, and enhances innovation, resulting in a global shift in social and human development processes. The purpose of this research is to examine the significance of ICT diffusion in fostering human development in the South Asian Association for Regional Cooperation (SAARC) countries from 2005 to 2019. ICT diffusion is measured using a principal component analysis (PCA)-based composite index that combines telephone, mobile, broadband, and internet usage. The United Nations Development Programme (UNDP) created Human Development Index (HDI) serves as a proxy for human development. To adjust for any confounding bias, macroeconomic indicators, such as gross domestic product (GDP), inflation, and trade are also included. Utilizing econometric methods robust to cross-sectional dependence (CSD) such as the dynamic common correlated effect (DCCE) estimator, Driscoll-Kraay (DK) regression, and the Dumitrescu-Hurlin (DH) causality test, the study highlights the strong positive relationship between ICT and HDI. In addition, GDP boosts HDI owing to productivity gains. Similarly, trade expansion, in addition to its direct effects, also influences HDI by boosting economic growth. Inflation, on the other hand, has a negative impact on the HDI. Consequently, the study recommends a cohesive setting that unifies ICT with human development in this modern framework.

Keywords: Human Development, ICT diffusion, DCCE, DK regression, SAARC.

1 Introduction

The world has become a globalized community over the course of the last few decades, owing to the transformative power of information, which has enabled the development of more substantial and faster forms of connectivity than ever before (Schwab, 2018). ICTs and global trade and industry shifts toward technology, services, and human resources have resulted in this information being dispersed around the globe. Policymakers in low-income countries are devising strategies to take advantage of the social and economic benefits of “information revolution” transforming their economies into the “knowledge economy” (World Bank, 2007). This includes many labels such as "knowledge society," "information economy," "information society," and "digital economy." In contrast to the concentration on the main sectors of the economy in previous decades, these words stress the increasing reliance on ICT and human resources. ICTs are viewed as a double-edged sword in the pursuit of long-term sustainable growth while also addressing ecological concerns (Asongu & Le Roux, 2017). Advancements in ICTs have had a profound effect on every facet of society, from infrastructure to transportation, businesses to service, education to culture, and entertainment to art (Lee et al., 2017).

Until the mid-twentieth century, income was regarded as a significant aspect of economic growth; however, the reliance steadily transitioned towards human development and technological innovation (Asongu & Le Roux, 2017). Human skills and abilities, in the context of human development, are viewed as complementary inputs in any country's production and development processes (Mustafa et al., 2017). It encompasses a diverse array of choices which includes healthy life, improved standard of living, and increased per capita income (Yakunina & Bychkov, 2015). In recent years, ICTs have spread to practically all aspects of human activity (Latif et al., 2017). Additionally, ICTs boosts both the productivity and economic growth, as well as human development and welfare, in both developing and developed countries (Farooqi et al., 2020).

The impact of ICTs extends beyond economic growth to human capital development in both developing as well as developed economies. The South Asian Association for Regional Cooperation (SAARC) is blessed with a plethora of natural resources yet has had declining GDP rate in the past few years. Almost all the countries in this region share the same culture and a similar economic, social, and geopolitical situation. More than a quarter (24.89 percent) of the world's population lives in the SAARC region, which cover 3.5 percent of the planet's area. According to the United Nations, the population of South Asia is predicted to grow between 0.4 and 1.9 percent by 2050 (Mohsin et al., 2018). SAARC has a cumulative GDP of $2.6 trillion (Abbas et al., 2018). With respect to the life expectancy, Sri Lanka has the highest rate in the world at 70 years. While in the rest of the SAARC economies, the average life expectancy is between 62 and 63 years old. Moreover, a closer look at the SAARC's public expenditure priorities reveals that countries in this region spend only 3 to 5 percent of the GDP on health and education (Lee et al., 2017). As per the global competitiveness index with respect to ICT adoption, Nepal leads the area with 40.4 points, followed by Bangladesh with 39.9 points, Sri Lanka with 32.9 points, India with 28 points, and Pakistan with 23.6 points (Pradhan et al., 2018). Contemporary research endorses SAARC as the region with sufficient opportunity for an investments in ICT domains in the current environment (Latif et al., 2017).

However, we must acknowledge that ICT adoption is not always easy, particularly for the developing economies. Effective ICT diffusion requires an active role of the government, given the various socio-cultural, infrastructural, economic, and technological constraints. On the other hand, the paucity of relevant local digital content is also challenging for ICT diffusion. There also exist certain prerequisites to ICT adoption which are merely obtainable in developing countries like that of SAARC where a substantial part of the inhabitants relies on agriculture income, suffer from low literacy, and low per capita income. Therefore, the above socioeconomic factors highlight the below average human development and ICT diffusion rate. As a result, research and investigation into techniques and strategies to promote the expansion of ICTs and human development within the SAARC economies is crucial.

In light of the above discussion that ICTs are critical to human development, the present study examines the influence of ICT diffusion on human development within the SAARC countries. Our research adds to the current literature in the following manner: First, to the best of the authors' information, this is the first research in the SAARC context to empirically evaluate the dynamic relationship and causality nexus between ICT diffusion and human capital development while also incorporating the impact of economic growth, inflation, and trade openness in a unified framework. Second, the study makes use of the most recent and extensive dataset available and constructed an index of ICT diffusion using principal component analysis (PCA) rather than focusing exclusively on a single ICT indicator. Finally, the study addresses the issue of cross-sectional dependence (CSD), which is often disregarded in the existing body of research on ICT. Therefore, the present study employs the Dynamic common correlated effect mean group (DCCE-MG) estimator introduced by Chudik and Pesaran (2015) and the Driscoll-Kraay (DK) standard error approach of Driscoll and Kraay (1998) which accounts for CSD and provides heteroskedasticity and autocorrelation-consistent standard errors.

The remaining paper is structured in this manner. Section 2 includes the theoretical basis and a brief analysis of relevant literature. Section 3 discusses the materials and methods used. The empirical results have been presented in Section 4. Section 5 discusses the theoretical and practical implications of the study and Section 6 concludes.

2 Literature Review

This section presents the theoretical framework and a brief review of the literature. The first section will cover the theoretical underpinnings. The second section will provide an overview of past research on ICT diffusion and human capital development.

2.1 Theoretical framework

The classical theory of economic growth has been supplanted in the existing literature by the theory of human development. The foundation of the classical theory was set up on the phenomenon of the gross national product (GNP), which is the combined value of all the goods as well as the services produced by the country at a given time period (Khodabakhshi, 2011). According to the neo-classical growth model (Solow, 1956), long run economic growth is contingent on exogenous factors such as technological advancement and populace expansion (Donou-Adonsou, 2019). In contrast to the Solow growth model, which sees technological revolution as an exogenic factor, the new growth model views it as an internal driver of growth. According to Alfaro et al. (2008), technological advancement is contingent on human development, and the combination of the two results in economic progress (Sepehrdoust & Ghorbanseresht, 2019). According to the new growth model proposed by Romer (1990), innovation has an impact on technological progression, which in turn has an impact on economic growth and human capital development (Pradhan et al., 2016).

Contemporary growth models accentuate the function of ICT diffusion in human capital development and its significance for economic growth in the long run (Balouza, 2019; Makoza & Chigona, 2013). The ICT literature is highlighted by significant advancements in human competencies, improvements in health conditions, and longer lifespan (Lee et al., 2017; Mora-Rivera & García-Mora, 2021; Yakunina & Bychkov, 2015). ICT is regarded as the core of human advancement because it not only contributes to growth but also improves the quality of life of the population (Thomas, et al., 2011). In the current age, ICT serves as both an input and an output i.e. by reducing market coordination costs and by enhancing public services like healthcare and education using e-services (Hwang & Shin, 2017). Individuals now have new options for a healthier lifestyle thanks to medical applications (Mosa et al., 2012). ICTs, such as personal computers and electronic whiteboards have since been implemented in classrooms to bring about substantial improvements in education and e-learning. This encourages pupils to participate more actively in the classroom because of enhanced communication between professors and students (Msila, 2015). Figure 1 summarizes the direct and indirect channels through which ICT diffusion leads to human development (Sarangi & Pradhan, 2020).

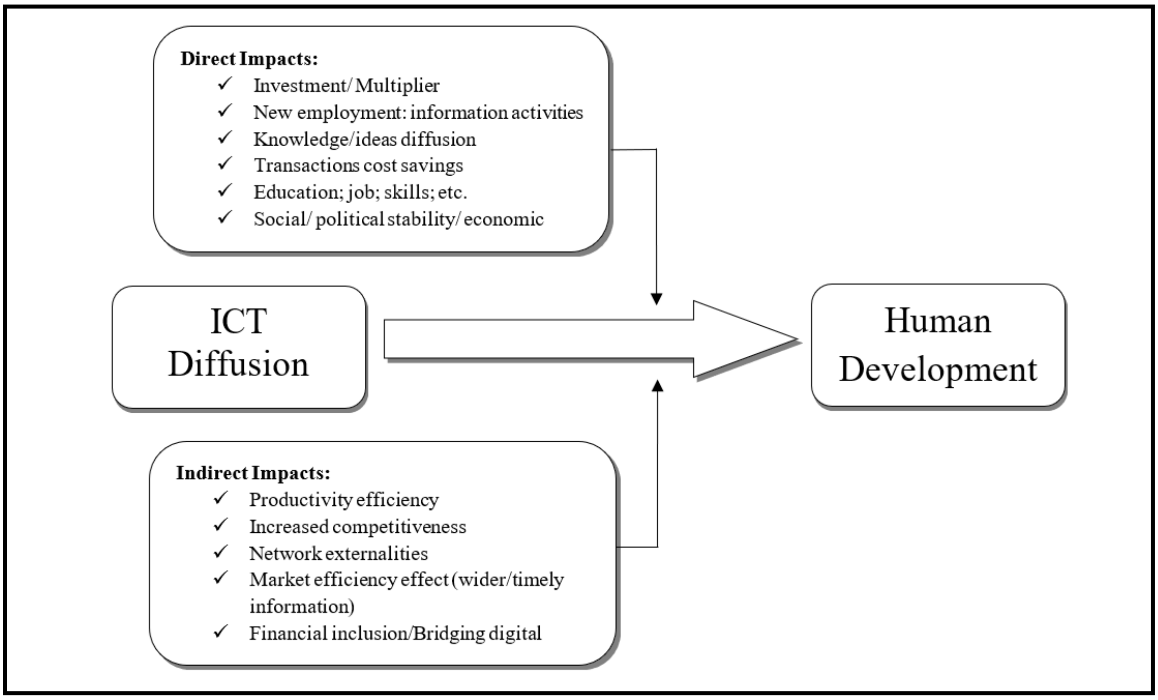

Figure 1. Impact of ICT diffusion on Human Development

2.2 Empirical Evidence

Even though ICTs have been present for a long time, studies to identify their distinctive significant contribution to the development are fairly recent, starting in the early 2000s. One strand of literature uncovers a positive association between ICT diffusion and Human capital development in the developed economies (Balouza, 2019; Bhattacharya, 2021; Farooqi et al., 2020; Qureshi et al., 2020; Zhang & Danish, 2019), whereas the other strand of the literature reveals an adverse impact of ICT on human life predominantly in the developing economies (Bollou, 2006; Bollou & Ngwenyama, 2008; Ngwenyama et al., 2006), mainly due to anxiety/nervousness (Kessler et al., 2009), addiction to cyberspace (Douglas et al., 2008) and, technical stress (Salanova et al., 2014).

Pohjola (2001) used an expanded version of the neoclassical growth model to assess the influence of ICTs on development in 39 economies to disprove the notion that ICTs may considerably contribute to macroeconomic growth in rich countries but not in emerging economies. The results of the study did not disclose a correlation between the two variables unless the investigation was restricted to OECD countries, which found a positive correlation. Why did emerging countries fail to imitate the accomplishments of their advanced counterparts, which constantly demonstrated a remarkable association between ICT and development? One likely explanation for this is the absence of ICT-complementary investments in poor nations (Samoilenko & Osei-Bryson, 2008). Another issue is the lack of infrastructure that is necessary to maximize the productive potential of ICT technology (Ziaie, 2013). There are also limitations on human capital in emerging countries, both in terms of quantity and quality.

While some researchers (Malik Khalid, 2013; Pohjola, 2001) speculated that developing countries were on a path to 'leapfrog' conventional stages of economic development into the digital future, more recent studies provide empirical support for those theories. Table 1 highlights the empirical evidence on the relationship between the diffusion of ICTs and human capital development.

Author(s)	Study Area	Method	Findings
Ngwenyama et al. (2006)	West Africa	1993-2003; Regression analysis	Negative impact of ICT on Health component
Bollou & Ngwenyama (2008)	West Africa	1995-2002; Total factor productivity analysis	Negative impact of ICT on HDI
Bankole et al. (2011)	South Africa	1998-2007; Regression analysis	ICT contributes to HDI
Bankole et al. (2011)	51 countries	1994-2003; Structural Equation Model	ICT impacts on HDI differ in high, middle and low income countries.
Asongu and Le Roux (2017)	49 SSA countries	2000-2012; Tobit regressions	ICT impact varies across fundamental characteristics of HDI and ICT dynamics
Badri et al. (2019)	15 Developing countries	2012-2017; Random effect modelling	ICT contributes to HDI
Balouza (2019)	6 GCC countries	2005-2014; Quantitative research method	Results ranging between positive, negative, and insignificant relationship
Gupta et al. (2019)	South Asian	2000-2016; Fixed effect modelling	Strong positive associations of internet and mobile usage with HDI
Zhang and Danish (2019)	Asia	1990-2016; Mean group estimator	HDI is influenced by mobile phone use, but not by internet use.
Maiti &Awasthi (2020)	67 countries	2000-2014; Two-stages least square (2SLS)	Less developed and developing countries have a slightly lower ICT impact.
Qureshi et al. (2020)	15 Advanced countries	1990-2017; Quantile-on-Quantile approach	Feedback hypothesis between ICT and HDI
Farooqi et al. (2020)	67 Developing countries	2000-2018; Auto regressive distributive lag (ARDL) model	ICT investment have different impacts on the components of HDI in four panels of the developing countries
Asongu (2021)	49 SSA countries	2000-2012; Tobit regressions	Mobile phone diffusion contributes to HDI
Bhattacharya (2021)	130 countries	2007-2019; Generalized Method of Moments (GMM)	Negative impact of ICT on HDI in low-income countries

Table 1. Summary of studies on ICT-HDI nexus

Hence, the literature asserts that the relationship between ICT diffusion and human capital development follows an integral but dynamic construct which strongly relies on the HDI dynamics, ICT indicators, country characteristics and the adopted methodology. Studies indicating a favourable relationship between ICT and human development in the emerging economies are sector-specific and not global in nature. In addition, the existing literature typically operationalizes the idea of development solely in terms of GDP and disregards other crucial aspects of the development paradigm. Further, the existing studies have overlooked the causality nexus (the feedback hypotheses, no causality hypothesis, One-way ICT-led development hypothesis, and one-way development-led ICT hypothesis) between ICT diffusion and human development. Presently, no consensus exists on the nature of the ICT-human development relationship. This necessitates a comprehensive examination of how ICT diffusion and human development are intertwined, using advanced methodologies robust to

CSD ensuring the transparency and reliability of the findings. Ipso facto, the main objective of the present study is to answer the following research questions (RQ) with respect to SAARC economies.

RQ1: Is there any association between diffusion of ICT and human development?

RQ2: What is the nature of the association (causal relationship) between ICT diffusion and human development?

3 Materials and Methods

3.1 Data

The present study aims to examine the impact of ICT diffusion on human development in the SAARC economies using panel data analysis cantered on the index of ICT diffusion (ICTI) and Human development (HDI). Utilising data from the United Nations Development Programme (UNDP), World Development Indicators (WDI) and International Telecommunication Union (ITU), the analysis utilizes the data of SAARC economies spanning 15 years from 2005 to 2019. The specified timeframe and extent of research is based on, the availability of data and the motivation stated in the above sections.

ICT diffusion is proxied by a composite index of ICT diffusion (ICTI) constructed using PCA which combines fixed telephone users per 100 people, mobile phone users per 100 people, fixed broadband users per 100 people and percentage of internet users. PCA is defined as "a statistical procedure that uses an orthogonal transformation to convert a set of observations of possibly correlated variables into a set of values of linearly uncorrelated variables called principal components" (Lenka, 2015). It has been frequently used in previous ICT research (Pradhan et al., 2016; Verma & Giri, 2020). The following formula, which is based on PCA, is used to integrate the four different indicators of ICT diffusion into a single composite index:

$$\text{ICTI} = \sum_{i=1}^{j} a_i \frac{x_{ij}}{sd\ (x_i)} \qquad (1)$$

where ICTI refers to the index of ICT diffusion; ai are the factor loadings; sd denotes standard deviation, and x_{ij} states i^{th} items in j^{th} year.

Eigen analysis (correlation matrix)				
PCs	Eigenvalue	Difference	Proportion	Cumulative
1	2.766	1.842	0.691	0.691
2	0.924	0.750	0.231	0.922
3	0.174	0.039	0.043	0.966
4	0.134		0.033	1
Eigen vectors (component loadings)				
Variables	PC1	PC2	PC3	PC4
Mobile	0.572	-0.045	0.137	-0.806
Telephone	0.229	0.958	0.108	0.127
Broadband	0.563	-0.083	-0.775	0.272
Internet	0.549	-0.267	0.606	0.508
KMO score: 0.80				

Table 2. Summary of PCA

The steps for constructing an index using PCA are discussed in detail by Yorulmaz (2018). Subsequently, the ICT index for each year and each economy is obtained through the principal components. The index was further screened for sampling adequacy using the Kaiser-Meyer-Olkin (KMO) test (Kaiser, 1974). The overall KMO score for the dataset is 0.80, indicating that our PCA produces accurate and reliable results. Table 2 presents the summary of PCA results. Figure 2 shows that Maldives and Bhutan are significantly ahead of the rest of the SAARC countries in terms of the diffusion of ICT. Afghanistan and Bangladesh, on the other hand, remain at the bottom of the list. However, ICT performance in India, Pakistan and Nepal continues to rise at a steady pace.

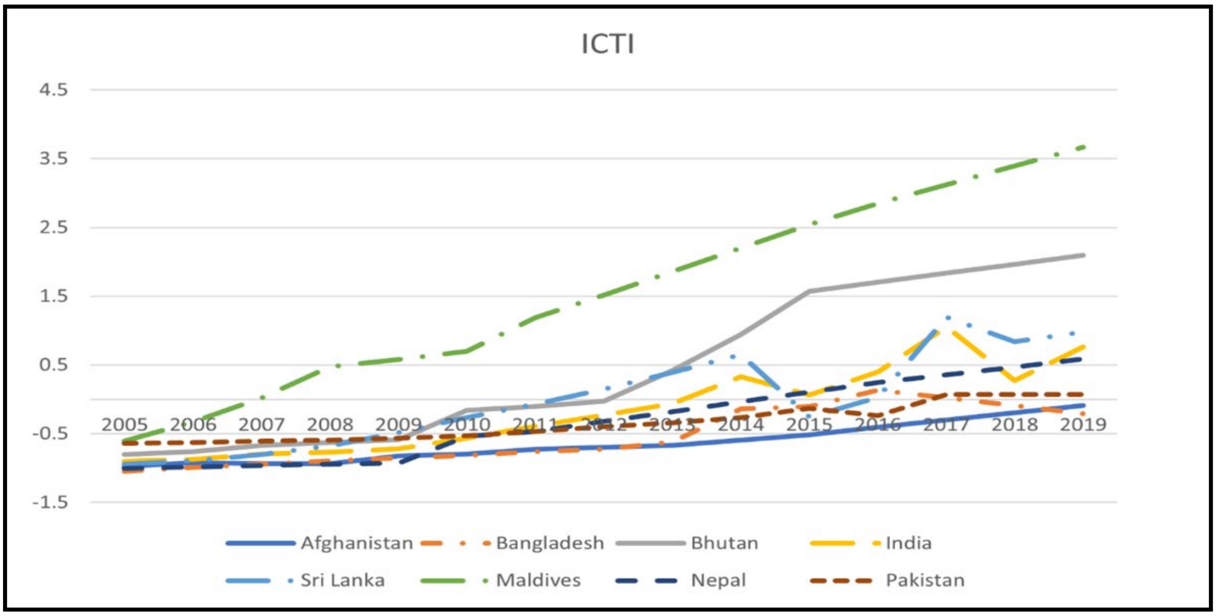

Figure 2. Trend of ICT diffusion in the SAARC economies

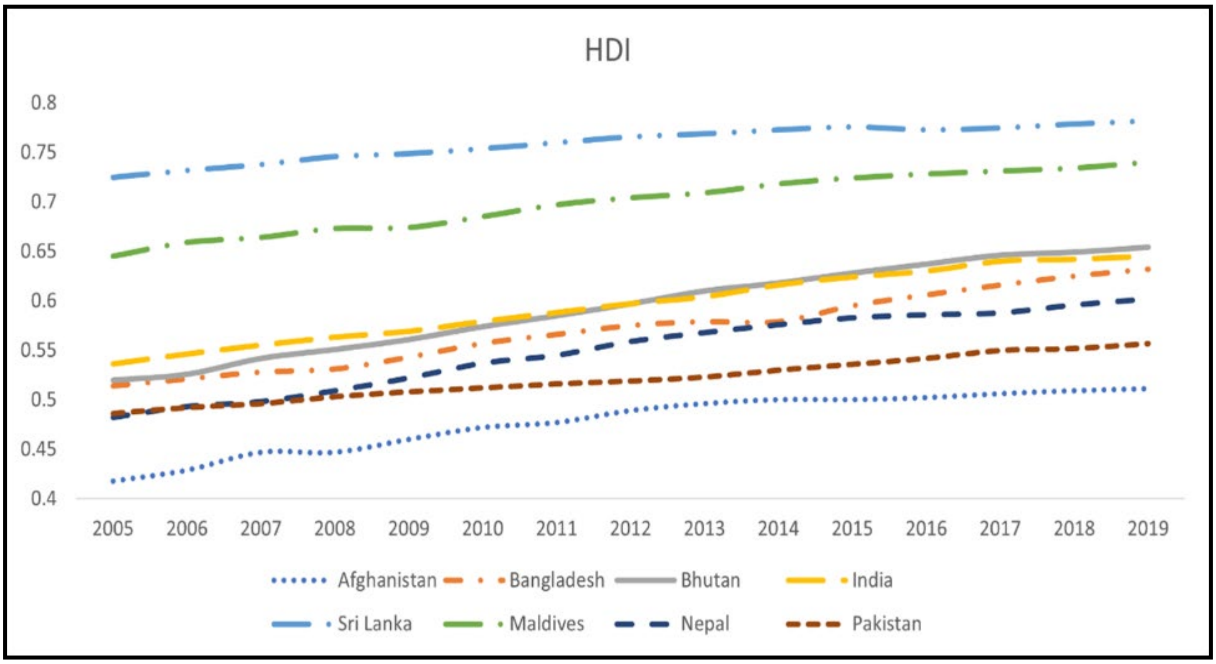

Figure 3. Trend of Human Development Index in the SAARC economies

The UNDP-created Human Development Index (HDI) serves as a proxy for human development. HDI is a qualitative and composite index that calculates the intensity of socio-economic development in an economy. It assesses the average levels of achievement in the areas of health, education, and a decent standard of living. Figure 3 shows the Human Development Index temporal trend for the SAARC countries. From 2005 to 2019, the HDI values of all SAARC economies reveals an upward sloping trend. HDI values in Sri Lanka and the Maldives are the highest in the region.

An important aspect of this research is that three control variables—per capita GDP growth (GDP), inflation (INF), and trade openness (TRD) are employed as a means of controlling for possible confounding or extrinsic variables. Economic growth has a direct impact on human development to the degree that it increases the options and capacities available to the government and the citizens (Ranis, 2000). Similarly, trade influences human growth through expanding markets, disseminating information, advancing knowledge, creating jobs, and increasing income (Jawaid & Waheed, 2017). Further, the purchasing power of money is devalued by inflation, which has a direct influence on the standard of living (Osiakwan & Armah, 2013). To facilitate analysis of the estimates as the elasticity of the analysed variables, the data utilised in this study are converted into natural logs. Table 3 displays the descriptive statistics and pairwise correlation matrix.

	lnHDI	**lnICTI**	**lnGDP**	**lnINF**	**lnTRD**
Mean	-0.529	0.577	2.627	1.787	4.076
Median	-0.546	0.552	2.648	1.908	3.949
Maximum	-0.245	1.265	2.990	2.550	4.915
Minimum	-0.872	0.072	2.243	0.820	3.663
SD	0.153	0.378	0.197	0.525	0.405
lnHDI	1				
lnICTI	0.657	1			
lnGDP	0.084	0.147	1		
lnINF	-0.239	-0.412	-0.061	1	
lnTRD	0.422	0.460	0.018	-0.198	1

Table 3. Descriptive statistics and pairwise correlation

3.2 Model Specification

The purpose of this research is to analyse the role of ICT diffusion in human capital development, taking into account economic growth, inflation, and openness to trade. As a result, an ICT-based theoretical model for human capital development can be derived as:

$$lnHDI_{it} = \alpha + \beta_1 lnICTI_{it} + \beta_2 lnGDP_{it} + \beta_3 lnINF_{it} + \beta_4 lnTRD_{it} + \theta_i t + \varepsilon_{it} \quad (2)$$

where i = 1, 2,…, N denotes the panel members, t = 1, 2,…., T is the time frame of the study, β1, β2, β3, and β4 signify the elasticity parameters of HDI relative to the ICTI, GDP, INF, and TRD in the long run and θi & αit denotes the deterministic trend and fixed country effects, respectively.

3.3 Methodology

3.3.1 Cross-sectional dependence

The present study employs panel data estimate approaches to illustrate the dynamic behaviour of the parameters and enhance the estimation precision. Therefore, it is possible that the issue of heterogeneity and CSD which captures the complexity of macroeconomic variables among the countries may arise. Panel data analysis necessitates checking for both stationary and cross-sectional dependency of economic variables. The results obtained in the presence of cross-sectional dependence are erroneous and biased in their interpretation. As a result, Breusch-Pagan LM (Breusch & Pagan, 1980), Pesaran scaled LM (Pesaran, 2004), Bias-corrected scaled LM (Baltagi et al., 2012), and Pesaran CD (Pesaran, 2004) tests were employed to check for CSD in the data. The null hypothesis (H0) of these tests is as follows:

$$H_0 : \eta_{ij} = corr\,(\varepsilon_{it}; \varepsilon_{jt}) = 0 \forall i \neq j$$

The mathematical expression of CSD test (Pesaran, 2004) is as follows:

$$\mathrm{CD}_P = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{p}_{ij} \right) \rightarrow N(0,1)\ i, j \tag{3}$$

$$R = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{p}_{ij} \right) \frac{(T-k)\,\hat{p}_{ij}^2 - E\,(T-k)\,\hat{p}_{ij}^2}{\mathrm{Var}\,(T-k)\hat{p}_{ij}^2} \tag{4}$$

where i and t correspond to the specific cross-section and time dimension, respectively, and $\hat{p}_{ij}$ is the projected multivariate cross-sectional correlation of error term across all cross-sections.

3.3.2 Unit root tests

The subsequent stage in analysis is to execute unit root tests to determine the stationarity of the variables in question. Therefore, panel unit root tests can be employed to attain this objective. It is not possible to employ first generation unit root tests to gain correct information regarding the cointegration order in the presence of CSD and slope heterogeneity since these tests over-reject the null hypothesis and have an inadequate size property. Because of this, the study uses second generation tests to account for CSD in all cross sections. Pesaran (2007) recommended two second generation panel stationarity tests: the cross-sectional augmented Dickey Fuller (CADF) and the cross-sectional Im Pesaran and Shin (CIPS).

Pesaran (2007) specified the stationarity test as:

$$x_i = \alpha_{it} + \beta_i x_{it-1} + \rho_i t + \sum_{j=1}^{n} \theta_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \tag{5}$$

Where, α_it refers to the intercept, t denotes the time, Δ is the difference operator, x_{it} and ε_{it}represents the variables and the error term, respectively. The null hypothesis asserts that the variables are non-stationary.

3.3.3 Cointegration Tests

Furthermore, panel cointegration analysis is used to verify whether or not there is a long-term relationship among the potentially integrated variables. Both first and second generation cointegration approaches, such as Pedroni (2004), Kao (1999), and Westerlund (2007) were used. Pedroni (2004) offers seven statistics for testing the null hypothesis of "no cointegration relationship" divided into two categories: "group-mean statistics", which average the findings of individual country test statistics, and "panel statistics", which pool the statistics along the within-dimension. The seven test statistics allows for panel heterogeneity both in the short as well as long run dynamics and also in the long run slope and intercept coefficients. The study also uses the Kao (1999) residual-based test to evaluate whether or not cointegration is present in order to validate the Pedroni test results.

However, we use the Westerlund (2007) technique to tackle heterogeneity and CSD issues, which gives more reliable and accurate information regarding long run cointegration relationships among the variables. The test examines two distinct statistics: group (Gτ and Ga) and panel (Pτ and Pa). The null hypothesis states that there exist no long run cointegration among the variables, as opposed to the alternative hypothesis that there is long run relationship between variables. The error correction system of Westerlund test is as follows:

$$\Delta Y_{it} = \delta'_i d_t + \alpha_i (Y_{it-1} - \beta'_i x_{it-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=-p_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + \mu_{it} \quad (6)$$

3.3.4 Panel Model Estimation

After confirming the long run cointegration between the variables, the study utilizes the fully modified ordinary least squares (FMOLS) method to calculate the magnitude of long run elasticity (Pedroni, 2004). FMOLS solves the issues of serial correlations, simultaneity biases, and endogeneity in the panel datasets. Moreover, it generates robust results when a small sample size is used (micro-numerosity), demonstrating the non-parametric approach of this regression estimation.

However, traditional methodologies, such as random effect, fixed effect, FMOLS, DOLS, and GMM methodology, presumes homogeneity and only enables modification of intercepts of the cross sections, when in real sense, the panel members are heterogeneous. Thus, considering the sensitive nature of CSD, the present study employs a dynamic common correlated effects mean group (DCCE-MG) estimator introduced by Chudik and Pesaran (2015). Based on the ideas of MG (Pesaran & Smith, 1995), PMG (Pesaran et al., 1999), and CCE estimation (Pesaran, 2006), DCCE can mitigate CSD effects, using a cross-section average,

$$lnU_{it} = \sum_{i=0}^{p} \alpha_{it} U_{it-1} + \sum_{i=0}^{p} \delta_{it} V_{it-1} + \sum_{i=0}^{p} \Upsilon_{it} \overline{W}_{it-1} + \varepsilon_{it}$$

where, $\overline{W}_{t-1} = (\overline{U}_{it-1}, \overline{V}_{it-1})$

U_{it} is used for human development as a dependent variable whereas V_{it-1} indicates all independent variables, i.e., ICTI, GDP, INF and TRD. The average of both dependent and independent variables is indicated as $\overline{W}_{t-1}$ to ease the CSD problem (t-1). While p represents the lag of each variable. One of the primary advantages of DCCE is its robustness in the event of structural breakdowns. Furthermore, by applying the jack-knife correction strategy, this approach is equally relevant in cases of small sample size. Also, the DCCE model works well when the panel data is unbalanced.

Finally, to ensure the robustness of DCCE test, the study also incorporates the Driscoll-Kraay (DK) standard error technique proposed by Driscoll and Kraay (1998) in addition to DCCE. This strategy offers long run estimates and can counter CSD, heteroscedasticity, as well as spatial/serial correlation in the data. This non-parametric regression is more efficient in the case of large time dimension because it is flexible and does not require any assumptions. In addition, the DK approach may provide estimates in both balanced as well as unbalanced panel dataset and is more efficient if the data set contains missing values (Park et al., 2018).

3.3.5 Causality Test

The final stage in the analysis is to establish a causal relationship between the variables under the study. As a corollary, the present study adopted Dumitrescu and Hurlin (2012) granger non-causality test, which addresses the CSD issue. The test is based on an individual wald statistic representing the average non-causality relationship between all individual variables and assumes cross-sectional variations among the coefficients (Usman et al., 2020). All coefficients are assumed to vary among cross-sections in this test. The following is the baseline regression equation given by Dumitrescu and Hurlin (2012):

$$y_{it} = \alpha_i + \sum_{k=1}^{K} \beta_{ik} y_{it-k} + \sum_{k=1}^{K} \gamma_{ik} x_{it-k} + \varepsilon_{it}$$

where K is assumed to have an equivalent lag order for all panel members, and the panel must be balanced. The null hypothesis postulates that "no causal relationship exists between the variables".

4 Results

To determine whether the series has CSD issues, this study utilised four different CSD tests. Table 4 indicates the existence of CSD in the variables. This suggests that the error components contain the presence of unanticipated common shocks across the countries because of economic interdependence. As a result, second generation panel unit root tests are more appropriate for testing the stationarity of the variables than the first-generation panel unit root tests in the presence of CSD.

Series	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnHDI	405.739*	50.477*	50.191*	20.141*
lnICTI	343.095*	42.106*	41.820*	18.472*
lnGDP	39.069*	1.479	1.193	-0.656
lnINF	101.400*	9.808*	9.522*	8.617*
lnTRD	97.229*	9.251*	8.965*	2.378*

Table 4. Cross-sectional dependence test

*Note: * Indicates levels of significance at the 1% level*

Variable	CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)
lnHDI	-2.316	-3.938*	-1.904	-2.392**
lnICTI	-2.406***	-3.326*	-1.810	-2.207***
lnGDP	-2.916*	-3.968*	-2.560**	-3.222*
lnINF	-2.790	-3.735*	-2.549**	-2.929*
lnTRD	-2.096	-3.066*	-2.252	-2.383**

Table 5. Panel unit root test

*Note: *, **, and *** indicates levels of significance at 1%, 5%, and 10%, respectively*

This study used two second generation panel unit root tests, CADF and CIPS, developed by Pesaran (2007) to determine the stationarity of the variables. Table 5 shows that the null hypothesis of the absence of a unit root is rejected at a 1% and 5% significance level. All the variables are stationary at first difference i.e. integrated at the order I (1) which fulfils the required condition to proceed for the panel cointegration analysis.

The long run association among the variables is tested using the Pedroni (2004), and Kao (1999) tests of cointegration, as shown in Table 6, which indicates presence of significant long run cointegration. The findings of these tests may sometimes be misleading since they overlook some critical issues such as CSD, serial correlation, heteroscedasticity, and structural breaks, among the cross sections, whereas Westerlund (2007) is a more advanced and powerful test of cointegration because it encompasses all of the abovementioned issues; thus, the findings are far more reliable. Westerlund (2007) cointegration results in Table 7 demonstrate that robust p-values for the Ga, Gt, Pa, and Pt tests are significant, rejecting the null hypothesis of "no cointegration" and confirming the existence of a long run link between the variables.

Pedroni test			
	I	IT	NIT
Panel v-statistic	-0.780	23.005*	-0.772
Panel rho-statistic	2.302	2.649	1.590
Panel PP-statistic	-0.136***	0.407	-0.197**
Panel ADF-statistic	-0.464**	-0.405	-1.222*
Group rho-statistic	2.685	4.224	1.941
Group PP-statistic	-3.186*	0.272*	-4.810*
Group ADF-statistic	-2.72*	-0.657*	-4.531*
Kao test		ADF t-stat	-3.866*

Table 6. Traditional cointegration tests
Note: *, **, *** Indicates levels of significance at 1%, 5%, and 10% level, respectively
Abbreviations: I, only intercept; IT, both trend and intercept; NIT, no trend and intercept

	Value	**Z value**	**Robust P value**
Gt	-1.280	1.923	0.000*
Ga	-2.719	2.848	0.000*
Pt	-1.945	2.074	1.000
Pa	-1.604	1.745	1.000

Table 7. Westerlund cointegration test
Note: * Indicates levels of significance at 1%

The results of both DCCE and DK regression are presented in Table 8. Because all the variables are converted to logarithmic form, the long-run coefficient estimate of ICTI, GDP, INF, and TRD are statistically equal to elasticities of HDI concerning ICTI, GDP, INF, and TRD, respectively. Table 8 shows that ICT diffusion has a favourable and significant impact on the HDI. A 1% increase in ICTI leads to a 0.26% increase in HDI, which is in agreement with economic theories and is statistically significant. Further, both GDP and TRD have a positive and statistically significant impact on HDI. However, inflation depicted a negative impact on HDI.

Variables	FMOLS-MG		DCCE-MG		DK Regression	
	Coefficient	P value	Coefficient	P value	Coefficient	P value
lnICTI	0.173*	0.000	0.268**	0.025	0.258*	0.000
lnGDP	0.024***	0.089	0.0215**	0.041	0.134**	0.020
lnINF	-0.003***	0.060	-0.001***	0.075	-0.011	0.477
lnTRD	0.025*	0.002	0.038***	0.055	0.050**	0.020
R-squared	0.70		0.63		0.68	
Root MSE	-		0.09		0.01	
Prob>f	-		0.00		0.00	
Groups	8		8		8	
Observation	120		120		120	

Table 8. The results of long-run elasticity estimates
Note: *, **, and *** indicates levels of significance at 1%, 5%, and 10%, respectively

Table 9 shows the results of the panel DH causality test, which showed a two-way causal linkage i.e. bidirectional causality between ICTI and HDI and unidirectional causality running from HDI to GDP and HDI to TRD. In contrast, the analysis depicts absence of any causal relationship between HDI and INF.

Null hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Remarks
lnICTI ⇹ lnHDI	5.945	2.459	0.013**	HDI↔ICTI
LnHDI ⇹ lnICTI	7.731	3.798	0.000*	
lnGDP ⇹ lnHDI	1.290	-1.032	0.301	HDI→GDP
lnHDI ⇹ lnGDP	4.966	1.725	0.084***	
lnINF⇹ lnHDI	2.122	-0.408	0.683	HDI⇹INF
lnHDI⇹ lnINF	7.130	3.347	0.486	
lnTRD ⇹ lnHDI	1.835	-0.623	0.533	HDI→TRD
lnHDI ⇹ lnTRD	5.168	1.876	0.060***	

Table 9. DH causality test
Note: *, **, and *** indicates levels of significance at 1%, 5%, and 10% level, respectively; and the symbols →, ↔, and ⇹ indicate unidirectional, bidirectional and no causality relationship, respectively

5 Discussion

This research aims to examine the impact of ICT diffusion on human capital development in the SAARC economies for the period 2005-2019, using the most recent available data. DCCE, DK regression, and the DH causality test were used to generate estimates robust to CSD. The results of the study resulted in various theoretical and practical contributions which are shown below after an overview of the findings.

5.1 Overview of the findings

First, the results highlight positive impact of ICTI on HDI. This outcome is line with the studies of Badri et al. (2019), Bankole et al. (2011) and Gupta et al. (2019). Increased ICT reliance on HDI characteristics such as health, education, and living standards influences HDI in a variety of ways. Since ICT diffusion in the medical industry helps to improve average lifespan, this subsequently contributes to the increase in HDI indicator across both the national and regional levels. In addition, the use of ICTs in educational institutions such as schools, education institutes, and training centres boosts the level of HDI. This is accomplished by the creation of virtual libraries and the facilitation of distant learning, both of which contribute to an improvement in the quality of education throughout the economy.

Second, our study confirms the favourable impact of GDP on HDI which is in line with the existing theories. Boosting growth leads to improvements in health, education, and life expectancy. Furthermore, as incomes improve, people are better able to invest in their own health and education, enabling them to enjoy a better standard of living (Bedir, 2016). Investing in a high-quality education will allow them to strengthen their competences and secure a better job position in the future. High-income individuals may afford to spend more money on food, clothing, and housing that are of the highest quality and so have a greater impact on life expectancy and mortality rate. (Bloom & Canning, 2000).

Third, the association between TRD and HDI is positive and significant. In addition to its direct benefits on human development, increased trade volume and trade liberalization improve HDI because businesses can provide better living conditions, more choices, promote sustainable, and enhance productivity, all of which have an impact on human capital in one way or another. The economic expansion that results from raising the volume of trade makes it simpler for individuals to acquire health and education services, hence fostering human development. (Jawaid & Waheed, 2017).

Fourth, in contrast, HDI is negatively impacted by inflation. This may be the result of its influence on monetary savings and spending habits, the decisions made by businesses and ultimately, the expenditures made by the government (Osiakwan & Armah, 2013). Rather than participating in activities that are profitable and productive, economic agents typically spend a significant amount of their time and resources adjusting to inflationary circumstances and attempting to avoid the asset devaluation. Inflation also influences the decision-making procedure, making it tricky for businesses to estimate their income and expenses. Consequently, inflation influences government expenditure because the government itself is a consumer, and at the same time, it is required to pay off its workforce.

Lastly, findings indicated a bidirectional causal relationship between ICTI and HDI which is in line with the findings of Qureshi et al. (2020). This suggests that an increase in human development indices motivates people throughout the SAARC region to embrace advances in technological activities, which in turn leads to information diffusion, thereby empowering economies to accomplish the desired development objectives, such as economic empowerment, education, wellbeing, economic potentials, and poverty eradication. Furthermore, the unidirectional causality association between HDI and GDP in SAARC countries suggests that HDI is a major determinant of GDP in the region. Education not only helps the economy thrive, but it also enhances the incomes of those who are economically disadvantaged, and improvements in health produce economic dividends. (Ngwenyama et al., 2006).

5.2 Contribution to theory

The fundamental theoretical contribution of the present research is that ICT minimizes informational asymmetries, which is linked to human wellbeing, ex-post of lowering information asymmetry; the saved information-based funds can be used to boost human development. One approach is by reducing the cost of searching. Mobile phones have allowed workers to avoid the time and expense of making the long and laborious trip by simply calling to verify job prospects. Second, by way of increasing communication, ICT boosts education quality. Texting, a less expensive alternative to voice calls, is increasingly being used by students in SAARC, particularly in higher education, to exchange notes with their professors and peers. From a corporate standpoint, the improved communication made possible by ICTs contributes to increased productivity by allowing for more efficient supply-chain management. The other approach is by employment creation as well as other income-inducing prospects in the technological sector in general and the communications business at large. Encouraging communication amongst the social networks to mitigate shock waves and lower the risk exposure of the households is the next approach. Individuals in the developing rely on their close friends and family members for services provided by organisations such as emergency units, childcare centres, fire departments, insurance, and social security agencies, among others. There is no doubt that informal and family institutions in SAARC have seen a major improvement because to the arrival of ICT. The fifth way that ICT can impact human capital development is through easing the provision of infrastructure and services in other economic sectors, like agriculture, healthcare, finance, and education. One example is Google Pay, a mobile banking service that allows the public to virtually store money on their smartphones and utilise it to make transactions anywhere in the country. It is impossible to comprehend the extent to which these services have affected the standard of living in SAARC.

5.3 Contribution to practice

Several policy recommendations can be derived from the findings in order to address the enormous challenges of ICT adoption in SAARC economies. The substantial investment and significant number of smartphone users in this region stimulates human development. People can readily communicate and convey information about health and education via smartphones and internet. The following recommendations are suggested for policymakers in the SAARC economies. First, it is imperative that the general public have simple and easy access to ICT and be provided with the requisite ICT skills and digital literacy. Second, formulate ICT policies for the most recent ICT applications, train ICT workers, and promote e-culture to improve healthcare, education system and living standard. Third, ensure that infrastructure and connectivity are of higher quality. Fourth, lower the cost of ICT equipment and provide low-cost mobile and internet service plans so that the majority of people can maximize the benefits of the technological revolution. Lastly, encourage greater investment in the promotion of the Internet, which is essential for human development and sustainable economic progress.

5.4 Limitations and future research directions

Notwithstanding its contributions, the present research has certain drawbacks and limitations. To begin, the HDI, which serves as the dependent variable, does not incorporate each facet of human capital development as well as the quality of living, specifically subjective indicators. The scope of future studies could also be broadened to include more variables that accurately reflects the human welfare. Second, the study can be expanded and improved by examining the impacts of utilising ICT at the regional or local level, where the model can incorporate the variables specific to certain regions, like those of cultural aspect. Second, the study can be expanded and improved by examining the impacts of utilising ICT at the regional level, in which the framework could further include variables specific to certain areas, like those of cultural aspects. Lastly, future research could increase the number of variables and utilise a wider variety of research methodologies to investigate the link in more depth.

6 Conclusion

Technological advancements are occurring at a rate, scale, and intensity that have never been seen before. The only way for the international community to fulfill the 2030 agenda for people, peace, and prosperity is to take advantage of this progress. Frontier technologies carry the possibility of reviving productivity and making abundant resources accessible to permanently eradicate poverty, permit more sustainable growth patterns, and reduce or even reverse decades of environmental degradation. In order to ensure that technological change and innovation are used to achieve equitable and sustainable outcomes, governments in developing countries, along with civil societies, businesses, and academicians, need to work together. If policymakers are not proactive, technological disruption can exacerbate inequality, further alienate the poor, and feed anti-open society and economy groups.

Using panel data analysis spanning the years 2005 to 2019, this study examines the role of ICT diffusion in spurring human capital development in the SAARC economies. It highlights the importance of policies that would assist individuals in navigating this transition period of advancements in ICT. This may necessitate that the stakeholders adjust the social contract to the new reality being created by frontier technology. Education will evolve into an increasingly more critical factor in determining the direction of human development and social progress. Since ICTs serve as enablers and multipliers of other cutting-edge technologies, we should ensure that everyone, especially women and girls, has the cognizant opportunity to develop digital skills. Technology Leapfrogging, as transpired in SAARC, must begin with a psyching phase that focuses on developing a plan for ICT development. Countries will need to think outside the box in order to provide efficient social protection systems for people who may not be able to keep up with the rapid technological change. The opportunity cost of not understanding the consequences of ICT is as substantial as the opportunity cost of not being able to access and utilize its contents.

Most importantly, the international community must make a concerted effort to narrow the numerous gaps in technological capability that exist between developed and developing nations. Investment in hard and soft infrastructure, human capital, and innovation platforms for sustainable development are important to ensure that the benefits of frontier technology are widely disseminated across the world.

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Note on Data availability: The data that confirm the findings of this study are publicly available on the World Bank database at https://databank.worldbank.org/source/world-development-indicators, International Telecommunication Union (ITU) database at https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx and United Nations Development Programme (UNDP) Database at http://hdr.undp.org/en/data.

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