Role of ICT Diffusion on Financial Development, Inclusive Growth and Environmental Sustainability in SAARC Countries: Issues and Evidence

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CERTIFICATE

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To My Brother

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ABSTRACT

The 2030 Agenda for Sustainable Development recognizes the potential of Information and Communication Technology (ICT) to accelerate economic development and overcome the digital divide problems. Even though none of the Sustainable Development Goals (SDGs) is specifically about ICT, most of the goals refer to ICT and technology, and ICT can serve as a foundation for accomplishing all of the SDGs. ICT, especially broadband network, is vital for attaining all 17 SDGs and advancing the three pillars of sustainable development (economic growth, social inclusion, and environmental preservation). Although ICTs are mentioned remarkably few times in the SDG goals and targets list, the United Nations (UN) General Assembly emphasized their significance as crucial drivers for achieving the new goals. It urged all stakeholders to integrate ICTs into their work towards the SDGs. However, the connection between ICTs and the SDGs remained unclear. In light of this, the present study aims to examine the impact, of ICT diffusion on financial, economic and sustainable development in South Asian Association for Regional Cooperation (SAARC) economies.

The present study emphasizes that ICT provides a unique opportunity to resolve many of the challenges encountered by SAARC economies, including financial instability, economic volatility, digital divide, poverty, and environmental degradation. ICT may support sustainable development and enhance people's lives by improving access to information, facilitating communication, and stimulating creativity. For instance, ICT has the potential to expand people's horizons by opening up new avenues for education, healthcare, financial inclusion, and employment. Additionally, it can help in the prevention and management of natural disasters, the mitigation of climate change, and the improvement of environmental monitoring and conservation initiatives. In addition, ICT may aid in the fight against inequality and advance social inclusion by expanding access

to resources for previously excluded groups.

The rise of mobile network coverage and greater internet use have allowed SAARC nations to begin reaping the benefits of ICT dispersion. However, digitalization has yet to reach its full game-changing potential in the region. The catastrophic impacts of the COVID-19 pandemic and the evident implications of climate change have increased dependence on digital technologies while exposing the costs of the digital divide. Even though 4G mobile network coverage has expanded rapidly in most SAARC countries over the past five years, Afghanistan and Nepal stand out as significant outliers. Despite these advancements, the region still has the highest percentage of people (61%) who live within the range of a telecommunications network but do not use the internet. Reasons for these gaps include poor affordability, low digital skills, and a need for more relevant content and applications.

Hence the present study is initiated to examine some of the unresolved issues and some new issues associated with the relationship between ICT diffusion and development in the context of SAARC economies. ICT diffusion is measured by constructing a composite index using principal component analysis (PCA) on mobile, fixed broadband, internet, and landline usage in SAARC economies. In many aspects of SAARC economies, such as healthcare, education, financial services, energy, and climate change mitigation, the diffusion of ICTs can be accelerated to support the SDGs. To show the potential of ICT to drive progress on the SDGs in SAARC, this study summarizes the impact of ICT diffusion on some critical financial, economic, social, and environmental issues using robust econometric techniques such as fully modified ordinary least square (FMOLS), dynamic ordinary least square (DOLS), cross-sectionally augmented autoregressive distributed lag (CS-ARDL), dynamic common correlated effects (DCCE) estimation, Driscoll and Kraay (DK) standard error approach.

The first issue of the present study is to investigate the relationship between ICT diffusion, financial development, and economic growth in SAARC economies in accordance with the "Economic dimension" of sustainable development.

The study examines the ICT-Finance-Growth nexus in SAARC economies and discovers a long-run association between the variables. ICT diffusion was found to have a positive impact on both financial development and economic growth. The results from the causality test demonstrate a unidirectional causal relationship between ICT diffusion and financial sector development and economic growth. However, the result of causation between the financial sector development and ICT is statistically insignificant. Overall, the study's findings emphasize the potential for ICT diffusion to promote financial development, foster economic growth, and advance financial inclusion and stability in SAARC nations.

The next issue of the present study is to examine the impact of ICT on inclusive growth in line with the "Social dimension" of sustainable development. Given that one-fourth of the world's population and almost half of the world's poor live in SAARC, the challenge for SAARC is how to harness ICT to achieve inclusive development in the region, which also suffers from the digital divide, a complex issue involving unequal access, use, and applications of ICT among and within economies.

The central aspect of inclusiveness is addressing poverty. Therefore, the study examines the relationship between ICT diffusion and poverty reduction in SAARC, finding that ICT diffusion reduces poverty both in the long and short run and has bidirectional causation with poverty reduction. The study further examines the significance of ICT diffusion in fostering human development and highlights the strong positive relationship between ICT and HDI. Thus, the study recommends a cohesive setting that unites ICT with human development in this modern framework and identifies three

factors that restrict human capital development: inequality of opportunities, poor service quality and effectiveness, and SAARC countries' increasing vulnerability to shocks and risks. This brings to light another essential aspect of inclusiveness, namely gender equality. To alleviate extreme poverty and enhance shared prosperity, gender discrepancies in technology use must be closed. Thus, the study examines how ICT diffusion empowers women to achieve the SDGs in SAARC, finding that ICTs and economic growth substantially and positively affect women's empowerment. However, the fertility rate and trade openness hinder women's empowerment. Expanding ICT use and bridging the digital divide, particularly among women, can help SAARC countries. The studies suggest that expanding the use of ICT can effectively achieve poverty reduction, human development, and women's empowerment-related SDGs in SAARC countries, thereby achieving inclusive growth in these economies.

SAARC nations have been grappling with severe economic challenges. However, the environmental crisis is one of the most significant and rapidly developing obstacles to SAARC's progress toward sustainability. The influence of ICT dissemination on sustainability has been studied extensively, but there has yet to be much progress in defining the exact nature of that impact. For this reason, the study investigates the effect of ICT on sustainability in line with the "Environment dimension" of sustainable development.

The study examines the impact of ICT diffusion, globalization, financial development, government effectiveness, and economic growth on sustainable human development (SHD) (i.e., the development of human capital adjusted against the human ecological footprint) in SAARC economies. Findings reveal that ICT diffusion and other critical macroeconomic indicators have significant positive impacts on SHD and a unidirectional causality running from ICT diffusion to SHD and globalization to SHD.

The study also investigates the transmission mechanism through which ICT impacts sustainability. Given that ICT devices are ubiquitous, any attempt to mitigate climate change should address the carbon footprint of the ICT sector. Therefore, it examines the direct impact of ICT on the environment and the indirect impact through interaction with energy consumption, financial development, and globalization in SAARC economies. Findings reveal that ICT, renewable energy consumption, and globalization significantly reduce CO_2 emissions, whereas non-renewable energy consumption and financial development significantly increase emissions. However, the interaction between financial development and ICT jointly reduces CO_2 emissions. The study also confirms the validity of the Environmental Kuznets Curve (EKC) hypothesis for ICT diffusion and confirms bidirectional causality between ICT and CO_2 emissions. The study concludes that in order to resolve the undesirable consequences of environmental degradation on human development in the globalized era, it is essential for SAARC economies to tackle the challenges of adequate ICT infrastructure: particularly access and affordability. By eliminating these significant barriers to ICT access, CO_2 emissions can be reduced, and human development can be sustained simultaneously.

The findings of this thesis recommend that governments establish a consistent strategy across three main pillars to maximize economic potential. Promoting inclusivity, strengthening institutions, and increasing trust are three actionable cross-cutting themes that are especially pertinent for the SAARC region.

In order to fully realize the promise of ICT for sustainable development, collective effort and collaboration across various sectors and stakeholders are required. It necessitates a holistic and coordinated strategy for developing and deploying ICTs that considers the priorities and requirements of a wide range of people and settings. It also highlights the significance of being ethical, transparent, and accountable in deploying

ICT in a way that respects human rights and dignity. The paper concludes that the era of sustainable development presents a once-in-a-generation chance to use ICTs for social good and bring about a more equal and sustainable global society.

Keywords: ICT diffusion, Financial development, Economic growth, Inclusive growth, Human development, Poverty reduction, Women empowerment, Sustainable development, SAARC, Cross-sectional dependence (CSD), Cross-sectional autoregressive distributed lag (CS-ARDL), Dynamic common correlated effects (DCCE) estimation, Driscoll and Kraay (DK) standard errors approach.

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ABBREVIATIONS

Abbreviation	Meaning
2SLS	Two-Stages Least Square
ADF	Augmented Dickey-Fuller
AMG	Augmented Mean Group
ARDL	Auto Regressive Distributive Lag
BAU	Business As Usual
CADF	Cross-Sectional Augmented Dickey-Fuller
CAGR	Compound Annual Growth Rate
CS-ARDL	Cross Sectional Autoregressive Distributed Lag
CIPS	Cross-Sectional Augmented Im-Pesaran-Shin
CPI	Consumer Price Index
CSD	Cross-Sectional Dependency
CUP-FM	Continuously Updated Full Modified
DCCE	Dynamic Common Correlated Effects
DFH	Demand Following Hypothesis
DH	Dumitrescu And Hurlin
DK	Driscoll And Kraay
DOLS	Dynamic Ordinary Least Squares
DSF	Digital Financial Services
DSUR	Dynamic Seemingly Unrelated Regression
ECT	Error-Correction Terms
EKC	Environmental Kuznets Curve
FGLS	Feasible Generalized Least Squares Model
FLP	Female Labor Participation

Abbreviation	Meaning
FMOLS	Fully Modified Ordinary Least Squares
G2P	Government-To-Person
GCC	Gulf Cooperation Council
GDP	Gross Domestic Product
GMM	Generalized Method of Moments
GNI	Gross National Income
GNP	Gross National Product
HAC	Heteroskedasticity And Consistent Autocorrelation
HIES	Household Income and Expenditure Survey
ICT	Information and Communication Technology
IMF	International Monetary Fund
IOT	Internet Of Things
IPS	Im Pesaran Shin Test
IT	Information Technology
ITU	International Telecommunication Union
KMO	Kaiser-Meyer-Olkin
LLC	Levine Lin Chu Test
MG	Mean Group
MIMIC	Multiple Indicators Multiple Causes
MMQR	Method Of Moments Quantile Regression
MSME	Micro, Small, and Medium-Sized Enterprises
NEH	Neutrality Hypothesis
NPL	Nonperforming Loan
OLS	Ordinary Least Squares

Abbreviation	Meaning
PC	Principal Component
PCA	Principal Component Analysis
PMG	Pooled Mean Group
POLS	Pooled Ordinary Least Squares
PP	Phillips–Perron
QQ	Quantile-On-Quantile Approach
QR	Quantile Regression
RMG	Ready-Made Garments
RQ	Research Question
SAARC	South Asian Association for Regional Cooperation
SDGS	Sustainable Development Goals
SEM	Structural Equation Model
SLH	Supply Leading Hypothesis
UN	United Nations
VAR	Vector Autoregressive
VECM	Vector Error Correction Model
WDI	World Development Indicators
WPI	Wholesale Price Index

Chapter-1

Introduction

1.1 Introduction

The United Nations (UN) leaders endorsed the 2030 Agenda for Sustainable Development in September 2015, calling it "a plan of action for people, planet, and prosperity" that will "shift the world onto a sustainable and resilient path" (United Nations, 2016). The 17 Sustainable Development Goals (SDGs) comprise the backbone of this global, interconnected, and game-changing agenda. The SDGs, sometimes known as the Global Goals, aim to balance sustainable development's economic, social, and environmental dimensions. Because of the unprecedented nature of these calls to action, all nations, and their citizens—in both the developed and developing worlds are obligated to do all in their power to help bring about a significant decrease in inequality. Because eradicating poverty is inextricably linked to the strategies that generate economic growth and address a wide range of social and environmental needs, the opportunities presented by the SDGs provide governments, multinational corporations, and civil society m medium to work together towards a more sustainable world.

However, many countries continue to experience difficulties or see the associated aims with a sense of hopelessness, particularly when development plans fall short of meeting the intended or projected dates. There are many causes for the delays in reaching

intermediate goals that would ultimately result in the attainment of SDGs. One of these is the lack of a communication tool that can help spread information and educate people about the steps they need to take to achieve their goals (Latif et al., 2017). The evolution of the Internet and mobile phones has contributed to the proliferation of accessible channels for disseminating information.

Information and communication technology (ICT) play a crucial role in achieving the SDGs (economic growth, social inclusion, and environmental protection) and play a catalytic function in each of these areas. ICT is an umbrella term for any device or application used for communication; this includes but is not limited to radios, televisions, mobile phones, computers, networks, satellites, and the services and applications which operate on them (Bhattacharya, 2021). E-government, e-health, e-education, e-commerce, and e-environment are just a few examples of the many fields that might benefit from this technology. ICT, especially mobile broadband, is a crucial platform for the SDGs' underlying infrastructure and a key acceleration technology that can pull societies off the business as usual (BAU) track (Kostoska & Kocarev, 2019). Future advancements in ICTs, such as the Internet of Things (IoT), sophisticated robots, AI, big data, 3-D printing, and others, will provide access to technologies that will enable revolutionary advances in healthcare, education, energy, and environmental protection. The UN Broadband Commission for Sustainable Development has also emphasized the critical role that ICT can play in delivering integrated, creative, and cross-sectoral sustainable development outcomes (Broadband Commission, 2015). In addition to improving accessibility, creativity, and output, ICT may increase the adaptability of vital infrastructure, making it easier to address social and economic exclusion (Broadband Commission, 2015). Compared to traditional infrastructure, mobile broadband offers unprecedented availability, scalability, and cost improvements that can help countries

narrow a wide range of development gaps at a record clip (Abor et al., 2018). Although none of the 17 SDGs is specifically about ICT and only a few targets refer to ICT and technology, the fundamental recognition of the scope of ICT and global interconnectedness to speed up human progress, bridge the digital divide and create knowledge societies is at the heart of the 2030 Agenda for Sustainable Development (United Nations, 2016).

ICT Diffusion can have a wide range of economic consequences, including but not limited to increased economic growth (Cheng et al., 2021; Iqbal et al., 2019), financial development (Alimi & Adediran, 2020; Godil et al., 2020), educational outcome (Zia et al., 2018), and environmental sustainability (Evans & Mesagan, 2022; Ozili, 2021). While the consequences may differ in different industries, the relevance to sustainability has grown in recent years. Therefore, with the advent of globalization, chances exist to accomplish numerous inclusive and sustainable development outcomes thanks to the increased diffusion of ICT across many nations that are far apart from each other throughout the globe. However, such sustainable development results must be shaped so that the economic, social, and environmental dimensions of sustainable development are considered in a balanced approach. In addition, policymakers should care for the environment and shape laws in a way that prioritizes eco-friendly technology to lessen the adverse effects of economic activity on the natural world (Jayaprakash & Pillai, 2021).

In terms of the environment, the impacts of ICT can be both positive and negative. The use of ICT may help individuals and businesses save money on the costs of carbon dioxide (CO2) emissions by lowering the amount of money spent on transactions and transportation. In fact, by lowering information rents that are linked to CO2 emissions, ICT lessens the information asymmetry that threatens environmental sustainability (Avom et al., 2020). In addition, Higón et al. (2017) note that using ICT will likely reduce CO2

emissions by creating smarter cities, transport systems, industrial processes, electrical grids, and energy-saving benefits. On the other hand, ICT adoption results in an increase in energy consumption by individuals and businesses and, consequently, a rise in CO2 emissions (Lange et al., 2020). Additionally, ICT enhances the financial system and information flow, promoting greater financial integration and increased economic activities (Alimi & Adediran, 2020). Growing economic activity releases more CO2 into the atmosphere (Avom et al., 2020). Consequently, the effects of ICT on environmental sustainability can be either favorable or unfavorable, depending on the circumstances. This has led several academics to propose that the two notions have an inverted U-curve linkage (Higón et al., 2017a; Madaleno & Moutinho, 2021; Zhang & Meng, 2019).

Besides the environmental impact, ICT can have a wide range of implications for social development. Innovations in mobile phone applications and services have contributed significantly to the impact of ICT on people's daily life. This is why the effects of ICT on economic and human development have received so much attention in recent publications (Abiodun & Sunday, 2013; Ejemeyovwi & Osabuohien, 2020; Ruhyana & Essa, 2020). Therefore, the favorable effects of ICT on globalization and CO2 emission might promote inclusive human development (Asongu et al., 2017a). Likewise, education may integrate ICT through smartphone technology to boost inclusive human development (Asongu & Nwachukwu, 2018). The extent to which ICT has a beneficial impact on inclusive human development varies according to many factors, including the availability of natural resources, the proximity to the coast, and the degree to which a country is landlocked (Nchofoung & Asongu, 2022). The literature also examines social development in terms of general health. Several researchers have shed light on how the latter has been affected by the former using ICT. By breaking down physical barriers and bringing healthcare professionals and patients closer together, ICT has facilitated the decentralization of health

systems (Dutta et al., 2019). According to Balouza, (2019), health strategies should prioritize expanding access to digital resources. However, for ICT to enhance people's lives, it must be used to safeguard their human rights, privacy, and security when they are online (Alhassan & Adam, 2021).

The economic sphere offers a parallel route to implementing ICT for sustainable development. Policies that foster economic expansion and fight poverty are examples of such long-term strategies. Increasing productivity and decreasing transaction costs are two ways ICT advancement might boost economic growth (Aghaei & Nasab, 2009; Cheng et al., 2021). Ibrahim and Alagidede (2018) note that it has positive externalities on economic growth and has the potential to boost financial development (Alshubiri et al., 2019; Chien et al., 2021). The widespread use of ICT has accelerated economic growth due to improvements in economies of scale (Chien et al., 2020; Latif et al., 2017), and therefore it may also contribute to globalization. In contrast, Albiman and Sulong (2017) argue that ICT may be detrimental to economic progress if economic change is not taking place.

Literature frequently cites the argument that ICT only increases productivity and provides other economic benefits in developed nations. Moreover, developing nations with low income lack the essential human capital to handle the technology. Thus, the social, environmental, and economic aspects of development can all be jeopardized by ICT. However, economic policies are sometimes challenging to implement because of their interdependence. For instance, research has shown that ICT progress causes higher CO2 emissions and economic growth (Aghaei & Nasab, 2009; Avom et al., 2020; Cheng et al., 2021). Increases in CO2 emissions are detrimental to health (Asadullah et al., 2020) and inclusive human development (Nchofoung et al., 2021), increase the persistence of inequality (Njangang et al., 2021), and reduce human well-being.

Given the tangled web of interconnections between ICT diffusion and the various dimensions of development, and the economic associations established in the literature between these indicators, it is essential to look into the impact of ICT on financial development, economic and inclusive growth, as well as achieving sustainable development. In light of the foregoing, the study is prompted by the lack of consensus in the literature about the relationship between ICT and development. Therefore, the study aims to empirically explore the impact of ICT on development and the underlying processes that make this impact feasible in South Asian Association for Regional Cooperation (SAARC) economies.

1.2 Need for the Study

The disruptions caused by the COVID-19 pandemic have brought to light the actual costs of the digital divide within the countries and the potential to rebuild more effectively. Those with the necessary knowledge, resources, or equipment to participate in the expanding digital economy were often included in its benefits. In a similar vein, nations that possessed robust digital stacks, which are interconnected platforms for electronic identification, online payments, data sharing, and other digital abilities, were in a better position to mount an effective response in the areas of economics, environment, social protection, public health, as well as to ensure the continuity of government affairs and commercial trade.

SAARC is home to one-fourth of the world's population and nearly half of the world's poor (Worldometer, 2023). The digital divide in the economy further marginalizes the poorer segment of society lacking ICT access. Also, it is a region of stark contrasts: from conflict zones to thriving democracies, young people to ageing populations, and power outages to multinational corporations. ICT Diffusion can improve the quality of life in SAARC by

increasing access to services and markets, fostering economic diversification and job creation, decreasing transaction and trade costs, and fostering innovation (Ruhyana & Essa, 2020). Throughout the region, governments, businesses, and individuals are actively pursuing this opportunity. For example, India's Aadhaar system revolutionized government-to-person (G2P) payments and spawned other platforms that have generated a dynamic, innovative ecosystem in the private sector (Rao & Nair, 2019); online payments in Pakistan have increased fourfold since 2015; and the proportion of SAARC's population that is not covered by mobile network signals has decreased from 30 per cent in 2014 to 8 per cent in 2021 (World Bank, 2022c).

However, the full game-changing potential of ICT Diffusion in SAARC is still largely untapped. Except for the Maldives (57%) and Sri Lanka (50%), only about a third of the population in most nations subscribes to mobile internet services (World Bank, 2022c). For the digital economy and government services, this is a major hurdle. Furthermore, a significant gender gap remains, with fewer women than men possessing mobile devices and accessing the internet. In Bangladesh, for instance, men are 65% more likely to use the internet than women. 88 % of school-aged children (449 million) do not have access to internet at home since many households remain unconnected across the region, and only 2 % of the poorest 20 % of the population do (World Bank, 2022c).

Further, inadequate, or nonexistent quick payment methods, credit, and data infrastructure are common obstacles to capitalizing on the growth of DSF and e-commerce. Important limitations include insufficient cybersecurity, poor data protection, low online trust, and inadequate consumer protection. Many of these issues stem from outdated policies, laws, and regulations as well as a lack of coordination

between government agencies and the business sector. During the recent COVID-19 outbreak, these flaws became abundantly clear as many kids lost access to online schooling (Ackers et al., 2021) and small businesses struggled to adapt to new sales channels (Brucal et al., 2021).

Both positive and negative developments in the global economy impact the prognosis for SAARC. Except for Bhutan, every nation in the area has lowered its forecasts. The largest economy in SAARC, India, is forecast to grow 6.3% in FY2023/24 as high borrowing prices and slower income growth reduce consumer spending (World Bank, 2023a). The Sri Lankan economy is projected to contract by 4.3% this year due to the lingering effects of the macro-debt crisis. Following the International Monetary Fund (IMF) program approval, future growth prospects primarily rely on debt restructuring and structural reforms (World Bank, 2023a). The economies of the Maldives and Nepal have benefitted from the revival of tourism and emigration. However, foreign shocks, domestic import restrictions, and monetary tightening are projected to slow growth in Nepal. At the same time, high external debt and tightened global financial conditions pose dangers to the Maldives' fiscal and external accounts. Besides, the inflation rate in SAARC is projected to decline to 8.9 % this year and to decrease below 7 % by 2024 (World Bank, 2023a). However, the fall in inflation has been slower than expected due to weaker currencies and slower domestic price adjustments. The recent rise in international and domestic food costs has made the situation even more precarious for people experiencing poverty in SAARC, who already spend a disproportionate amount of their income on food.

Considering the above socioeconomic challenges in SAARC, we must acknowledge that, adopting ICT is not always easy and affordable, especially for the poorer section

of society, On the other side, ICT spread needs to be improved by a dearth of locally relevant digital material. A considerable proportion of the population of SAARC countries relies on agriculture, has poor literacy, and suffers from low per capita income, all of which are preconditions to ICT adoption. Since most ICT content is in English, individuals with limited English proficiency need help mastering them. The existence of ideals that conflict with a community's local culture is another factor that contributes to the development of socio-cultural barriers (Cruz-Jesus et al., 2018). Given the many societal, cultural, infrastructural, economic, and technological barriers to ICT diffusion in SAARC, the government must play an active role.

Therefore, the present study delves into the challenges confronted by an area that holds great potential for the success of global development in the early twenty-first century through an ICT revolution. The need for the study also arises due to the contradictory research evidence on the links between ICT diffusion, financial, economic, and sustainable development. Therefore, further research is required to comprehend the interplay between these variables to implement efficient policy measures to guarantee sustainable development in SAARC.

1.3 Objectives of the Study

The present work is designed to answer the abovementioned issues for SAARC economies. Accordingly, the specific objectives of the study are designed as follows:

1. The first objective is to examine the role of ICT diffusion in financial and economic growth.
2. The second objective is to analyze the impact of ICT diffusion on achieving inclusive growth.
3. The third objective is to investigate the effect of ICT diffusion on environmental

sustainability.

1.4 Significance of the Study

The study is a fresh attempt to examine how ICT diffusion might help SAARC economies reach their SDGs. Policymakers will benefit significantly from the insights provided by this study, which should help them better understand the difficulties of the aforementioned interrelationships and chart a course towards high, sustained, inclusive growth. Sustainable development is crucial to humanity's long-term survival. Therefore, it is paramount for modern society to figure out how to manage sustainability. The study can help create a groundbreaking ICT framework for development to ensure a paradigm shift in tackling SDGs to advance SAARC. It will contribute to the existing literature by filling a fundamental gap in the development literature by examining the trivariate relationship between ICT diffusion, financial development, and economic growth. So that effective policy measures for ensuring sustainable economic development can be introduced, this study also investigates the causal mechanism between these variables in SAARC economies - a group of nations that have not been studied before in this literature.

Further, because one-fourth of the world's population and nearly half of the world’s poor live in SAARC, the organization faces the challenge of figuring out how to use ICT to bring about inclusive development in a region plagued by the digital divide. For growth to be truly inclusive, it must ensure that economic gains and opportunities are afforded to everyone who chooses to participate. In light of this, the study's goal to examine how ICT contributes to inclusive growth in the region to reduce poverty, boost human development, and provide women in particular more empowerment is significant.

Moreover, the study intends to accomplish something that has yet to be done: investigate the ecological effects of ICT in the developing economies of SAARC. This will inform

policymakers so that they may promote green growth and ICT use in developing economies without compromising environmental safeguards. Furthermore, the study suggests the mechanisms through which ICT influences sustainability over time. The study is a fresh attempt to examine how ICT diffusion might help SAARC economies reach their SDGs. Policymakers will benefit significantly from the insights provided by this study, which should help them better understand the difficulties of the interrelationships and chart a course towards high, sustained, inclusive growth. Sustainable development is crucial to humanity's long-term survival. Therefore, it is paramount for modern society to figure out how to manage sustainability. The study can help create a groundbreaking ICT framework for development to ensure a paradigm shift in tackling SDGs to advance SAARC. It will contribute to the existing literature by filling a fundamental gap in the development literature by examining the trivariate relationship between ICT diffusion, financial development, and economic growth. So that effective policy measures for ensuring sustainable economic development can be introduced, this study also investigates the causal mechanism between these variables in SAARC economies - a group of nations that have not been studied before in this literature.

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Moreover, the study intends to accomplish something that has yet to be done: investigate

the ecological effects of ICT in the developing economies of SAARC. This will inform policymakers so that they may promote green growth and ICT use in developing economies without compromising environmental safeguards. Furthermore, the study suggests the mechanisms through which ICT influences sustainability over time.

Most of the existing ICT literature is geared towards the developed world and pays little attention to the developing world (Akande et al., 2019; Salahuddin & Gow, 2016). In addition, prior research has only examined ICT along a single dimension (i.e., mobile phones and internet usage), which cannot be extrapolated to encompass other facets of ICT (Hossain & Samad, 2021; Salahuddin & Gow, 2016). In addition, the possible issue of endogeneity of the variables needs to be addressed in empirical investigations (Higón et al., 2017b). Finally, the ICT research often overlooks CSD in the data (Pradhan et al., 2013; Pradhan et al., 2017a). Nevertheless, neglecting CSD may result in a loss of efficiency inside the estimator and may provide biased results. Thus, care should be taken when interpreting the findings of studies employing non-endogeneity and cross-sectional independence assumptions. The gaps mentioned above in the currently available ICT literature served as the inspiration for the present investigation.

This research adds to the growing body of literature exploring the impact of ICT diffusion on financial, economic, and sustainable development in SAARC economies, a group of nations which, to our knowledge, has yet to be addressed in the existing literature. The study is based on the latest available data and an in-depth analysis of trends. The analysis is not limited to a single ICT indicator. The research uses PCA to construct a composite ICT index, including mobile technology, fixed broadband usage, internet usage and fixed landline usage. It employs the latest econometric methodologies, some of which are robust to CSD, such as Cross-sectional-autoregressive-distributed lag (CS-ARDL), Dynamic common

correlated effects (DCCE) estimation, Driscoll and Kraay (DK) standard errors approach, Dumitrescu-Hurlin (DH) Panel Granger Causality etc. The study aims to spark discussion among policymakers, academics, and the general public. It reveals the choices available to regional decision-makers and underlines the tremendous opportunity of ICT diffusion for financial, economic, and sustainable development in this rapidly developing region.

1.5 Structure of the Thesis

The present study consists of 7 chapters. Chapter 1 introduces the concept and framework of ICT diffusion. It also highlights the situation of SAARC economies, the need and significance for the study, and the research objectives. Chapter 2 summarizes vital trends and examines the state of ICT infrastructure in the SAARC region, its financial and economic development, macroeconomic situation, and environmental characteristics. Chapter 3 presents the empirical methodology employed in this study.

The rest of the research is laid up as follows: Chapter 4, titled "ICT Diffusion, Financial Development and Economic Growth", examines the dynamic relationship between ICT diffusion, financial development, and economic growth in SAARC economies, in line with SDG 8 and SDG 9 for 2030 by the UN.

Chapter 5, titled "ICT Diffusion and Inclusive Growth" looks into the impact of ICT diffusion on three main aspects of inclusivity. First, the study examines the relationship between ICT diffusion and poverty reduction in SAARC countries, in line with SDG 1 for 2030 by the UN. Second, it examines the significance of ICT diffusion in fostering human development in SAARC countries, in line with SDG 3 and SDG 4 for 2030 by the UN. Finally, the study sheds light upon the issue of Women's empowerment by analyzing ICT's role in women's labor force participation in SAARC countries, in line with SDG 5 for 2030 by the UN.

Chapter 6, titled "ICT Diffusion and Environmental Sustainability" examines the impact of ICT diffusion, globalization, financial development, government effectiveness, and economic growth on sustainable human development (i.e., the development of human capital adjusted against the human ecological footprint) in SAARC economies. It also examines the transmission mechanism through which ICT impacts long term sustainability and tests the validity of environmental Kuznets curve (EKC) hypothesis. It looks into the direct impact of ICT on the environment and the indirect impact through interaction with energy consumption, financial development, and globalization in SAARC economies.

Lastly, Chapter 7 of this thesis concludes with policy implications. It highlights the issues discussed in previous chapters and suggests policy implications, limitations, and the future scope of the study.

Chapter-2

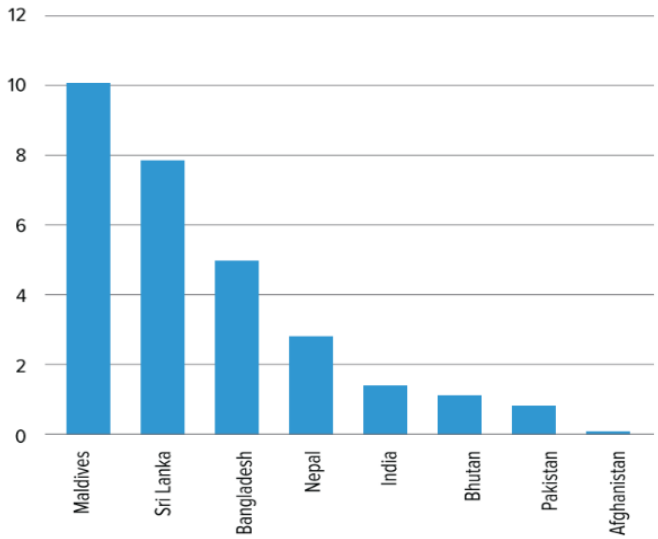
Stylized Facts and Trends

This chapter summarizes key trends and examines the state of ICT infrastructure in the SAARC area, its financial and economic development, macroeconomic situation, and environmental characteristics. Building on the assessments in eight country-specific reports (Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka), it discusses the opportunities and bottlenecks emerging in SAARC countries at the national and regional levels to fully realize its transformative potential for economies, society, and governments.

2.1 ICT Diffusion in SAARC

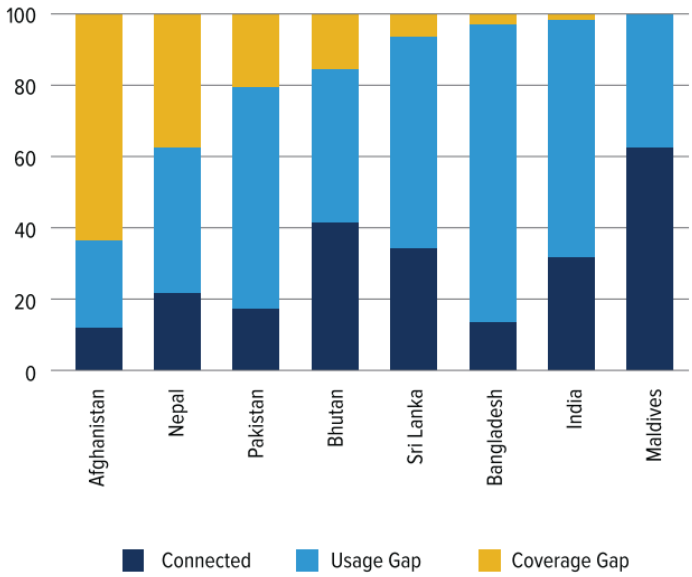
Access to information, education, and training, increased administrative efficiency in public services, and increased economic growth and productivity are just some of the many societal and economic benefits that could result from the widespread adoption, increased affordability, and increased availability of ICTs (Hughes et al., 2017). Strong evidence links to access to the internet with improved employment and re-employment prospects (Nkoumou Ngoa & Song, 2021), greater labor force participation (Samargandi et al., 2019) and household spending (Akeel, 2022). By allowing for remote labor and giving alternate channels to access knowledge, markets, and services, Internet access promotes economic and social resilience amid unfavorable shocks such as COVID-19.

Broadband availability and adoption, however, vary significantly among SAARC nations. Most nations have eliminated coverage holes for mobile networks, but fixed broadband access is still difficult for many. Significant digital literacy gaps, insufficient data and device affordability for the lowest income quintiles, and a dearth of helpful content and applications all contribute to the significant usage gap (the number of individuals who live within the range of a mobile network but do not use the internet).



[Source: World bank (2022b)]

Figure 2.1: Fixed broadband subscriptions per 100 Inhabitants, 2019



[Source: World bank (2022b)]

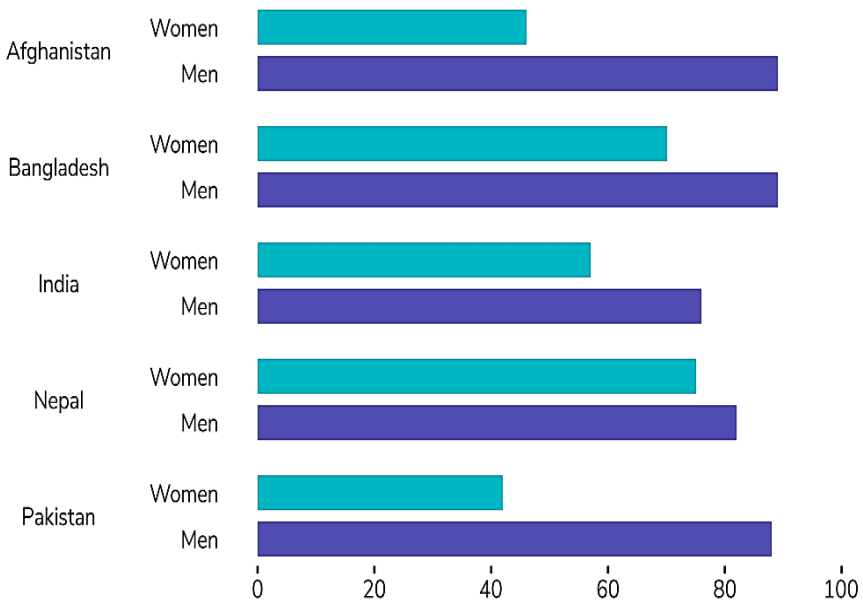
Figure 2.2: Coverage gaps and usage gaps by country, SAARC

The area has the most significant number of individuals (61%), relative to the rest of the globe, who are within the range of a telecommunications network yet do not use the internet (World Bank, 2022c). Since 2017, this has stayed the same. Low adoption in the region's three most populous countries Bangladesh, India, and Pakistan (Figure 2.1) and restricted adoption by low-income groups and women are significant factors in the wide usage disparity. In addition to financial expenditures in networks, favorable regulatory rules on spectrum allocation and management are necessary to reduce coverage gaps. Besides, a more in-depth investigation of the causes of low internet adoption across demographics is necessary to narrow the use discrepancies.

Although the gender gap in mobile ownership in SAARC has shrunk from 26% to 19%, and the difference in mobile internet usage has shrunk from 67% to 36%, it remains the largest in the world (World Bank, 2022c). Preliminary data conducted during the COVID-19 epidemic reveals that gender differences in mobile internet use have widened in the region, from 36% for women to 52% for males (World Bank, 2022c). In SAARC, women are 18 % less likely than males to own a mobile phone. With differences in mobile ownership of 19 and 17 percentage points, respectively, India and Bangladesh are close to the SAARC mean (Figure 2.3). India and Bangladesh had the most considerable rural-urban differences of the nations examined in the nationally representative After Access Surveys (Figure 2.4). Also, except for Afghanistan and Nepal, 4G coverage across SAARC has expanded significantly during the past five years (Figure 2.5). The following sections further delve into country-wise assesment if ICT infrastructure in SAARC economies:

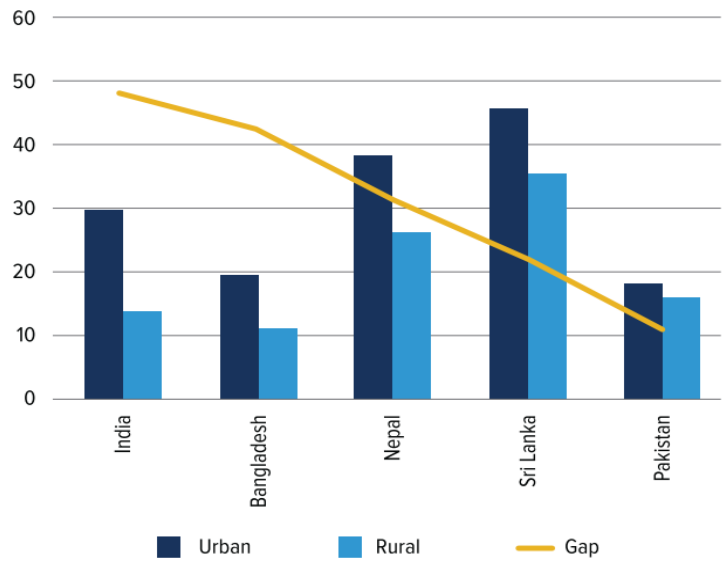
Afghanistan

From 2002 to 2021, there was a rise in the number of Afghans who subscribed to mobile phone service. The number of mobile phone users in Afghanistan were 22.68 million in 2021(ITU, 2022). The private sector has spearheaded the development of mobile networks. Broadband internet penetration is rising gradually due to the rollout of 3G and 4G mobile services in 2013 and 2017, respectively. However, there are still voids in the rollout of high-speed Internet connections. While reports indicate that 3G coverage across the country has improved to 90%, adoption rates still need improvement, with only 0.4% of the population having access to 4G/LTE (World Bank, 2022c). About 70% of people, especially those living in remote locations, rely on slow, reliable 2G connections. Subscriptions to fixed broadband are also scarce: At 0.4% in the middle of 2019, household penetration of fixed broadband was below the average for countries in the same area and the same decile of gross domestic product (GDP) per capita.



[Source: The global findex database, 2021 (Demirgüç-Kunt et al., 2022)]

Figure 2.3: Adults with a mobile phone (%), 2021



[Source: World bank (2022b)]

Figure 2.4: Rural-Urban gaps in internet use

Bangladesh

Bangladesh moved from position 132 in 2014 to 125 in 2016 on the World Bank's Digital Adoption Index (World Bank, 2016). This indicates the increased use of technology in everyday life, commerce, and government. While other SAARC nations like Nepal and Afghanistan have made more strides in adopting digital technology, Bangladesh has lagged. Several encouraging trends point to room for development. The Mobile Economy Asia Pacific Report 2022 (GSMA, 2022) predicted that Bangladesh will increase from its current subscriber penetration rate of 55% to 59% by the year 2025. Second, the government of Bangladesh's ICT Division reports that the country's 650,000 registered freelancers bring in USD 100 million yearly, making Bangladesh the second biggest country in the world offering online labor, after India (World Bank, 2022c). Nonetheless, fixed broadband penetration per 100 people has increased, from 6 in 2020 to 6.58 in 2021 (ITU, 2022). In addition, there is a significant gender disparity in the country, with females being 55% less likely to use the internet than males (World Bank, 2022c). The absence of facilities catering to both sexes plays a role, but widespread cultural obstacles are also to blame (Figure 2.6).

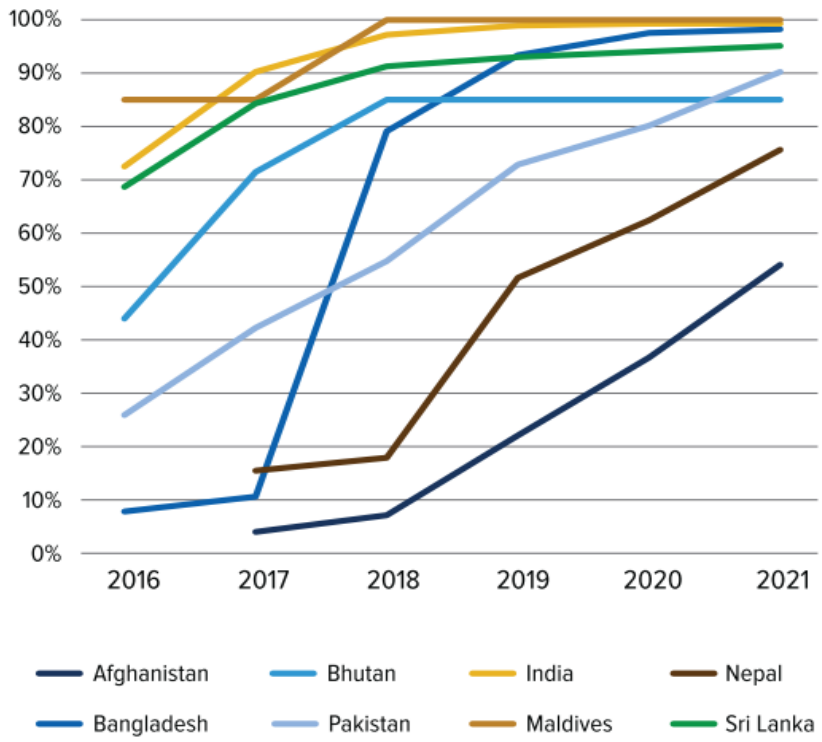
Bhutan

The current situation in Bhutan makes it ideal for the country to use ICT diffusion to promote economic growth and social inclusion. 90% of people have internet access, and 98% have mobile phones (World Bank, 2022c). Most people in Bhutan are confident in using various types of online communication. To advance digital governance and foster creativity, the government set up a central hub where citizens may access various services. Thimphu Tech Park was established in 2012 to cater to the demands of ICT and knowledge-based startups (World Bank, 2022c). The World Bank's Digital Adoption Index shows that the adoption and use of digital technologies in Bhutan have improved over time (World Bank, 2016). However, the country still trails significantly behind Bangladesh, India, and Pakistan. While most homes have access to mobile and internet basics, just 2% of people have fixed broadband connections (World Bank, 2022c). The development of affordable and high-speed internet services in Bhutan is hindered by competitive and market structure constraints, such as the country's near duopoly in the internet services market and its heavy reliance on Indian telecommunications operators for international connectivity. As a result, only 4% of users in the country experience internet speeds above 10 Mbps (World Bank, 2022c). More work must be done before the digital economy is accessible and beneficial to everybody.

India

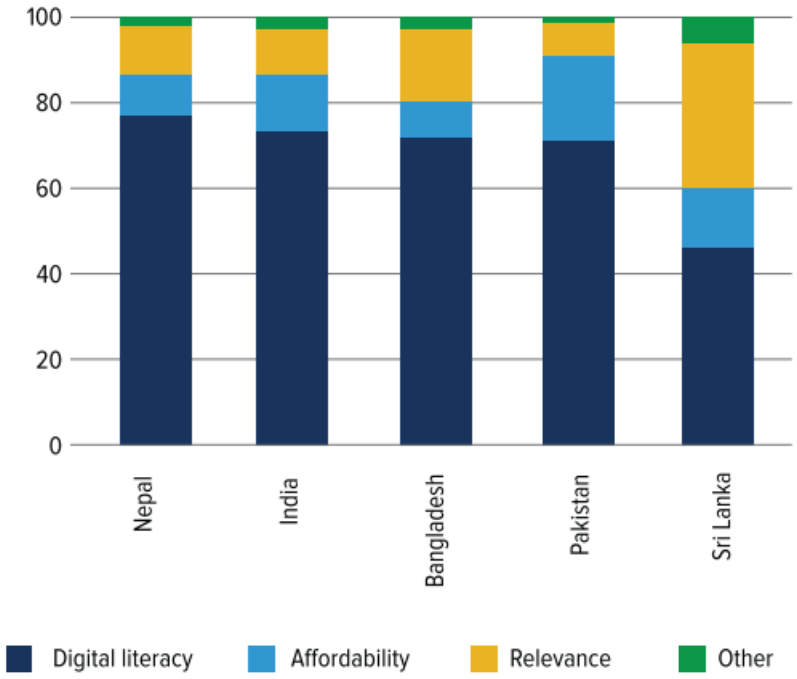
India is home to the world's second-largest telecom market, with over 1.2 billion phone users and over 830 million internet subscribers (World Bank, 2022c). The number of internet users per 100 people has increased by 2.4 times between June 2015 and June 2021, from 25.3 to 61 (interestingly, the increase in rural internet usage has been higher than in the urban areas, with the number of users per 100 people in rural areas increasing by almost 2.9 times, from 13 to 38) (ITU, 2022). Mobile-based services have driven this expansion,

while India's fixed broadband adoption lags behind its global competitors. Several lower and middle-income nations such as Indonesia (3.9), the Kyrgyz Republic (4.2), Bangladesh (5.8%), and Vietnam (17.2%) all had more fixed broadband subscribers per 100 inhabitants in 2020 than the United States (1.61 per cent). India's capacity to use next-generation high-bandwidth services like 5G would be hindered because just a third of telecom towers have an optical fibre backhaul. Despite the country's progress towards a fully digital culture, India still has a significant digital divide. According to the Fifth National Family and Health Survey (Government of India, 2022), just 42.6% of women and 62.16 % of males have used the Internet. Women's Internet access and utilization are hindered by several factors, the most prominent of which are a lack of technical know-how to access the Internet and reading or writing difficulties (Figure 2.6).



[Source: World bank (2022b)]

Figure 2.5: Percentage of population covered by 4G networks



[Source: World bank (2022b)]

Figure 2.6: Reasons for not using the internet

Maldives

When compared to other SAARC countries, Maldives has superior internet access. 60% of the population utilized the Internet in 2019 (World Bank, 2022c). However, considerable differences in perception and usage continue between groups based on geography and educational attainment. According to the Household Income and Expenditure Survey (HIES) 2019 (National Bureau of Statistics, 2019), 83% per cent of Malé homes, according to preliminary estimates from have access to fixed internet services, but just 51% of island families have. Furthermore, Malé residents get twice as fast download speeds (on fixed broadband connections) as those in the atolls. Adoption of fixed broadband services is below the upper-middle income nation average and the level expected for a country of this income level. A monthly subscription for an entry-level fixed broadband package costs roughly 3.1% of per capita income, likely a significant disincentive (World Bank, 2022c). The average download speed in the Maldives in January 2021 was just 24.5 Mbit/s, making it much slower than the speeds available in

Bangladesh (33.5 Mbit/s) and India (54.7 Mbit/s) (World Bank, 2022c). In contrast, developed countries are expanding access to super-fast broadband internet with download rates of more than 100 Mbit/s. Many people in the Maldives cannot afford to use the Internet. Problems with affordability are partly due to their locations. For example, less than ten of the bigger islands have fibre optic cable networks connecting them.

Nepal

Good progress has been made in Nepal towards universalizing access to the Internet, with over 75% of the population already using it (World Bank, 2022c). Approximately 7 million people have access to fixed broadband, whereas 18 million people have subscriptions to mobile Internet and broadband (equal to roughly two-thirds of the population) (ITU, 2022). Mobile networks are the most common way to get online in Nepal because access to fixed-line networks and the faster connection is restricted outside of metropolitan regions. All the 77 districs of the country now all have access to the Internet. Despite recent improvements, broadband Internet access still needs to be developed in Nepal, especially outside of major towns. Continuous disparities exist in adopting and using services because of high prices, inadequate coverage, and unreliable service (Figure 2.6). In addition, there is a significant gender disparity in Nepal regarding account coverage and use: 58% of women and 50% of men are unbanked (World Bank, 2022c). This is because of a combination of factors, including low customer trust and confidence and low financial and technological awareness levels. While the affordability criteria are set at 2% of gross national income (GNI) per capita, the cost of an entry-level mobile broadband bundle is closer to 2.75 %. Similarly, at 2.30 % of GNI per capita, the price of a fixed-broad-band basket with monthly data use of (at least) 5 GB exceeds the affordability criterion of 2% (World Bank, 2022c). Nepal is 115th out of 134 nations regarding the affordability of mobile devices, and phone costs continue to be high. These

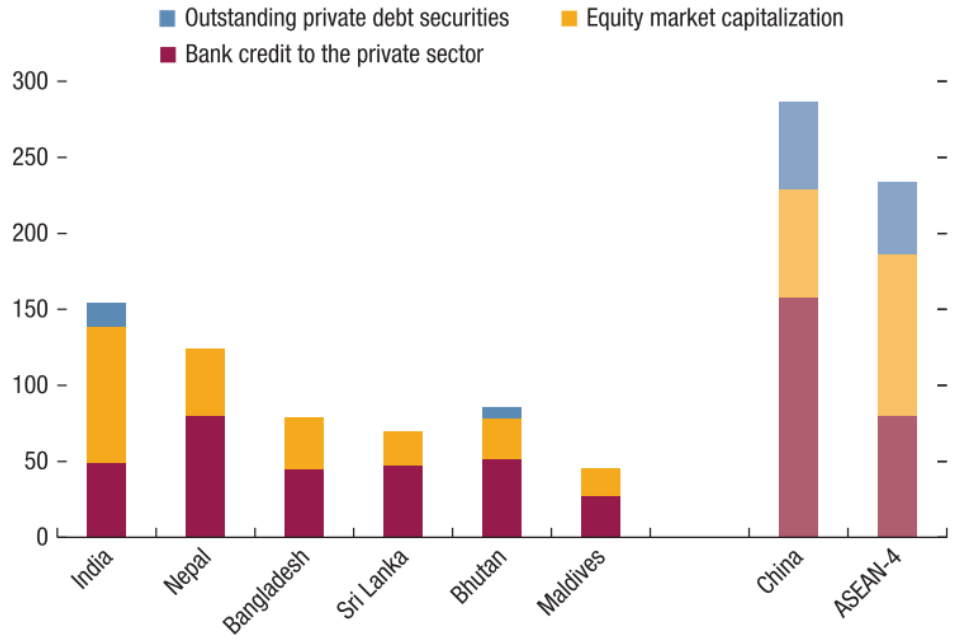
digital access gaps are exacerbated by factors including the high cost of equipment (particularly smartphones), high customs duties, and consumer reluctance to embrace smartphones owing to a lack of digital literacy.

Sri Lanka

The foundation of a prosperous digital economy is the widespread availability of low-cost, high-quality broadband Internet connectivity. Online education, shopping, and access to public services would all suffer without it. The percentage of the population using the Internet between the ages of 5 and 69 in Sri Lanka was 30.3% in the first half of 2019, which is lower than many nations with similar levels of GNI per capita (ITU, 2022). Furthermore, there was a disparity in internet usage across different regions and different demographics. In 2018, those living in cities had a 23% higher rate of internet use than those living in rural regions. There is also a significant gender discrepancy, with males being 34% more likely to use the Internet than women (World Bank, 2022c). Both fixed and mobile broadband penetration is low. In comparison to Thailand (98%), Vietnam (36%), and India (51%), just 28% of the population has access to 4G mobile broadband. Even though the average cost of mobile broadband services is less than 2% of GNI per capita, this is still out of reach for the poorest 60% of the population. Additionally, there are limitations on connection speed and quality (Figure 2.6). Regarding mobile broadband speed, Sri Lanka rated 121st out of 141 nations in February 2021, while fixed broadband speed ranked 107th out of 175. The lack of competitive pressure on the market is primarily to blame for the dismal market results regarding digital infrastructure. The two leading service providers control most of the market, with the monopoly Sri Lanka Telecom implementing some of its own initiatives with no challengers (World Bank, 2022c).

2.2 Financial Development in SAARC

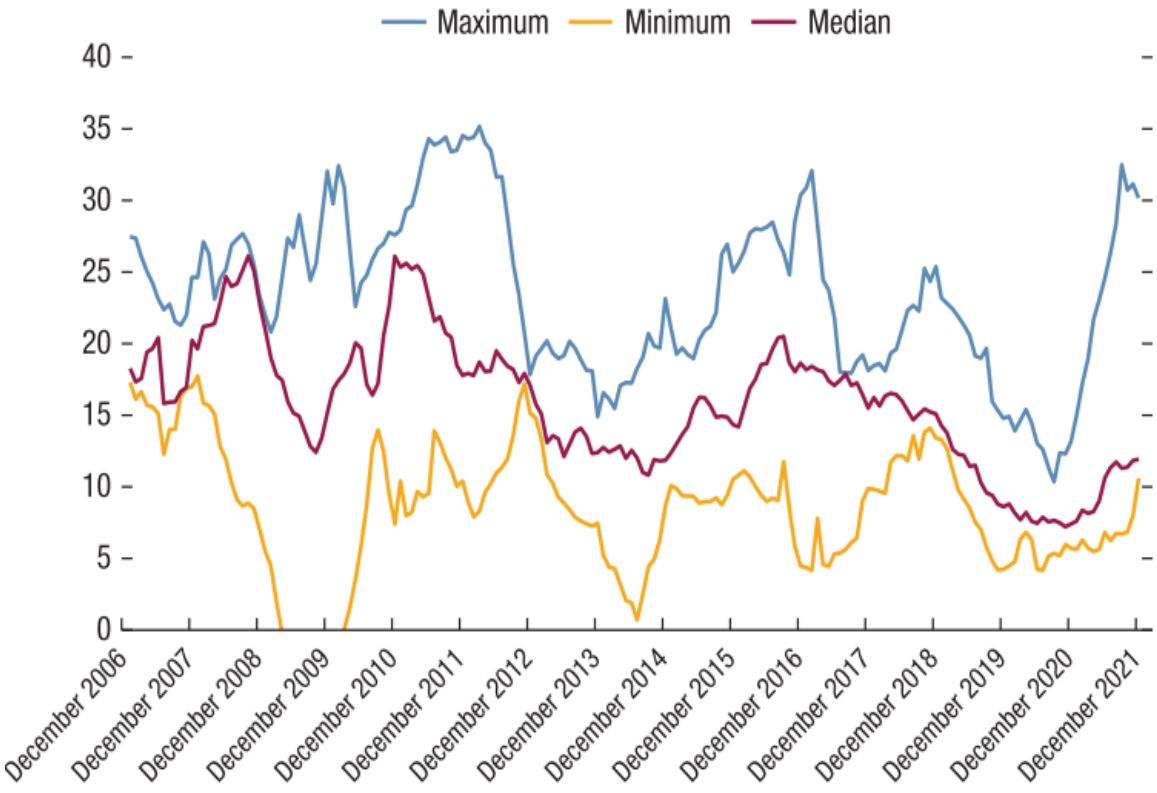
SAARC economies lags behind its rivals when it comes to financial development and inclusion. The IMF created the Financial Development Index to measure the breadth, ease of access, and effectiveness of a country's financial system. In 2017, SAARC ranked lower than its G20 and ASEAN-8 counterparts on the IMF Financial Development Index (Svirydzenka, 2016). The financial sector in SAARC (excluding India) is still in its formative phases and confronts many challenges. Bhutan, for instance, issued its first-ever government bond in 2020. Due to the greater risk-free yield offered by national savings certificates, bond markets in Bangladesh remain limited. Given the high levels of national savings, there is great potential for market growth in these nations, provided that market-based pricing of government assets is implemented with further liberalization (such as lifting the ceiling on interest and deposit rates in Bangladesh). Regarding the growing degrees of liberalization that aided market growth, the example of India is instructive for other nations due to its considerably more extensive and more developed financial sector.



[Source: IMF (2023)]

Figure 2.7: SAARC: Financial depth (Percent of GDP, 2018 or latest)

Figure 2.7 shows that equities and bond markets are undeveloped everywhere but India. For a private enterprise to flourish and long-term capital to be efficiently mobilized especially for infrastructure investment further development of the sector and depth of capital markets are required. The median private sector credit growth in the region's four largest economies slowed to 7.4 per cent in December 2020, the lowest level in at least 14 years (Figure 2.8), highlighting the importance of reviving efforts to advance financial development once the pandemic has been overcome. A number of interrelated issues have contributed to a slowdown in credit growth in the area. A cyclical decline in the regional economy, made worse by the crisis produced by the COVID-19 epidemic, has provided the stage for the manifestation of underlying structural flaws impacting the region's banking systems.



[Source: IMF (2023)]

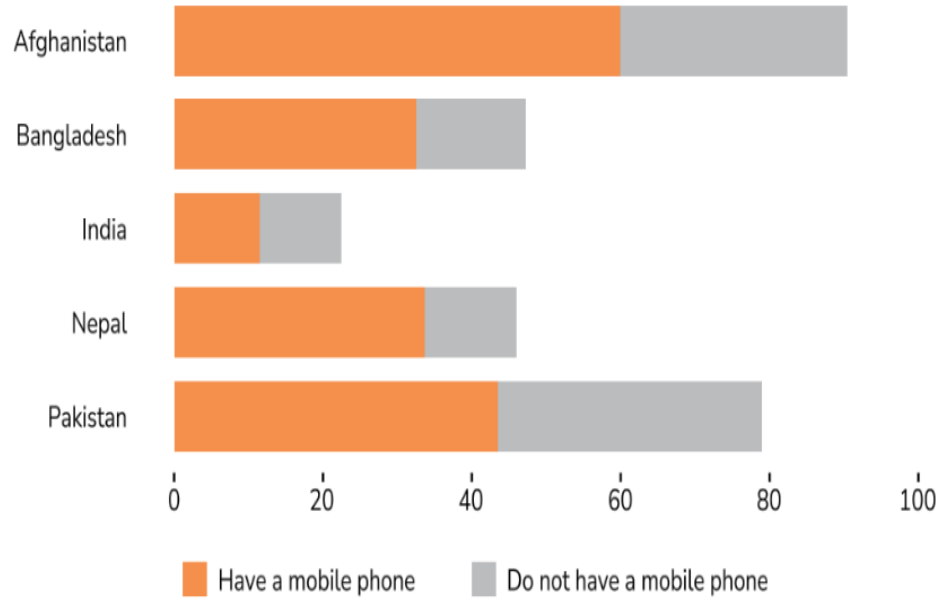
Figure 2.8: Private sector credit growth in SAARC, except Bhutan and Maldives (%)

Regarding both financial market development and access to financial institutions, SAARC nations fall well behind their contemporaries. Only 11% of adults in SAARC used a financial institution for borrowing and saving in 2021 (Demirgüç-Kunt et al., 2022). While nearly half of adults admitted to taking out a loan in the previous year, most of those who did so did not use a traditional bank but rather borrowed from friends and family. In addition, 32% of adults in SAARC who have a bank account said they never use it because they do not make deposits or withdrawals, indicating low financial service utilization and ample room for policies to promote greater adoption of the no-frills accounts that have been so successfully introduced in SAARC countries.

With respect to financial inclusion, SAARC, which has a total population of more than 1.9 billion people, is struggling with a lack of access to financial services. The Global Findex 2021 database reports that the area has a financial inclusion rate of 68%, which is lower than the 71% average of emerging economies (Demirgüç-Kunt et al., 2022). Since 2017, there has been no change in the percentage of adults with accounts. However, the proliferation of smartphones presents a one-of-a-kind chance to expand access to financial services using mobile payments. Over half of the 430 million individuals in the region who do not have bank accounts have a mobile phone. According to the Global Findex Report (Demirgüç-Kunt et al., 2022), 56% of individuals without a bank account in the SAARC have access to a mobile phone; this includes 51% of Indian adults and 55% of Pakistani adults. The percentage of adults without bank accounts who own a mobile phone is 69% in Bangladesh and 73% in Nepal (Figure 2.9).

Further, gender parity in access to financial services remains a problem in SAARC (Demirgüç-Kunt et al., 2022). In India and Sri Lanka, where there is no gender disparity in account ownership, it is 17 and 18 percentage points, respectively. Similarly, in

Bangladesh, there is a gender discrepancy of 15 percentage points when making digital payments and a gap of roughly 20 percentage points for account ownership. In Pakistan, there is a gender discrepancy of 15% in account ownership, yet regardless of gender, the vast majority of account holders (84%) utilize their accounts for digital payments.



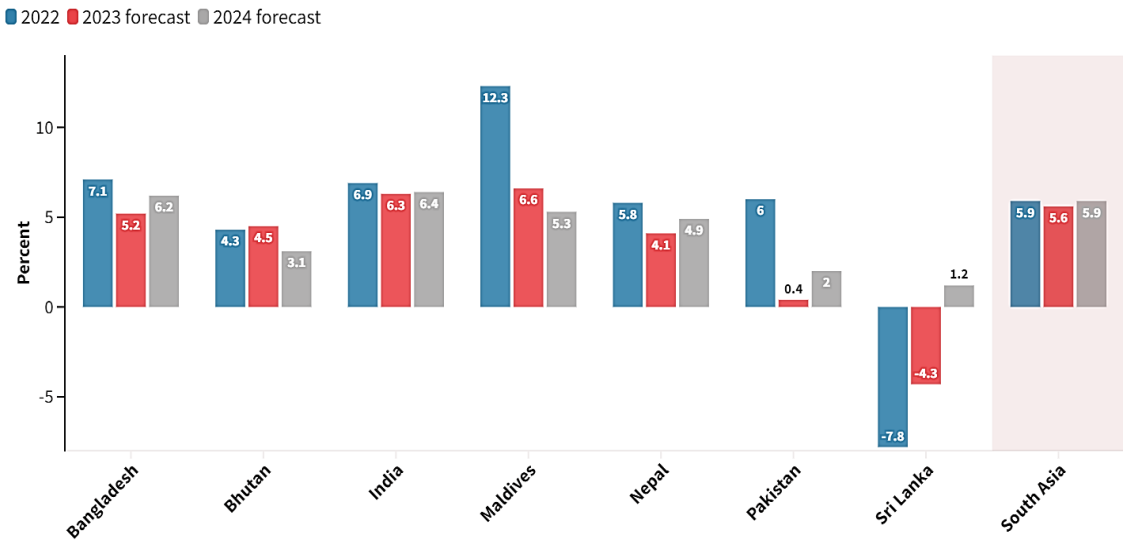
[Source: The global findex, 2021]

Figure 2.9: Adults with no account (%), 2021

One of the most critical aspects of financial inclusion is financial resilience i.e., the capacity to bounce back from financial setbacks, such as job loss or a large, unexpected bill. The percentage of adults who say they have easy access to an emergency fund is much lower in SAARC, at just 8%. This figure is far lower than the average of 27% for emerging economies. Even though savings are the safest way to cover unexpected expenses, just 23% of SAARC adults said they had done so in the previous year (IMF, 2023). This percentage is far lower than the average of 42% seen in emerging economies. These challenges must be met head-on if the area is to achieve financial resilience and expand access to financial services for its residents.

2.3 Economic Development in SAARC

After a rapid recovery from the pandemic in 2021, growth in SAARC's GDP is predicted to slow to 5.6% in 2023 and 5.9% in 2024 (Figure 2.10).



[Source: World bank report, 2023]

Figure 2.10: SAARC real GDP growth

The growth rate projection for 2023 was lowered by 0.5 percentage points from the previous projection made in October 2022 (World Bank, 2023a). Slowing consumer spending and continuous fiscal consolidation will likely reduce India's GDP growth prediction to 6.3% in the fiscal year beginning in April 2023, from the previous October 2022 and January 2023 projections (World Bank, 2023a). Even with the IMF programme that would assist in reducing the country's funding deficit, Sri Lanka's GDP will continue to decline in 2023, but at a slower pace than in 2022. The economic toll of the floods in Pakistan in the second half of 2022 persists. This coincides with a host of economic issues and uncertainties facing the country as it awaits the renewal of its programme with the IMF. This causes a downward revision of more than one percentage point for Pakistan's GDP growth rates in the current and next fiscal year. The effects of the tightening of monetary policy, steps to restrict imports, and post-electoral political instability all contributed to a negative adjustment of

GDP projections for Nepal also in the current fiscal year. Since the January 2023 forecast already factored in the effects of the IMF programme and related policy measures signed into effect at the end of January, the forecast for Bangladesh's growth was revised downward from October 2022 but remained unchanged. The following sections further delve into the country-wise economic profile of SAARC economies:

Afghanistan

In 2021, the Afghan economy shrank by a staggering 20.7 per cent, but by mid-2022, it appeared to have reached a precarious low-level equilibrium (World Bank, 2023b). Trade and other transfers into and out of Afghanistan continue to be conducted through largely unofficial routes as the country's financial infrastructure remains constrained. In addition, poor demand still significantly affects the private sector's recovery. In 2019-2020, 47 % of the population lived in poverty. According to recent statistics, in 2022, two-thirds of Afghan households could not buy food and other essential non-food goods, causing many individuals to participate in low-productivity jobs to make ends meet (World Bank, 2023b). Significant electrical shortages in cities have deteriorated living conditions throughout the brutal winter months. The base impact of the exchange rate devaluation was fully seen in December 2022, causing annual headline inflation to drop sharply from the high levels seen during the year to 5.3% (World Bank, 2023b). This trend was reinforced by falling global prices, stable exchange rates, and seasonal declines in aggregate demand.

Bangladesh

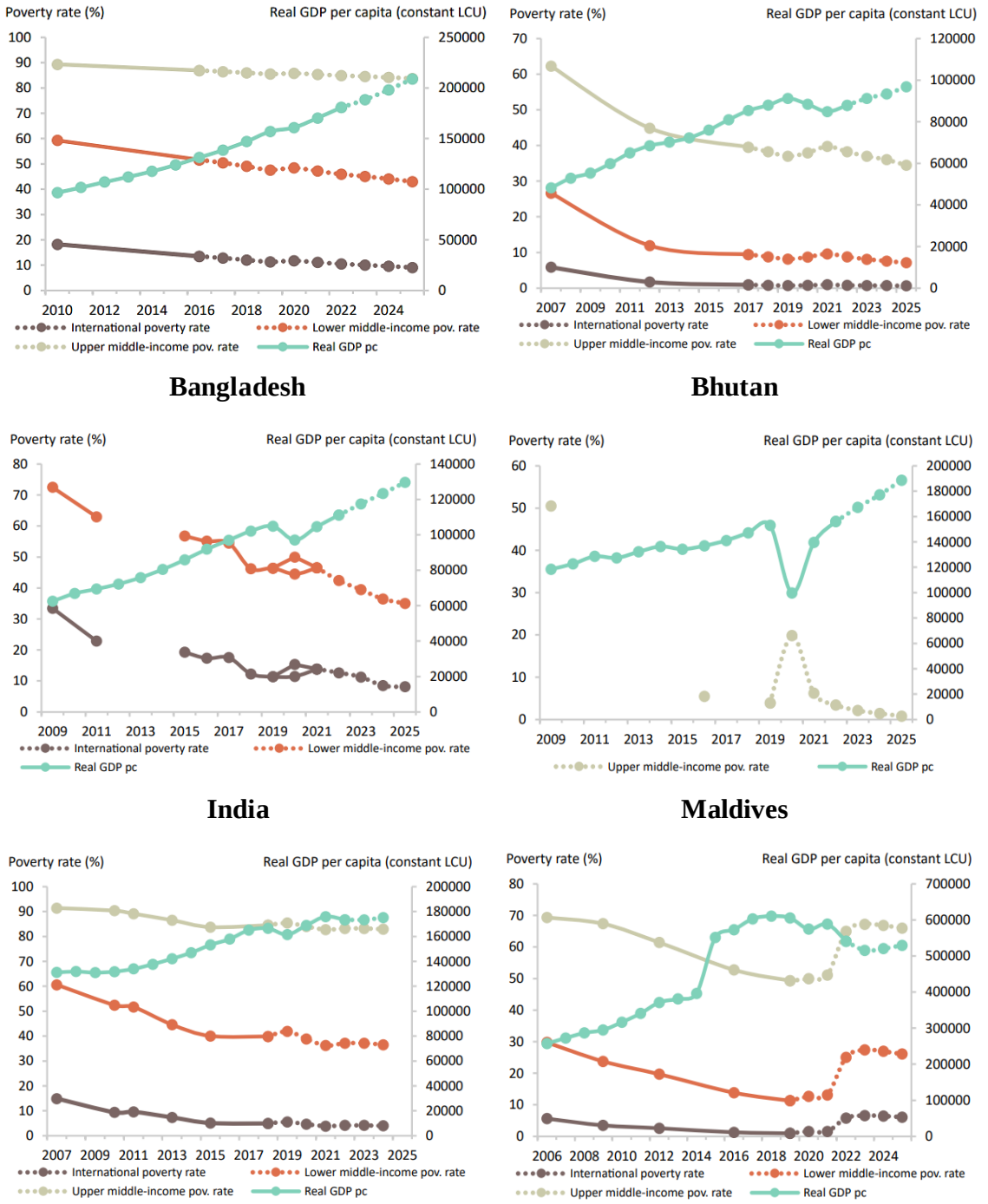
Since 2000, Bangladesh's real GDP has grown by an annual average of 6%, making it one of the world's fastest-growing economies (World Bank, 2023b). Accelerating exports of ready-made garments (RMGs) and a "demographic dividend" has also contributed to the

expansion. Nonetheless, progress in creating new jobs and reducing poverty has stalled during the past decade. Low public sector institutional capacity, export concentration, rising financial sector vulnerabilities, inefficient urbanization, a business environment that lags behind peer economies, and significant susceptibility to climate hazards are all examples of structural flaws that persist. Access to concessional funding and preferential export market access would gradually decrease for Bangladesh once it loses the UN Least Developed Country classification in 2026 (World Bank, 2023b). Bangladesh's macroeconomic measures helped it survive the COVID-19 epidemic, and the country is now seeing positive real GDP growth. The poor, especially women, were hit hardest by the widespread layoffs and declining wages caused by the epidemic. An increase in the administered price of petroleum products and a general increase in the cost of raw materials fueled a surge in inflation. Although employment has increased, pre-pandemic levels of real wages have not yet been restored. The decline in buying power mitigated some of the benefits of the improving labor market. More than two-thirds of the income of the lowest 10% of households goes towards necessities, including food, shelter, and transportation (World Bank, 2023b).

Bhutan

Although poverty and inequality have decreased significantly over the past two decades, they are still severe problems in Bhutan despite the country's rapid economic progress. Since the 1980s, the public sector-led hydropower industry and exemplary performance in services, notably tourism, have contributed to annual real GDP growth of 7.5% on average (World Bank, 2023b). In 2017, it was projected that 8.8 per cent of the population lived on less than $3.65 a day; rural areas and large geographic districts had the highest poverty rates. The socioeconomic situation has significantly worsened due to the COVID-19 outbreak and the spillover effects of the war in Ukraine. Rising young unemployment,

from 20.9% in 2021 to 29.0% in 2022, pushed more people to look for work abroad. In general, inflation fell from 8.2% in FY20/21 to 5.9% in FY21/22, with the drop being driven by lower food prices (World Bank, 2023b).



[Source: World bank (2023b)]

Figure 2.11: Actual and projected poverty rates and real GDP per capita

Maldives

The economy has returned to pre-pandemic levels, and increased tourism will likely keep it on a path of rapid expansion and accelerating poverty reduction. The travel industry, which contributes about a third of the GDP, has bounced back quickly since the epidemic. Strong arrivals from Russia and rising arrivals from India and the Gulf have more than made up for decreasing arrivals from Europe and China despite the conflict in Ukraine. Maldives is very sensitive to macroeconomic shocks, yet the country's excessive reliance on tourism and lack of sectoral diversification remains a fundamental structural concern. Because it relies on imported goods, the Maldives feels the effects of rising external and inflationary pressures. As a result of increases in the cost of imported raw materials, domestic inflation in 2022 averaged 2.3%, much above the historical norm of 0.5% (World Bank, 2023b). The food and beverage industry, the transportation industry, the healthcare industry, and the hospitality industry all saw significant price rises.

Nepal

From FY13 to FY22, the economy grew by an average of 4.5 per cent yearly, propelling Nepal into the world's lower middle classes by 2020 (World Bank, 2023b). Remittance inflows, which averaged 23% of GDP yearly, also contributed to growth during this time. There is a greater chance of poverty and inequality in the medium term due to the sluggish and poor job recovery following COVID-19. Recovered jobs had worse quality (23% lower) and resulted in lower wages (53% lower) compared to lost positions, and almost 30% of individuals who recovered a job experienced more than one employment change (World Bank, 2023b).

Pakistan

Powered by robust public spending, GDP expanded by a sizeable margin beyond its potential in FY22, putting upward pressure on domestic prices, the external and fiscal sectors, the currency rate, and foreign reserves. The devastating floods in 2022, rising global commodity prices, tightening global financial conditions, and local political uncertainty all worsened these imbalances. Also at risk are health and education results since low-income households may need more money to afford food and transport to and from school due to high inflation. In H1 FY23, headline consumer price inflation averaged 25% y-o-y, up from 9.8% in FY22, a multi-decade high (World Bank, 2023b). This is because of the reduced value of the currency, the rising cost of commodities on the international market, the reduction of local fuel and energy subsidies, and the interruptions caused by floods.

Sri Lanka

Several shocks, especially COVID-19, have considerably slowed development and poverty reduction during the past five years. Contributing factors to external imbalances included a restrictive trade system, a lackluster investment climate, periods of lax monetary policy, and a centrally managed currency rate. High fiscal deficits and substantial gross financing needs resulted from years of fiscal irresponsibility, driven mainly by inadequate tax receipts. Tax cuts in 2019 added to these preexisting fiscal imbalances, resulting in an unsustainable increase in debt. Half a million employees in industry and services were lost due to the economic crisis, and even lower-paying agriculture positions could not make the difference. The national poverty rate increased to 25%, and the urban poverty rate increased to 15% due to the economic downturn and rising living costs (World Bank, 2023b). The recession exacerbated existing geographical inequalities and caused a rise in total inequality, leaving 52% of the population in estate regions in poverty.

2.4 Human Development in SAARC

The HDI is a composite indicator that ranks nations according to their degree of human development and divides them into four categories: (1) Very High Human Development; (2) High Human Development; (3) Medium Human Development; and (4) Low Human Development. Life expectancy statistics, educational levels, and GDP per capita are the pillars of HDI. HDI does not place SAARC nations in the top category. According to the Human Development Report (UNDP, 2022), Sri Lanka and the Maldives represent high Human Development, while Medium Human Development includes India, Bangladesh, Nepal, Bhutan, and Myanmar. While India and China have high human development, Pakistan and Afghanistan have poor. Except for Pakistan, every country's position changed from the previous year. Some countries' ranks have dropped from the previous year, including India, Bhutan, Bangladesh, Myanmar, and Afghanistan. On the other hand, Sri Lanka, Maldives, and Nepal improved their rankings from the previous year.

The following sections further delve into the country-wise HDI ranks as per the Human Development Report (UNDP, 2022) of SAARC economies:

Afghanistan

With an HDI of 0.478 and a ranking of 180, Afghanistan is considered to be in the "low development" category. HDI is calculated using the average life expectancy, which is 62.0 years in this case. In Afghanistan, the average number of years spent in education is 3.0, while the expected number of years is 10.3 years. The GNI per capita is $1,824.

Bangladesh

The HDI score of 0.661 and overall ranking of 129 places Bangladesh in the medium human development category. The life expectancy rate of 72 years and 4 months is a major contributor to the HDI rating. In Bangladesh, the average student spends 7.4 years in education, whereas the expectation is 12.4 years. Average annual income per citizen is $5,472.

Bhutan

With an HDI of 0.666 and a ranking of 127, Bhutan is in the middle of the pack when it comes to human development. The life expectancy rate of 71.8 years is a major contributor to the HDI rating. In Bhutan, the average student spends 5.2 years in school whereas the expected number of years in education is 13.2 years. The average yearly income per person is $9,438. The low average number of years spent in schools suggests that boosting access to education is a priority.

India

With a HDI score of 0.633 and a position of 132, India is considered to have medium development. The life expectancy rate of 67.2 years explains the HDI number. The average number of years spent in school in India is 6.7, whereas the country's projected number of years in education is 11.9. The average yearly income per citizen is $6,590.

Table 2.1: Human development index 2022

HDI Rank 2022	Country	HDI Value	SDG3: Life expectancy at birth	SDG 4.3: Expected years of schooling	SDG 4.4: Mean years of schooling	SDG 8.5: GNI per capita	HDI Rank 2020
73	Sri Lanka	0.782	76.4	14.1	10.8	12.578	75
90	Maldives	0.747	79.9	12.6	7.3	15448	97
127	Bhutan	0.666	71.8	13.2	5.2	9.438	125
129	Bangladesh	0.661	72.4	12.4	7.4	5472	128
132	India	0.633	67.2	11.9	6.7	6590	130
143	Nepal	0.602	68.4	12.9	5.1	3877	144
161	Pakistan	0.544	66.1	8.7	4.5	4624	161
180	Afghanistan	0.478	62.0	10.3	3	1824	177
	SAARC	0.632	67.9	11.6	6.7	6.481	-

[Source: UNDP (2022)]

Maldives

With a HDI of 0.747 and a ranking of 90, Maldives is among the most developed nations in the world. The average lifespan of 79.9 years is a major contributor to HDI. The average

number of years a Maldivian spends in school is 7.4 years, whereas the country's projected number of years in education is 12.5. The average annual income is $15,448. Despite having a greater gross national product (GNP) per capita than Sri Lanka, the country has scored worse because of educational factors.

Nepal

With a HDI of 0.602 and a ranking of 143, Nepal is in the medium development group. The average lifespan of 68.4 years is a major contributor to the HDI. The average number of years spent in school in Nepal is 5.1, whereas the country's projected number of years in education is 12.9. The GNI per capita is $3,877.

Pakistan

With an HDI of 0.544 and a ranking of 161, Pakistan is in the "low development" category. A life expectancy of 66.1% is a major contributor to the HDI score. The average number of years spent in education in Pakistan is 4.5, while the expected number of years is 8.7. The average yearly income per citizen is $4,624.

Sri Lanka

Sri Lanka has the highest HDI rating of any SAARC country, at 0.782, ranking it at number 73 in the world. The longer average lifespan of 76.4% explains the higher HDI. The average number of years spent in school in Sri Lanka is 10.8, while the anticipated number of years is 14.1. The average yearly income per citizen is $12,578. The HDI Index does not represent the contemporary viewpoint of the collapse of the Sri Lankan economy in 2022 and the political turmoil.

2.5 Environmental Profile on SAARC

Throughout the twenty-first century, SAARC nations have been confronted with and coping with massive problems. The environmental catastrophe, however, is one of the most pressing new problems. Economic activity, population increase, industrialization, urbanization, and poverty all contributed to the onset of most environmental problems after the 1960s. Since negative and deviant behavior in economic activities could have been more effectively managed due to all these factors, the situation became more complicated. SAARC is a developing region comprised primarily of middle-income countries that are working hard to improve their economies and meet the challenges of political and environmental sustainability challenges. Despite this, the region is still grappling with many pressing environmental crises that are inextricably linked to human activities and, by extension, human lives.

According to the UN's most recent population estimates and predictions, China is expected to give up its long-held position as the world's most populated country in the near future. The population of India is predicted to reach 1,425,775,850 in April 2023, at which point it will equal and eventually surpass that of mainland China (United Nations, 2023). Population growth in SAARC countries, including India, has had a significant negative impact on the region's natural and environmental resources. This is primarily due to increased resource extraction from the environment. According to the Intergovernmental Panel Discussion (IPCC) on climate change, most environmental issues may be traced back to human activity. Pakistan's population is growing at a pace of 1.9% each year, and the populations of neighboring SAARC are also growing at rates that are not sustainable for the region's economy or environment (United Nations, 2023).

Further, the effects of global warming are equally problematic. Developing nations in SAARC are especially at risk from natural disasters brought on by global warming.

Climate-related flood catastrophes have had a devastating historical impact on Pakistan and Bangladesh (Azeem et al., 2023). Both Pakistan and India suffer significantly from severe weather virtually annually. In the summer of 2022, environmental issues will significantly impact economic activity due to "Heat Waves" in India and Pakistan and the "Flood Crisis" in Pakistan, which damaged the country's most populous area last year or roughly a third of the country (Chathu & Ramesh, 2023). In Pakistan, melting glaciers threaten water supplies, as do the almost twenty glacier bodies in Nepal and the twenty-five in Bhutan. According to the World Bank Report, this climatic situation is nothing new to this area. Twenty years have affected the lives of seven hundred and fifty million individuals in SAARC civilizations (World Bank, 2022a). India is placed fourth, while Bangladesh and Pakistan are ranked sixth and seventh on the climate change risk index (Burck et al., 2023)c. According to UN Secretary-General Antonio Guterres's recently released "Code Red for Humanity" assessment on climate change, the world is projected to warm up to 1.5 degrees Celsius over the next two decades.

Urbanization and population growth have made pollution a significant issue in SAARC countries. Pollution results from human activities such as industrialization, transportation, burning of coal and biomass, excessive use of metals, and soil depletion of natural resources and minerals. According to the Air Quality Life Index (Energy Policy Institute, 2023), Bangladesh is the most polluting country in the world followed by India and Pakistan at second and fourth rank respectively.

In addition, burning fossil fuels like coal and petroleum, as well as fires and releasing hazardous gases, has been identified as a significant contributor to global warming. CO2 emissions from SAARC countries substantially contribute to climate change. To counteract this, several nations in SAARC have instituted a tax on carbon-related components as a modest fiscal policy measure (Nozaki et al., 2021). SAARC consumes

around 5.9% of the world's energy resources (excluding non-commercial energy resources) as a whole. Since 2000, energy consumption in SAARC countries has surged by as much as 50 %. Population expansion and increased industries are driving the increased need for energy. Over the past two decades, electricity demand in all SAARC countries has grown by an average of more than five per cent annually. This growth is expected to accelerate the country imports around 65% of its energy needs. As a result, there is a push to improve cost recovery in anticipation of rising demand. SAARC governments are under increased pressure to safeguard their energy supplies as interruptions caused by violence in neighboring countries have a negative effect on gasoline imports.

2.6 ICT Diffusion-Development Framework

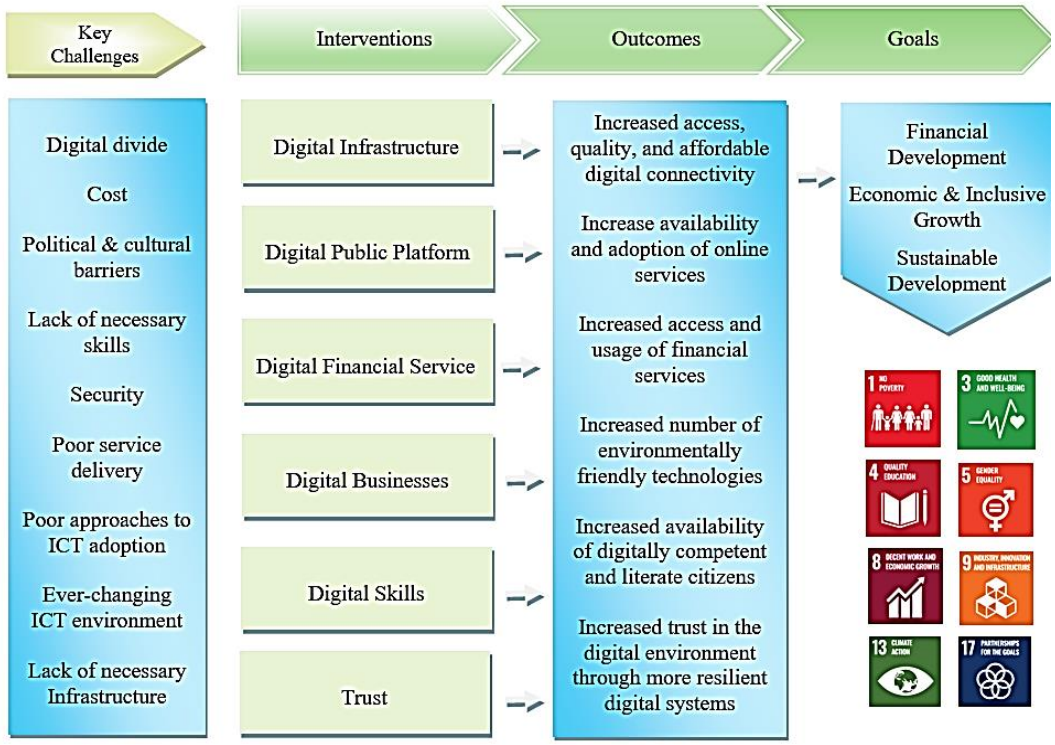
The widespread adoption of ICT has altered the dynamics among nations, businesses, and citizens. The transition to digital economies, society, and governments has the potential to significantly improve quality of life by increasing access to services and markets, generating new jobs, fostering innovation, decreasing transaction costs, and advancing sustainability. As mobile network infrastructure has improved and internet use has grown, countries in SAARC have started to reap the benefits of ICT diffusion. However, ICT diffusion has yet to reach its full game-changing potential in the region. The devastating effects of the COVID-19 pandemic and the evident implications of climate change have increased reliance on ICT tools while exposing the tangible costs of digital inequalities. Therefore, a holistic digitization strategy through ICT diffusion may play a crucial role in SAARC's path towards sustainable, resilient, and inclusive growth.

Core to this strategy is the framework of ICT diffusion and development (Figure 2.12), which demonstrates how a cohesive and coherent approach to ICT diffusion leading to a

digital economy could enable the region's development by enabling every individual, business, and government to participate in the digital economy. The adoption and implementation of ICT comes with both possibilities, and challenges. The high price of services is likely a significant deterrent. In Bangladesh, the price of a monthly subscription for an entry-level fixed broadband plan is about 3.1 per cent of per capita income (World Bank, 2022c). Political and cultural barriers also prohibit the successful implementation of efficient ICT services (Shachaf, 2008). Examples include how the two leading service providers in Sri Lanka control most of the market and how Sri Lanka Telecom unilaterally implements several of its programs (World Bank, 2022c). Traditional businesses in Bangladesh likewise need to make more use of digital technologies. Low levels of digital literacy, a lack of internet access, and expensive pricing are all contributing factors (World Bank, 2022c). Data and information communicated via ICTs are vulnerable to vulnerabilities from unauthorized parties, which has been identified in the literature as another management concern with ICTs (Zissis & Lekkas, 2012). Moreover, ICT adoption is complicated by the dynamic nature of ICT settings (Shachaf, 2008). Cultural biases may also impact communication, adding another layer of complexity to teams with a diverse range of members from various backgrounds (Shachaf, 2008). Anxiety over keeping up with the rapidly evolving ICT landscape slows the rate at which ICTs are adopted and spread.

Access to the internet and other forms of ICT infrastructure are prerequisites for participating in the digital economy on a local, national, and international scale. It aids in developing digital infrastructures, such as government websites, that support the efficient provision of public services and the conduct of government business. They may significantly enhance operational and economic efficiency, raise service quality and creativity, and assure accountability if developed with a "whole-of-government" and

"user-centric" perspective.



Source: Author's adaptation from World Bank Group Digital Economy Framework (World Bank, 2022c)

Figure 2.12: ICT Diffusion-development framework

Further, the use of digital financial services (DSF) to make payments, save money, and get loans facilitates trade between businesses and their clients and suppliers, as well as the establishment of digital credit records and the acquisition of working capital (Morgan, 2022). Jobs, productivity, growth, and living standards may be boosted by incorporating ICT into business models to maximize efficiency and boost private sector competitiveness (Gomber et al., 2017). The advent of digital enterprises presents a rare chance for SAARC to support the development and expansion of Micro, Small, and Medium-Sized Enterprises (MSMEs), encourage innovation and entrepreneurship, promote economic integration, help catch up with economically lagging people and regions, boost productivity, and create more and better employment. The backbone of thriving digital economies is citizens fluent in technology and possessing the necessary digital skills. Citizens proficient in using digital technologies can better participate in modern society,

from finding reliable sources of information to networking with others.

However, using ICTs puts communities at risk of cybercrime, hacking, and other forms of data abuse (Hughes et al., 2017). These threats, if left unchecked, hinder the realization of ICT's advantages, and can lead to further issues, such as widening digital disparities and lowering public trust and confidence in digital services and transactions. To effectively implement the legal and regulatory framework to handle these risks and develop confidence, it is essential to have both effective and robust institutions. SAARC can benefit from institutional strengthening by reducing individual and market vulnerability. Inclusion must be prioritized if impoverished people and countries in the region are to partake in the benefits of the digital economy. Building people's faith in the digital economy would protect consumers, companies, and governments from fraud and stimulate more investment in the ICT sector.

To sum up, ICT has enormous potential to speed up the widespread adoption of several technologies, programs, and systems throughout the economy and can bring about a complete digital transformation of society as depicted in the framework. In addition to being essential for financial and economic development, ICTs have a catalytic role in the three pillars of sustainable development (economic growth, social inclusion, and environmental protection) which eventually can lead to achieving SDGs.

Further, the next chapter discusses the empirical methodology incorporated in the present study.

Chapter-3

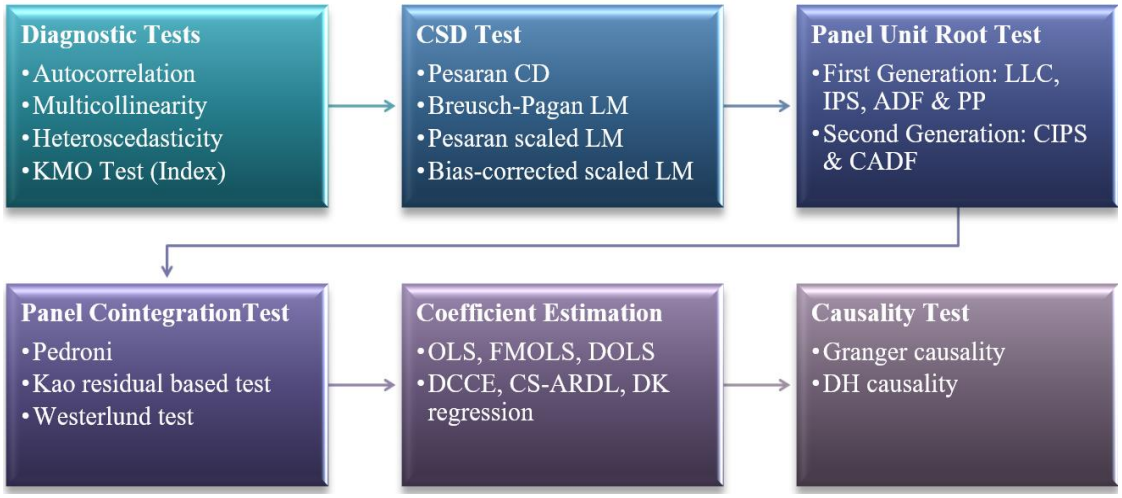
Empirical Methodology

Existing research has only examined ICT along a single dimension (i.e., mobile phones and internet usage), which cannot be extrapolated to encompass other facets of ICT (Hossain & Samad, 2021; Salahuddin & Gow, 2016). In addition, the possible issue of endogeneity of the variables needs to be addressed in empirical investigations (Higón et al., 2017b). Finally, the ICT research often overlooks CSD in the data (Pradhan et al., 2013; Pradhan et al., 2017a). Therefore, after carefully considering advanced and sophisticated econometric tools, the research chooses its empirical analysis methods. The panel data analysis flowchart utilized in this study is shown in Figure 3.1. Following are the fundamental steps that make up the analytical process:

1. Before the analysis, our main variable of interest i.e., ICT diffusion is constructed using PCA.
2. A series of diagnostic checks are carried out before beginning the estimating process, including tests for autocorrelation, multicollinearity, and heteroscedasticity. The effects of common shocks are estimated using CSD tests.
3. Next, panel unit root tests are employed to ascertain the order of stationarity for the variables of interest.
4. Further, the long-run cointegration among the variables is tested using panel

cointegration tests, such as those developed by Kao (1999), Pedroni (2004), and Westerlund (2007).

5. After establishing the cointegration among the variables, the short run or the long run coefficient are estimated using different approaches which includes but is not limited to fully modified ordinary least square (FMOLS) model, dynamic ordinary least square (DOLS) model, CS-ARDL, DCCE estimation, DK standard errors approach.
6. Finally, the causal relationship is ascertained among the variables using granger causality or DH causality test.



[Source: Author's compilation]

Figure 3.1: Panel data analysis flowchart

3.1 Principal Component Analysis

PCA is a statistical method for reducing many variables into fewer linearly uncorrelated variables. This is accomplished by applying an orthogonal transformation on the original data set of observations, which may contain correlated variables. Compared to the number of original variables, the number of PCs is always less than or equal to one. The resulting transformation can be described so that the first PC has the greatest possible variance (it accounts for as much of the variation in the data set as possible). Each succeeding component consequently has the highest possible variance while adhering to the constraint

that it is orthogonal to (that is, uncorrelated with) the components that came before it. In other words, the first PC accounts for as much variability in the data as possible. If the dataset is normally jointly distributed, then the PCs will always be unrelated to one another. When using PCA, it is essential to consider the original variables' relative scales. The following formula is incorporated to formulate the index:

$$\text{ICT} = \sum_{i=1}^{j} a_i \frac{x_{ij}}{sd\,(x_i)} \tag{3.1}$$

where ICT is the ICT diffusion index; sd = Standard Deviation, X_{ij} = i^{th} items in j^{th} year and a_i = Factor loadings as obtained by PCA. Thereafter, an index for each country and for each year is derived using the principal components (PCs). The index is further screened for sampling adequacy using the Kaiser-Meyer-Olkin (KMO) test (Kaiser, 1974). KMO scores between 0.8 and 1 are often indicative of sufficient sampling adequacy. KMO values below 0.6 indicate insufficient sampling and prompt corrective action. On the other hand, some researchers use a 0.5 threshold. The overall KMO score for the index used in the present study is 0.80, indicating that our PCA produces accurate and reliable results.

3.2 Cross-Sectional Dependence Test

CSD has gotten a lot of attention lately. As a result of increased economic, financial, and trade integration, there is no doubt about the existence of CSD in the modern economy. CSD cannot be overlooked considering the shared worldwide shocks (e.g., the financial and oil crises), common global organizations (e.g., the IMF), and shared global spillover effects between nations. Regression models rarely incorporate all these variables, therefore CSD may show up in the residuals. As a matter of fact, it is stated that CSD is a crucial concern for panel data and that disregarding CSD may lead to an inefficient estimator and to an incorrect test statistic. But panel data estimation methods relying on the

presupposition of cross-sectional independence fail to deal with this major problem. For panel data analysis, however, the assumption of cross-sectional independence can be deemed inaccurate (Farooqi et al., 2020; Khan et al., 2020). Therefore, to check the presence of CSD, the present study utilized the Pesaran CD (Pesaran, 2004), Breusch-Pagan LM (Breusch & Pagan, 1980), Pesaran scaled LM (Pesaran, 2004), and bias-corrected scaled LM (Baltagi et al., 2012). The null hypothesis (H0) of the CSD test is presented as follows:

$$H_0 : \eta_{ij} = corr\,(\varepsilon_{it}; \varepsilon_{jt}) = 0 \forall i \neq j \tag{3.2}$$

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

$$\mathrm{CD}_P = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{p}_{ij} \right) \rightarrow N(0,1)\ i, j \tag{3.3}$$

$$R = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{p}_{ij} \right) \frac{(T-k)\,\hat{p}_{ij}^2 - E\,(T-k)\,\hat{p}_{ij}^2}{\mathrm{Var}\,(T-k)\hat{p}_{ij}^2}, \tag{3.4}$$

where *i* is the specific cross-section, *t* depicts the time dimensions, and the term $\hat{p}_{ij}$ signifies the projected multivariate correlation of the error-term across all cross-sections *i* and *j*.

3.3 Panel Unit Root Tests

The majority of the economic as well as financial time series are generally found to be non-stationary. Therefore, regressing one series against the other might exhibit spurious statistical results. Also, confirming the stationarity of variables is a pre-condition before undertaking panel cointegration and causality test. Hence, the first step in the analysis is to confirm the static properties of the series. There are many panel unit root tests available. The first-generation test includes (1) The Levine Lin Chu test (LLC; Levin et al., 2002), (2) The Im Pesaran Shin test (IPS; Im et al., 2003), (3) The Maddala & Wu Fisher Augmented Dickey-Fuller (ADF) test (4) the Maddala & Wu Fisher Phillips and Perron (PP) test (Maddala & Wu, 1999) to confirm the stationary properties of the variables used in the study.

While LLC is a homogeneous panel unit root test, IPS, ADF, and PP are heterogeneous. The LLC test, based on the traditional ADF test, presumes a common AR coefficient among each unit in the panel but takes into consideration individual effects, time effects and time trends in the panel. On the other hand, it examines the heterogeneity of intercept only across the panel member. Unlike the LLC test, the IPS test is unrestrictive because it relaxes the postulation of homogeneity and allows the inclusion of heterogeneous coefficients. Furthermore, the IPS test considers individual effects, time trends and time effects in the panel. Maddala and Wu (1999) also suggested two non-parametric tests, i.e., ADF and PP tests, based on the Fisher test, which combines the p values from each unit root test.

However, in the presence of slope heterogeneity and CSD, first generation unit root tests cannot be used because they result in an excessive rejection of the null hypothesis and have inadequate size properties, both of which, in turn, generate misleading results. As a result, second-generation unit root tests, which assumes CSD across cross-sections in heterogeneous panels are used. Pesaran (2007) suggested cross-sectional augmented Dickey-Fuller (CADF) and cross-sectional augmented Im-Pesaran-Shin (CIPS), which can be depicted as:

$$x_i = \alpha_{it} + \beta_i x_{it-1} + \rho_i t + \sum_{j=1}^{n} \theta_{ij} \Delta x_{i,t-j} + \varepsilon_{it} \qquad (3.5)$$

where, α_{it} refers to the intercept, t denotes the time, Δ is the difference operator, x_{it} represents the variables under study and ε_{it} is the error term. The null hypothesis states that the investigated series are not stationary.

3.4 Cointegration Tests

After validating the unit root properties, the next stage in panel data analysis is to check for long-run cointegration between series. Cointegration is one of the analytical concepts which examine the long-run relationship among the non-stationary variables. Provided that

the difference in between any two non-stationary series comes out to be stationary, the series can thus be accounted as being cointegrated with each other. Further, if the series are cointegrated with each other, then the long-run equilibrium relationship between the two series can be attained. Contrastingly, if the series are not cointegrated with each other, then there is no possible relationship between them, and the series may deviate from one another. The study included first- and second-generation co-integration techniques, such as Kao (1999), Pedroni (2004), and Westerlund (2007).

Pedroni (2004) presents two distinct set of statistics, one based on panel statistics within dimensions and the other on statistics between dimensions. Within the cointegrating equation, it includes the process of variable regression with CSD constraints while accounting for the heterogeneity of the intercepts. There are seven different test statistics obtained in total, namely "panel v, panel rho, panel pp, panel ADF, group rho, group pp, and group ADF statistics," which follows the asymptotic normal distribution specified by the corresponding group and panel cointegrated statistic. The presence of long run relationship is established by rejecting the null hypothesis of 'No Cointegrating'. In addition, the Kao-residual based test has been used in the study to validate the results of the Pedroni test.

However, to address the issue of CSD and heterogeneity, the study also employs Westerlund (2007) technique which gives more reliable and accurate information regarding long run cointegration relationships among the variables. Westerlund (2007) developed a structure dynamic based error correction panel cointegration test that addresses both the CSD and heterogeneity challenges in panel data analysis. The test focuses on two types of groups ($G\tau$ and Ga) and panel ($P\tau$ and Pa) statistics. The null hypothesis of the Westerlund cointegration test is 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:

$$\Delta Y_{it} = \delta'_i d_t + \alpha_i (Y_{it-1} - \beta'_i x_{it-1}) + \sum_{j=1}^{p_i} \alpha_{ij} \Delta y_{it-j} + \sum_{j=-p_i}^{p_i} \gamma_{ij} \Delta x_{i,t-j} + \mu_{it} \qquad (3.6)$$

3.5 Model Estimation

Further, the long-run coefficients are estimated. Pedroni proved that the ordinary least squares (OLS) are super convergent, and their distribution is inconsistent and biased when variables in the panel are cointegrated. Various problems in the time-series analysis might also occur in panel-data analysis. This is frequent if the analysis faces heteroskedasticity (Kao, 1999). Henceforth, this study uses DOLS and FMOLS estimation techniques, allowing greater flexibility in the cointegrated vectors in the presence of heterogeneity. DOLS and FMOLS give uniform estimates of the standard errors, making statistical analysis robust. They solve the issues of serial correlations, simultaneity biases, and endogeneity in the panel datasets. While the DOLS uses a parametric approach, FMOLS accomplishes this by employing a non-parametric approach.

However, traditional methodologies, such as random effect, fixed effect, FMOLS, and DOLS, presume homogeneity and only enable modification of intercepts of the cross-sections, when in the real sense, the panel members are heterogeneous. Thus, considering the sensitive nature of CSD, the present study also employs econometric techniques robust to CSD such as DCCE, CS-ARDL and DK standard errors approach.

3.5.1 Dynamic Common Correlated Effects Estimation

DCCE estimator developed by Chudik and Pesaran (2015) is based on the ideas of PMG (Pesaran et al., 1999), MG (Pesaran & Smith, 1995), and CCE estimation (Pesaran, 2006). According to Chudik and Pesaran (2015), the CSD effects, also known as common correlated effects (CCE), may be mitigated using a cross-sectional average, U_{it} is used for the dependent variable,

$$lnU_{it} = \sum_{i=0}^{p} \alpha_{it} U_{it-1} + \sum_{i=0}^{p} \delta_{it} V_{it-1} + \sum_{i=0}^{p} \Upsilon_{it} \overline{W}_{it-1} + \varepsilon_{it} \quad (3.7)$$

where $$\overline{W}_{t-1} = (\overline{U}_{it-1}, \overline{V}_{it-1}) \quad (3.8)$$

whereas V_{it-1} indicates all independent variables. 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 key advantages of this technique is its robustness in the presence of structural breakdowns. Furthermore, by applying the jackknife 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.

3.5.2 Driscoll and Kraay Standard Errors Approach

DK standard error approach proposed by Driscoll and Kraay (1998). This nonparametric approach to estimating standard errors imposes no limitations on the limiting behavior of the number of panels. Therefore, even if the number of panels N, is substantially greater than T, the size of the cross-sectional dimension in finite samples does not pose a constraint on feasibility. This non-parametric regression is extra efficient with large time frames because it is flexible and does not require any assumptions. The DK model provides accurate and rigorous results long-run estimates and can counter CSD, heteroskedasticity, as well as spatial/serial correlation in the data. In addition, the DK approach may provide estimates in both unbalanced as well as balanced panels and is more efficient if the data set contains missing values (Park et al., 2018). Therefore, the relationship between the variables was examined using the DK standard error technique. First, the average values and residuals are analyzed. Thereafter, the estimates of weighted heteroskedasticity and consistent autocorrelation (HAC) were computed, and standard errors were generated against the CSD problem (Heberle & Sattarhoff, 2017). The linear model of DK standard errors is so represented as follows:

$$y_{i,t} = x'_{i,t}\beta + \varepsilon_{i,t} \tag{3.9}$$

where *i* and *t* depicts the cross-sectional and the time-series units respectively.

3.5.3 Cross Sectional Autoregressive Distributed Lag

CS-ARDL methodology proposed by Chudik and Pesaran (2015), has also lately become more popular than conventional estimate techniques (i.e., OLS, FMOLS, DOLS). It outperforms alternative cointegration approaches as it accounts for endogeneity, serial correlation, and heterogeneity issues in the model. Furthermore, it considers CSD and the order of variable integration. One of the most notable benefits of employing CS-ARDL is that it produces consistent findings even when the sample size is small. According to Chudik and Pesaran (2015), the CSD effects, also known as CCE, may be mitigated using a cross-section average,

$$lnU_{it} = \sum_{i=0}^{p} \alpha_{it} U_{it-1} + \sum_{i=0}^{p} \delta_{it} V_{it-1} + \sum_{i=0}^{p} \Upsilon_{it} \overline{W}_{it-1} + \varepsilon_{it} \tag{3.10}$$

where, $$\overline{W}_{t-1} = (\overline{U}_{it-1}, \overline{V}_{it-1}) \tag{3.11}$$

U_{it} is used for the dependent variable whereas V_{it-1} indicates all independent variables. The average of both dependent and independent variables is indicated as $\overline{W}_{t-1}$to ease the cross-section dependency problem (t-1). While p represents the lag of each variable.

3.6 Causality Test

The final stage in the empirical analysis is to determine if any causal relationship exists among the variables under study. The short-run and the long-run causality association among the variables are examined using Granger causality method proposed by Engle and Granger (1987). This method states that when the two series are integrated of order one and cointegrated with one another, there exists at least one causal relationship in any direction. Further, the direction of causality could be attained using Vector Error

Correction Model (VECM) of long run cointegrating vectors. Therefore, we examine the long-run equilibrium association from the cointegration equation and note the corresponding residuals from the equilibrium point. Secondly, we estimate the parameters pertaining to the short-run adjustments. After that, a panel causality test is executed to infer the causality nexus of the variables. The following panel VAR model is adopted:

$$\begin{bmatrix} \Delta \ln \mathrm{GDP_{it}} \\ \Delta \ln ICTI_{it} \\ \Delta \ln FD_{it} \\ \Delta \ln INF_{it} \\ \Delta \ln TRD_{it} \end{bmatrix} = \begin{bmatrix} \lambda_{1j} \\ \lambda_{2j} \\ \lambda_{3j} \\ \lambda_{4j} \\ \lambda_{5j} \end{bmatrix} + \sum_{k-1}^{p} \begin{bmatrix} d_{11ik}(L) d_{12ik}(L) d_{13ik}(L) d_{14ik}(L) d_{15ik}(L) \\ d_{21ik}(L) d_{22ik}(L) d_{23ik}(L) d_{24ik}(L) d_{25ik}(L) \\ d_{31ik}(L) d_{32ik}(L) d_{33ik}(L) d_{34ik}(L) d_{35ik}(L) \\ d_{41ik}(L) d_{42ik}(L) d_{43ik}(L) d_{44ik}(L) d_{45ik}(L) \\ d_{51ik}(L) d_{52ik}(L) d_{53ik}(L) d_{54ik}(L) d_{55ik}(L) \end{bmatrix} \begin{bmatrix} \Delta \ln \mathrm{GDP_{it-k}} \\ \Delta \ln ICTI_{it-k} \\ \Delta \ln FD_{it-k} \\ \Delta \ln INF_{it-k} \\ \Delta \ln TRD_{it-k} \end{bmatrix}$$

$$+ \begin{bmatrix} \omega_{1i}\, \mathrm{ECT_{it-1}} \\ \omega_{2i}\, ECT_{it-1} \\ \omega_{3i}\, ECT_{it-1} \\ \omega_{4i}\, ECT_{it-1} \\ \omega_{5i}\, ECT_{it-1} \end{bmatrix} + \begin{bmatrix} \varepsilon_{1it} \\ \varepsilon_{2it} \\ \varepsilon_{3it} \\ \varepsilon_{4it} \\ \varepsilon_{5it} \end{bmatrix} \tag{3.12}$$

where Δ=first difference filter (I – L); i=1,2,…N; t = 1,2,…T; p=lag length; ε_j (j = 1,…5) are normally distributed random variables for all i and t having zero mean and finite heterogeneous variances (σ_i^2). ECTs i.e. the error-correction terms are obtained from the cointegration equations which represent the long-run dynamics whereas the differenced variables depict the short-run adjustment dynamics among the variables.

The short-run causality association is depicted by interpreting the statistical significance of the F-statistic along with the significance of the lagged changes of the independent variables. On the other hand, long-run causality is revealed by the statistical significance of the respective ECTs using t test.

Additionally, the present study uses the DH causality test proposed by Dumitrescu and Hurlin (2012), which addresses the concern of CSD in the dataset and is subjected on individual Wald statistics of average non-causal relationship across all individual units (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):

$$y_{it} = \alpha_i + \sum_{k=1}^{K} \beta_{ik} y_{it-k} + \sum_{k=1}^{K} \gamma_{ik} x_{it-k} + \varepsilon_{it} \tag{3.13}$$

where, the lag order of K is assumed to be the equivalent for all panel members, and the panel must be balanced. According to the null hypothesis, there is no causal link between the variables.

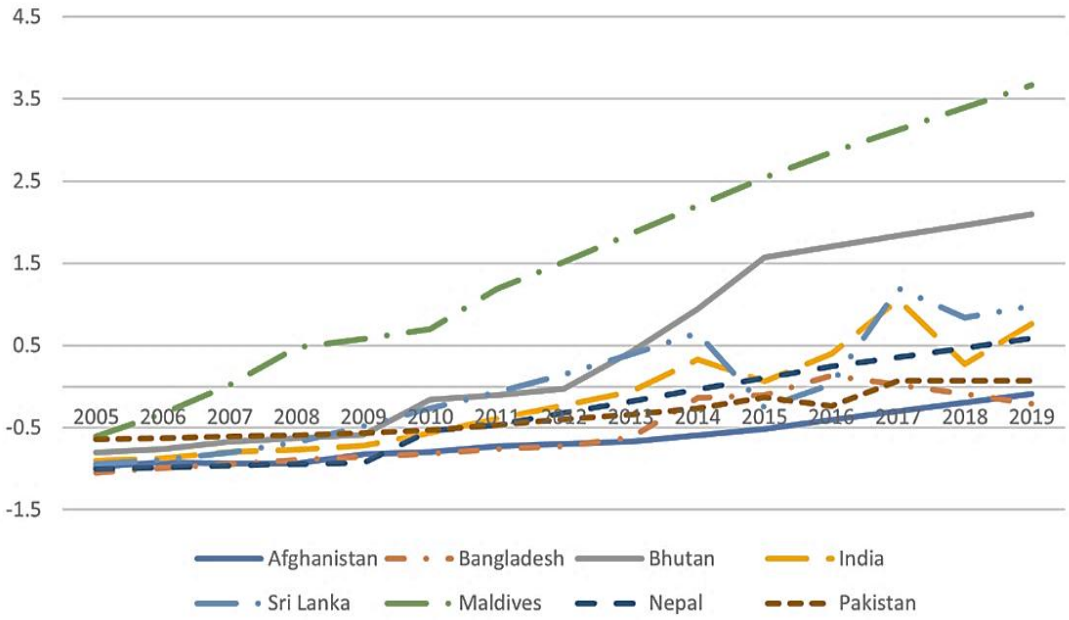
Chapter-4

ICT Diffusion, Financial Development and Economic Growth

4.1 Introduction

The past five decades have seen a great diffusion of ICT, leading to the rapid transformation of the global economy. ICT is almost everywhere in everyone's hands, unlike when it was confined to the labs of prominent universities or R&D centres of top-class companies. The ICT revolution has led to a powerful global transformation into an information society. A fundamental segment of the global economic infrastructure, ICT is now reckoned as the essential bedrock of a knowledge-intensive economy (Pradhan et al., 2017b). ICT is progressively described as having a solid competence to influence economic growth through various means. ICT can, directly and indirectly, contribute to economic welfare through increased employment & demand and social returns in society (Datta & Agarwal, 2004). ICT also helps in better flow of information which boosts efficiency and productivity, provides access to broader markets, and generates opportunities for new investments and capital such as foreign direct investment and portfolio and venture capital (Kpodar & Andrianaivo, 2011). It also provides smooth access to an extensive range of financial products and services, further improving financial inclusion and facilitating economic development.

Asia is among the world's rapidly growing economic regions, comprising about 60% of the global population. Furthermore, 3.8 % of the world's population resides in the eight emerging economies of SAARC.



[Source: ITU (2022) and Author compilation]

Figure 4.1: Trend of ICT diffusion in the SAARC economies

Figure 4.1 displays the ICT diffusion trend of the countries under consideration from 2005 to 2019. It is apparent from the figure that the ICT index for SAARC economies has been rising since 2006, attributable to evidence that ICT has been contributing to eradicating poverty by creating job opportunities and by improving financial inclusion status in these countries. Further, the government of these countries are developing policies to foster the development and use of ICT, such as the Digital Bangladesh Programme, Youth Solutions and Bhutan's first information technology (IT) park. In 2013, Nepal and Bangladesh published plans to incorporate ICT into education. However, most SAARC countries still suffer from poor infrastructure, increasing unemployment, mass poverty, and declining personal consumption. These are the primary hurdles to ICT diffusion in backward and

remote regions. Contributing to this is the inappropriate provision of telecom services, including fixed telephones, mobile phone technology and fixed broadband service. According to ITU, access to mobile data is increasing tremendously. Due to the increasing capacity of mobile phone technology, demand for high-speed data is rising daily.

Table 4.1 depicts the ICT scenario of India. With 1.1724 billion users, India has the second-largest telecommunication network comprising fixed and mobile connections. It has the second largest Internet subscriber base worldwide, including 661.94 million broadband subscribers as of 31 Dec 2019 (TRAI, 2020). Presently India is in 138th position among 175 nations in ICT Development Rankings released by ITU. Though the value of the index increased from 2.5 to 2.69, the ranking slashed from 125th rank in 2010 to 129th in 2013 to 135 in 2015 before finishing at 138th as the world has moved at a faster rate. Therefore, access to technology is still restricted because of various factors. India needs to quickly build its ICT infrastructure and improve citizens' access to the Internet before programs like Digital India can significantly change people's lives.

Table 4.1: ICT scenario in India as on Dec 2019

Total Telephone Subscribers	1.1724 billion
Teledensity	88.56%
• Urban	156.26%
• Rural	56.67%
Wireless Subscribers	86.98%
Mobile Subscribers	1.1514 billion
Fixed Line Subscribers	21.00 million
Internet users	687.62 million
Broadband subscribers	661.94 million

[Source: TRAI]

On the other hand, the financial system opens doors for trading, diversifying, pooling risks, allocating resources, mobilizing savings and exchanging goods and services, which induces growth mainly through capital accumulation and technology innovation (Levine, 1997). Furthermore, financial institutions reinforce innovation & creativity, thus enhancing future growth through identifying and further funding investments that are productive for society (Schumpeter, 1983).

Various researchers have comprehensively examined the role of technology diffusion as a pivotal channel of economic growth and vice versa (Dahmani et al., 2022; Pradhan et al., 2014; Yousefi, 2011). Also, several research (Paun et al., 2019; Shamim, 2007) investigated the nexus of financial sector development and economic growth, yet, only a handful of studies examined the nexus of ICT diffusion, financial sector development and economic growth in the SAARC nations. Therefore, the foremost objective of this research is to fill this gap and investigate the causal nexus of ICT diffusion, financial sector development and economic growth for the SAARC countries from 2000 to 2017. The chapter employs panel Granger causality and cointegration tests to do this meticulously. The study makes a valuable contribution to the existing literature on the ICT-finance-growth nexus in four ways:

1. This study integrates three separate strands of empirical literature.
2. It is the first study on SAARC countries which examines the impact of ICT diffusion and financial development on growth.
3. It uses relatively sophisticated econometric techniques and empirical approaches to examine the direction of causality among the three variables in the short and long run.
4. This study is based on the recent data of SAARC; therefore, the findings will help policymakers to frame policies accordingly.

4.2 Literature Review

4.2.1 Theoretical Framework

The present study intends to scrutinize the impact of ICT diffusion and financial development on per capita economic growth. Further, it examines if ICT and financial sector development can act as the causation factor for growth and if they cause each other. This section focuses on the theoretical relationship among these three variables.

According to Grossman and Helpman (1994), there are three driving forces behind economic growth: (1) Capital Accumulation, which includes human capital (2) External economies (3) Industrial innovation. The first two forces cannot identify how real growth is sustained. The improvement in technology acts as a real force behind the continuously growing standards of living.

The development and diffusion of ICT are progressively being recognized as the significant factor which helps in determining economic growth pertaining to the following features: (i) The omnipresent nature of ICT in most of the business sectors, (ii) The perpetual improvements in ICT which keep reducing costs for the users, and (iii) The contribution of ICT to innovation and production of latest product and process (Kpodar & Andrianaivo, 2011).

The technological advancement in the ICT sector has significant macroeconomic consequences, leading to the notion of a 'New Economy'. Regarding macroeconomic performance, increasing ICT investment boosts productivity and contributes to greater market flexibility and transparency (Houben & Kakes, 2002). Theoretically, ICT can impact the real economy by utilizing its two important channels, i.e., ICT production and use. Primarily, the ICT sector has swiftly become a key industry at the international level, along with the rapid expansion of the service sector industries. Moreover, the worldwide

revolution of ICT has contributed fundamentally to the global economy by increasing productivity.

Similarly, financial markets unveil a decisive function in producing strong economic growth due to their contribution to diversifying monetary funds from unproductive sources to abundant sources leading to economic efficiency. The origin of this role can be outlined from the study of Schumpeter (1983), which accentuated the function of financial markets along with financial services in accelerating growth and highlighted the significance of the financial system in promoting innovation, encouraging innovation savings and funding productive investments. Contrastingly, Robinson (1979) argued that all other things remaining equal, growth is followed by progression in the financial sector and not the contrary. With the escalation in output, demand for financial products and services also escalates, which successively positively impacts financial sector development.

The theoretical relationship between the financial sector development and growth first emerged in the early last century, putting forward considerable evidence of a positive relationship between these two variables (Levine, 1997).

Furthermore, ICT infrastructure is also a key determinant in accelerating financial development. It helps progress and provides access to financial services in the economy. Improvement of ICT infrastructure can also reduce costs through better communication systems (Datta & Agarwal, 2004). Therefore, ICT diffusion helps to provide a better flow of information, improves access to deposit facilities, boosts investment activities, reduces loan expenses and tends to increase trading activities, monitoring of resources and effective allocation of credit (Kpodar & Andrianaivo, 2011).

4.2.2 Empirical Literature

4.2.2.1 ICT diffusion-economic growth

The first section of the literature review inspects the potential nexus of ICT diffusion with economic growth. Over the past few decades, numerous types of research were conducted using cross-sectional and time series data. While most of the studies depict a favorable effect of ICT diffusion on economic growth, others found a non-relevant or even negative relationship between the two (Bojnec & Fertő, 2012; Ishida, 2015; Stanley et al., 2018). However, only some of this research missed ascertaining the causal nexus of ICT diffusion and economic growth. Therefore, the present study investigates causality, an issue of concern in the development of literature. There exist four likely causality nexuses in ICT diffusion and growth literature.

Firstly, the supply leading hypothesis (SLH) views ICT as a mandatory pre-condition for growth, i.e., unidirectional causality runs from ICT diffusion to growth. The theory states that ICT investment helps induce change by increasing productivity and innovative capability leading to wealth-creation opportunities for the economic agents. Studies which support a similar viewpoint include Chakraborty and Nandi (2011) and Shahiduzzaman and Alam (2014).

Secondly, the demand following hypothesis (DFH) argues that causality is unidirectional, which runs from growth to ICT diffusion. As the country's economic growth increases, the spending on ICT infrastructure also tends to increase, i.e., the economic agents start demanding more sophisticated technology. Studies which support this viewpoint include Beil, Ford, and Jackson (2005) and Shiu and Lam (2008).

Further, the feedback hypothesis (FH) suggests the existence of bidirectional causality among the variables. It states that ICT and economic growth can complement and reinforce

each other. ICT deepens the impact of economic growth and requires the ICT architecture to be incorporated into the economy. Studies which support this viewpoint include Zahra, Azim, and Mahmood (2008), Saidi and Rahman (2021) and Hong (2017).

Also, some studies present negative consequences of ICT diffusion on economic growth and support the Neutrality hypothesis (NEH), which maintains the assumption of no causality between ICT and growth variables, stating that they are independent. Studies which support this view include Veeramacheneni and Vogel (2007) and Ishida (2015).

4.2.2.2 Financial development-economic growth

Similarly, four possible causal nexuses exist of financial sector development and economic growth. SLH states that financial sector development is primal for economic growth and has a favorable impact, depicting unidirectional causality from financial sector development to economic growth. Studies which support this hypothesis include Caporale et al. (2015), Sehrawat and Giri (2016), and Patra and Dastidar (2018).

There are also studies which support the DFH, where a constant surge in economic growth generates an increase in demand for the robust financial sector. This is because economic growth will induce wealth accumulation and provide adequate resources to upgrade technology, innovative capacity, human resources, institutions, and corporate governance. Studies showing unidirectional causality from growth to financial sector development include Chakraborty and Nandi (2003) and Ang and McKibbin (2007).

Also, studies support FBH, suggesting the existence of bidirectional causality in both directions (Apergis et al., 2007; Sunde, 2012; Uddin et al., 2014) and NLH where there is no causal nexus between financial sector development and economic growth in either direction. Singh and Mishra (2014) found that financial development did not promote economic growth in the short or long run. Thus, Schumpeter's perspective on the finance-

growth nexus does not hold in the context of the Indian economy. Studies supporting similar views include Atindéhou, Gueyie, and Amenounve (2005), Mukhopadhyay, Pradhan, and Feridun (2011) and Singh and Mishra (2015).

4.2.2.3 ICT diffusion-financial development

Nipo, Bujang, and King (2014) highlighted the significance of financial development and economic growth in determining the global digital divide. The study's findings strongly motivate nations to lift their economy to bridge the global digital divide. A handful of research has examined the causality nexus of ICT diffusion and financial development. One such study was conducted by Shamim (2007) who showed bidirectional causality between these two variables for a group of countries. Although many economies presented significant results in favor of the fact that ICT diffusion assists in financial depth, results about studies in Australia and Spain depicted causality running from economic development to ICT. Similar results were stated by Yarte, 2008 who found that the growth of banks and the stock market tends to foster ICT diffusion because a well-established financial market leads to smooth ICT financing. Similar results were found in studies by Marszk and Lechman (2019), Comin and Nanda (2019) and Alshubiri, Jamil, and Elheddad (2019).

4.2.2.4 ICT-finance-growth nexus

The literature on the nexus of ICT diffusion-economic growth and finance-growth is deeply rooted. Still, only a few studies examine the trivariate relationship between ICT diffusion, financial sector development and economic growth. The advancement of ICT and the financial sector, mostly in developing nations, has motivated researchers to explore the collective impact of ICT diffusion and financial sector development on growth. Shamim (2007) found that better connectivity through increment in mobile and internet

subscribers significantly enhances economic development, further accelerating the economy. Another empirical study was conducted by Sassi and Goaied (2013) which shows a positive and favorable impact of telecommunication proxies on economic growth but a negative effect of financial sector development on growth. Also, the association between ICT diffusion and financial sector development is positive and significant, articulating that countries can benefit from financial sector development only when ICT infrastructure development is initiated. (Rudra Prakash Pradhan et al. (2017) examined the interlink between these three variables in the Next 11 countries where the causality relationships varied with the types of ICT in the short run. In contrast, bidirectional causality is observed in the case of financial sector development and growth. This is in accordance with the ICT and financial sector development results however, the long-term empirical analysis shows causal relationships running from ICT diffusion and economic development to growth.

4.2.2.5 Relevance of the study

The relationship between financial development and economic growth is well-established in the literature. Also, it makes sense that today ICT diffusion links financial development and economic growth owing to its spillover effects. Countries are implementing plans and strategies to strengthen their financial systems. SAARC countries are no exception. Whether through liberalization or privatization policies or by reducing government, these countries have sought continuous improvement in their financial sector since the 1990s. These policies aim to promote economic growth through increased savings and investments. However, the effectiveness of these policies depends on the positive causal relationship between these variables. The above literature review shows mixed results when exploring the causal nexus of ICT diffusion, financial sector development and

economic growth. Therefore, additional analysis is required to recognize the direction of causality among the three variables. Because of the research gap in the literature, the present research explores the causal nexus of ICT diffusion, financial sector development and economic growth for SAARC economies. Above all, the study distinguishes between short-run and long-run causality.

4.3 Data and Model

The present research endeavors to integrate the effect of ICT diffusion with the already established nexus of financial development and economic growth by using a sample of SAARC countries that has not been considered in the already existing literature. The study is conducted for the period of 2000-2017 using advanced panel cointegration technique along with a granger causality test aiming to analyze the nexus of these three variables. This section covers the data, hypotheses and the conceptual models being used in this study.

4.3.1 Data

Country wise data for the variables used in the study are extracted from sources like International Telecommunication Union (ITU), World Development Indicators (WDI) and the IMF. The analysis is based on a natural log of yearly data of six SAARC nations for the period covering 2000-2017. The countries incorporated in the study include India, Sri Lanka, Pakistan, Maldives, Bangladesh and Nepal. Due to absence of data for Bhutan and Afghanistan, they have not been included in the analysis.

4.3.2 Definition of Variables

ICT i.e., the composite index of ICT diffusion which includes five variables: Mobile cellular subscription per 100 people; Fixed telephone subscription per 100 people; Fixed broadband subscription per 100 people; Internet users (% of population) (Dahmani et al., 2022) and ICT imports (% total imports) (Sassi & Goaied, 2013) and is formulated using PCA.

FD i.e., the comprehensive index proposed by Svirydzenka (2016) as a proxy variable for

financial sector development. Provided with the connotation as well as the theories of financial development, the index provides nine indices that sum up how the developed financial markets and institutions are with respect to depth, efficiency, and access. These are further consolidated into a broad index of financial sector development. Please refer to Svirydzenka (2016) for more detailed information concerning these indexes.

GDP i.e., the real GDP per capita at market price, constant at 2010 US$ is utilized as the proxy for economic growth (Odhiambo, 2010) which is an accurate measurement when you want to compare economies with different population size over time.

To avoid the potential for any spurious findings and to reduce the confounding bias, two control variables namely: trade openness (TRD) and inflation (INF) are also incorporated in the study. TRD (Total amount of export and import over GDP) has had profound influence on economic growth; therefore, it is used for depicting the openness in the economy (Sassi & Goaied, 2013). On the other hand INF refers to growing rate of consumer price index (CPI) over one year period in the model (Sassi & Goaied, 2013). Theories suggest that low and stable inflation is propitious for economic prosperity whereas high inflation brings uncertainty to the economic environment thereby limiting investment activities and economic operations. CPI is preferred over wholesale price index (WPI) as it takes care of the service sector unlike the WPI measure. Natural logarithmic form of GDP and TRD are taken in the model.

4.3.3 Model Specification

Thus, the following equations can be used to build a theoretical model for the above relationship:

$$GDP_{it} = \alpha_0 + \delta_i t + \beta_1 FD_{it} + \beta_2 ICT_{it} + \beta_3 INF_{it} + \beta_4 TRD_{it} + \varepsilon_{it} \qquad (4.1)$$

$$\varepsilon_{it} = \rho_{it} + \varepsilon_{it-1} + \omega_{it} \qquad (4.2)$$

where i =1,2,..,N denotes a country in the panel; t =1,2,..,T refers to the time period for each country; α_i= country specific effects; δ = deterministic time trend; β_i = estimated residual indicating the deviation from the long-run relationship. In order to examine the null hypothesis of zero cointegration i.e. $\rho_i = 1$, unit root tests on residuals is executed. The variable GDP refers to real GDP per capita which is constant at 2010 US$; FD denotes the composite index of financial sector development; ICT is the composite index of ICT diffusion measured by five individual indicators: Mobile, Telephone, Broadband, Internet and ICT imports. X represents other control variables affecting growth including inflation rate (INF) and trade openness (TRD).

4.4 Results and Discussion

Table 4.2 depicts the estimated results of the panel unit root test. The calculated results uphold that all the variables employed in the panel vector autoregressive (VAR) model are non-stationary at level but stationary when at first difference. The results confirm that the variables proved to be integrated of order one, i.e. I (1). Further, the results of Pedroni's panel cointegration technique and Kao's residual-based cointegration test are summarized in Table 4.3. Results suggest the presence of the long-run interaction among the variables, and the combined effects of both tests point out the existence of long-run association among the variables.

Provided that all the variables in the model are cointegrated, further, the long-run parameters are estimated by FMOLS and DOLS method, which is recorded in Table 4.4. Results confirm that growth is considerably impacted via ICT diffusion and financial sector development like the analysis of Hassan (2003) which states that ICT is necessary to expand the overall productivity of the country. Also, macroeconomic indicator, i.e., trade openness, has a favorable and significant impact on economic growth, which proposes the elimination of trade barriers to stimulate the country's economic development. Contrastingly, Inflation depicted a negative and dampening effect on economic growth.

Table 4.2: Panel unit root test

Test Statistic		Levin, Lin & Chu t*	Im, Pesaran and Shin W-stat	ADF - Fisher Chi-square	PP - Fisher Chi-square
GDP	I	-7.36178***	-5.84926***	52.3841***	52.1662***
	I&T	-7.10711***	-4.1817***	38.4216***	54.6732***
FD	I	-7.34283***	-5.98503***	53.841***	62.6913***
	I&T	-6.18221***	-4.50064***	39.1939***	52.6587***
ICT	I	-6.64717***	-5.73744***	53.2647***	48.4692***
	I&T	-6.4484***	-5.04932***	44.4699***	43.7219***
INF	I	-8.05553***	-6.36951***	61.6032***	112.567***
	I&T	-6.70665***	-5.32443***	48.215***	106.734***
TRD	I	-7.57572***	-5.86782***	52.9513***	60.4904***
	I&T	-8.32967***	-6.04796***	51.8281***	75.4795***

Note: ***, **, and * indicate levels of significance at 1%, 5%, and 10%, respectively. Figures are reported here at first difference level.

Table 4.3: Panel cointegration tests

Pedroni test	No Intercept	With Intercept & Trend	With Intercept
Panel v-Statistic	-1.201674	3.121967***	0.66494
Panel rho-Statistic	0.53598	0.970102	1.252033
Panel PP-Statistic	-1.715872**	-2.716019***	-1.22406
Panel ADF-Statistic	-1.849143**	-2.779648***	-1.57998*
Group rho-Statistic	1.416925	2.006091	1.889913
Group PP-Statistic	-2.110495**	-2.556627***	-1.32736**
Group ADF-Statistic	-2.013788**	-3.519383***	-2.34868**
Kao test	ADF t-stat	-3.581915***	

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

Table 4.4: Panel FMOLS and DOLS results

Dependent variable	Independent variable	FMOLS		DOLS	
		Coefficients	t-Statistic	Coefficients	t-Statistic
GDP	FD	5.860162	6.332794***	5.853802	4.528531***
	ICT	0.20669	20.00717***	0.208597	13.96391***
	INF	-0.00036	-0.072386	-0.002824	-0.38146
	TRD	1.434421	30.66198***	1.450986	21.79234***

Note: *** indicate levels of significance at 1%.

After verifying that variables are cointegrated, the causality direction among the variables

incorporated in the study is examined using the panel Granger causality test based on the panel VECM. VECM is adopted to examine the causality nexus of ICT diffusion, financial development and economic growth based on the unit root and cointegration results. Table 4.5 outlines the results of the panel's long-run and short-run causality. In the long run, when GDP is taken as the dependent variable, the error correction term corresponding to it is statistically significant at the 1% level. Also, when the control variables are taken as dependent variables, the error term is again statistically significant at 1% and 5%. However, this is not the case when financial development and ICT diffusion are dependent variables. This is identical to the research conducted by Pradhan et al. (2017) The estimated ECT carries a negative sign which implies that in the long- run, growth can act as a regulating factor when the system deviates from equilibrium. Unidirectional causality from ICT diffusion to economic growth is detected in the short run. This supports the SLH articulating ICT diffusion as a mandatory prerequisite for development and is consistent with the study of Mehmood (2013) and Shahiduzzaman and Alam (2014). Similarly, unidirectional causality from financial sector development to economic growth was obtained per the supply lending hypothesis (SLH) akin to the studies of Caporale et al. (2015), Sehrawat and Giri (2016), and Patra and Dastidar (2018). In addition, the empirical results suggest the absence of causality between financial sector development and ICT diffusion.

Table 4.5: Panel causality test

Source of Causation	**Short Run (F-Statistics)**					**Long Run**
Dependent Variable	GDP	FD	ICT	INF	TRD	ECT(t-Statistic)
GDP	-	2.76531*	4.00896**	1.12526	0.60405	-2.87659***
FD	0.15973	-	0.08093	5.61343***	0.39461	-0.641428
ICT	1.1486	0.27671	-	1.5023	0.64194	1.949323
INF	1.49963	0.84812	4.25605**	-	1.24862	-4.746380***
TRD	1.55374	0.10971	1.48102	2.49625*	-	-2.183519**

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

4.5 Conclusion and Policy Implications

In the present study, we investigate the potential joint effects of ICT and financial development on economic growth in the group of SAARC countries for the year 2000-2017. For this purpose, we used panel Granger causality and cointegration tests. First-generation panel unit root tests, LLC, IPS, ADF & PP, were employed to check the stationarity test of the variables used. All the variables were discovered to be integrated of order one at first difference. The study used Pedroni's cointegration test and Kao's residual-based cointegration, revealing the long-run relationship among the variables. Further, cointegration coefficients are computed with the help of FMOLS and DOLS methods.

In the short run, the causality network between ICT diffusion and economic growth supports the SLH. This is in accordance with the study of Mukherjee and Chakraborty (2010), Mehmood (2013), and Shahiduzzaman and Alam (2014). Similarly, unidirectional causality was observed in financial sector development and economic growth akin to the existing studies of Caporale et al. (2015), Sehrawat and Giri (2016), and Patra and Dastidar (2018). This implies that financial sector development is primal for growth in these countries.

The study also found evidence of long-run relationships among ICT diffusion, financial sector development and growth in accordance with the study conducted by Hassan (2003) which states that ICT is necessary to develop the country's overall productivity. The empirical results depict causality nexus from ICT diffusion and financial sector development to economic growth. Hence to ensure long-term growth in these economies, there is a requirement to fortify ICT infrastructure and promote e-finance which has the unique benefits of broad access, price transparency and convenience to its users. Furthermore, ICT diffusion, along with trade openness, significantly impacted growth,

implying that reducing trade barriers will be beneficial for enhancing economic growth. In conclusion, the following points are recommended for policymakers in SAARC nations:

- Adequate investment in the financial sector enables easy access to a large population, predominantly rural and remote communities.
- Incentives and subsidies to safeguard affordable ICT services for vulnerable communities.
- Synchronization of public and private sector investment for a synergistic effect on ICT infrastructure.
- Training programs focusing on enhancing digital literacy to empower all sections of society to adopt digital platforms for financial services.

Therefore, SAARC nations should develop ICT infrastructure and the financial sector, which will assist in increasing the growth rate and maintaining sustainable growth of these nations.

Chapter-5

ICT Diffusion and Inclusive Growth

5.1 Introduction

The positioning of this Chapter is inspired by three trends: the rising rate of ICT diffusion in SAARC, the rise of exclusive development in the area, and a lack of empirical evidence on these issues. When compared to other high-end economies in North America, Asia, and Europe, where the penetration of ICT has reached levels of saturation, the literature on ICT supports the view that there is the most room for ICT penetration in SAARC. Also, there is widespread agreement that severe poverty has been declining globally, except in SAARC, throughout the transition from the MDGs to the SDGs. The current pandemic has caused 78 million additional poor people in SAARC, as reported by the World Bank's Macro Poverty Outlook (World Bank, 2023b). The digital divide is a complex issue involving unequal access, use, and applications of ICT among and within economies; given that one-fourth of the world's population and almost half of the world's poor live in SAARC, the challenge for SAARC is how to harness ICT to achieve inclusive development in the region. Therefore, it is reasonable to conclude that the fruits of economic prosperity are not significantly trickling down to underprivileged segments of the population, making it challenging to eradicate extreme poverty. In light of the above, the present chapter examines the impact of ICT diffusion on poverty reduction, human

development and women empowerment.

Over the years, an important concern to development economists is the paucity of relevant information and knowledge accessibility among the poor. Conventionally, access to information is considered as an important element for the effective functioning of the markets. Henceforth, developing countries around the world are spending heavily on ICT, based on this premise that it can help increase the diffusion of information, accelerate economic growth and therefore, uplift the poor. ICT diffusion, for instance fixed telephone, broadband, internet, and cell phones have notably accelerated worldwide. According to the ICT indicators database of the ITU (2020), penetration of internet rose from 16.8% in 2005 to 53.8% in 2019. Similarly, fixed broadband subscriptions surged over 15 (per 100 inhabitants) in 2019 from 3.612 in 2005. On the other hand, mobile phone penetration (per 100 people) reached nearly 106 in 2019 from 33.7 in 2005.

The 2030 vision for Sustainable Development essentially acknowledges that the extent of ICT and worldwide interconnectivity has enormous capability to fast forward individual progress, overcome the digital divide, and form knowledge-intensive societies. Besides the innovative and productive capacity of ICT, it also helps in dealing with social and economic exclusion (ITU, 2020). However, while some studies argue that ICTs accelerate economic growth, subsequently contributing to poverty reduction, others contend that ICTs embed inequities because it deepens the digital divide in society, which triggers social exclusion.

Until the mid-twentieth century, income was regarded as a significant aspect of development; 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. SAARC is blessed with a plethora of natural resources yet has had a 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 covers 3.5 percent of the planet's area. According to the UN, the population of SAARC 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).

Additionally, ICT has been recognized as a vital indicator of women's empowerment. They have become more widespread in the past few decades and have evolved in SAARC

economies as a significant opportunity for relegated groups, particularly women. (ITU, 2020). Leveraging ICT for women has shown significant implications for the empowerment and economic independence of rural and underprivileged women in SAARC nations. Women can now participate in the knowledge economy proactively and productively owing to advances in ICT. Economic empowerment of women has been generally acknowledged to be one of the most important weapons for eradicating poverty and attaining gender equality for long-term economic growth (United Nations, 2020). Apart from playing an essential role in women's empowerment and financial inclusion, ICT is tremendously contributing to advancements in e-commerce, e-education, training and development, capital markets, international finance, and social networks (Bon et al., 2016). In addition, by enabling women to strike a balance between their professional and family lives, ICT enhances labor market openness and increases the female labor participation (FLP) rate (Roztocki et al., 2019). Such advancements have opened a wide range of economic prospects, particularly in developing economies.

Over the last three decades, women in developing countries have acquired an unprecedented number of skills. Fertility rates have fallen in tandem, resulting in smaller family sizes and a reduction in childcare and other domestic obligations (Klasen & Pieters, 2021). In conjunction with economic progress, women ought to have taken advantage of the growing labor market. This, however, has not occurred in the setting of SAARC, which continues to have millions of women confined to the home. The percentage of women in the workforce in SAARC is 23.6 percent, compared to 77.1 percent for men (World Bank, 2022d). According to the World Economic Forum (2021), closing gender differences in the region will require over 200 years. The percentage of women holding full time employment is three time less than that of the men in the region (Hafeez et al., 2020). In India, FLP has declined steadily over the past decade, and even more dramatically since

COVID-19. According to recent data, India's FLP has fallen to a historic low of 15.5% in 2021, following the epidemic (World Bank, 2022d). There has been a decline in female employment in the region since 1990. Furthermore, SAARC is part of a geographical belt that is characterized by patriarchal household structures and female confinement (Asadullah et al., 2020). As a result, the condition of women in these nations is unlikely to alter soon. Notwithstanding the tremendous diffusion of ICTs in SAARC over the last two decades, there is a significant gender gap in ICT usage (Nandi, 2021).

Global literature has adequately depicted how ICT has impacted our lives during the last two decades. International institutions also advocate the use of ICT to empower women, and ICT is also a key component of the SDGs 2030. Women's easy and rapid access to ICT can support and expedite the accomplishment of the SDGs. When it comes to ICT usage, women in developing countries significantly lag behind men (Perryman & Arcos, 2016). Therefore, addressing gender disparity is a top priority for the SDGs. It is crucial to acknowledge that, for an economy to prosper, measures to empower the vulnerable groups which includes the poor and especially women must be implemented.

However, we must acknowledge that ICT adoption is not always easy, particularly for the poorer members of society, particularly for 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 inclusive growth and ICT diffusion rate. As a result, research and investigation into techniques and strategies to promote the expansion of ICTs and inclusive

growth within the SAARC economies is crucial.

Significance of the study

Considering the above discussion that ICTs are critical to inclusive growth, the present study examines the influence of ICT diffusion on poverty reduction, human development and women empowerment 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 different aspects of inclusive growth 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 PCA rather than focusing exclusively on a single ICT indicator. Finally, the study addresses the issue of CSD, which is often disregarded in the existing body of research on ICT. Therefore, the present study employs the DCCE estimator introduced by Chudik and Pesaran (2015) and the DK standard error approach of Driscoll and Kraay (1998) which accounts for CSD and provides heteroskedasticity and autocorrelation-consistent standard errors.

5.2 Literature Review

5.2.1 ICT Diffusion and Poverty Reduction

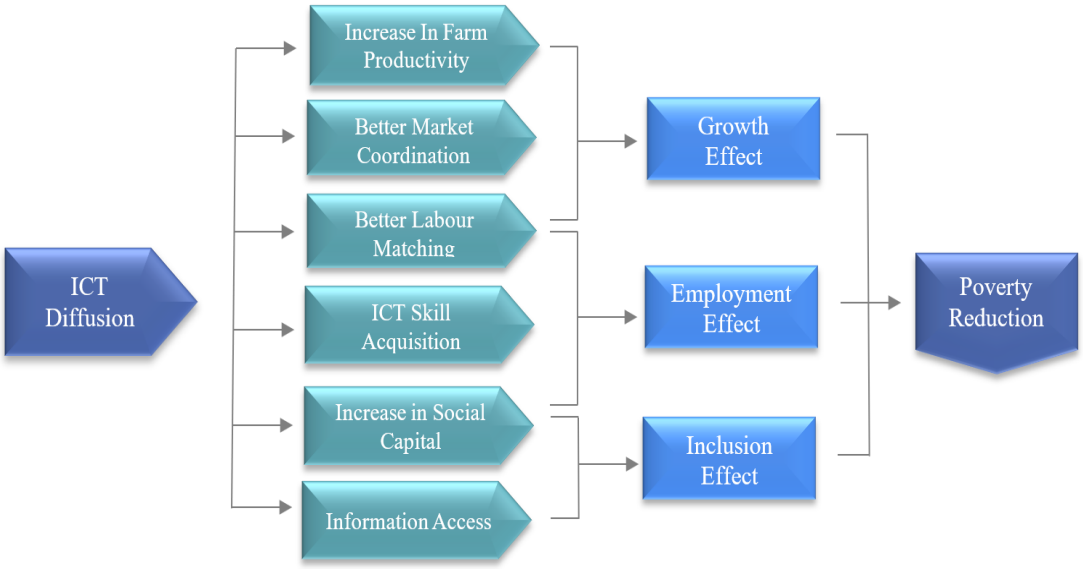
There is a consensus within the development literature that economic growth serves as the foremost channel for poverty alleviation (Kraay, 2006). Moreover, ICT financing has long been accredited along with boosting productivity as well as economic growth (Madden & Savage, 1998). Based on this ground, various studies have delved into the relationship of ICT diffusion with aggregate economic activity to find out if ICT diffusion has a positive growth effect (Czernich et al., 2011). However, the literature also agrees that growth itself

is non-sufficient for poverty reduction, given the soaring levels of inequality, particularly in developing countries (Krishna et al., 2005). Therefore, to lessen inequality and break the cycle of poverty, appropriate matching between growth dynamics and redistribution policies is required. The evidence concerning this distributional effect is inconclusive. One school of thought suggests that ICT aggravates inequality because of the skill-bias impact on the labor market. Another school of thought indicates that it promotes economic integration among the isolated areas. In this context, Figure 5.1 distinguishes three different but interconnected effects that are deeply correlated with poverty reduction: i) Growth effect; ii) Employment effect, and iii) Inclusion effect.

5.2.1.1 Growth effect of ICT diffusion

The literature propounds three channels by which ICT may boost economic growth. First, increasing the firm productivity as better dissemination of information enables the firms to identify improved means to combine both humans as well as physical capital, thereby raising output per labor (Aghion & Howitt, 1992). Second, by enhancing market performance through reduced transaction costs. Under perfect market conditions, the most productive firms are optimally allocated labor and capital, thereby promoting aggregate growth. Yet, there exist various factors such as incomplete or asymmetric information and ideas that prevent the markets from being perfectly competitive (Salop & Stiglitz, 1977). Incomplete and uneven distribution of information in the market leads to greater rent-seeking behavior opportunities, thereby resulting in variations from the Pareto efficiency (Stahl, 1989). Therefore, whichever channel helps to minimize the information-seeking cost and spurs diffusion of information accelerates long term economic growth by amplifying resource allocation within the economy and thereby reducing poverty. Third, by advocating a better match between labor demand and supply. ICT use has been associated with revamping the social interactions i.e., strengthening of

relationships with family and friends, which sequentially enables labor migration and helps sustaining a huge network which is often activated, during job search or changing occupation (Boase et al., 2006).



[Source: Author's compilation]

Figure 5.1 Channels through which ICT diffusion leads to poverty reduction

Empirically, a substantial amount of evidence can be found, both at the macroeconomic level (Avila et al., 2014; Kumar et al., 2016) and the company level (Albiman & Sulong, 2017; Eze et al., 2018) addressing the nexus between ICT diffusion and economic growth, either attributable to changes in productivity or to externalities related to dispersing knowledge and innovations.

Empirical analysis by Dimelis and Papaioannou (2010) exhibited a positive as well as significant effect of ICT, the impact being larger among developing countries. Dedrick, Kraemer and Shih (2013) also analyzed the ICT stock and productivity data of 45 countries during 1994 to 2007. The author found that the impact of ICT led productivity are regulated by individual country components, including trade openness, human resources, and the quality and cost of the ICT infrastructure. Akerman, Gaarder and Mogstad (2015) analyzed the influence of ICT exposure on the productive efficiency and detected an

upsurge of 7.5% in the income due to broadband availability. Niebel (2018) with respect to ICT-economic development nexus based on panel-data of 59 countries during 1995–2010 also confirmed the positive association between ICT and development.

Despite mainstream suggesting a positive relationship between ICT and growth, others question the association between ICT and economic performance. Such as, Thompson and Garbacz (2011) and Haller and Lyons (2015) discovered no significant impacts of certain ICT indicators over business productivity.

5.2.1.2 Employment effect of ICT diffusion

Based on the review, the study hypothesizes that ICT diffusion has a positive impact on employment via three distinct channels:

First, by improving labor market coordination, as discussed in the previous section. Presuming that ICT use impacts the size, structure, intensity as well as kind of communication that takes place within the personal network, associated transformations can be anticipated in the matching of employers and the workforce, and perhaps in the consequential income distribution (DiMaggio & Bonikowski, 2008). Second, by reinforcing social capital, which helps to seek employment, primarily for the poor (Granovetter, 2018). Third, by endorsing ICT skills to present and future employees. ICT increases the employability of the poor by endorsing the procurement of necessary technical skills (DiMaggio & Bonikowski, 2008).

Forman, Goldfarb and Greenstein (2012) investigated the impact of ICT investments on local wage growth variation in the US for the time 1995-2000 and found a positive correlation of ICT investments with wage rate as well as employment opportunities in areas which are highly populated with skilled workers. Similarly, Kolko (2012) found evidence of positive association among ICT and employment growth in the US from 1999

to 2006, the relationship being stronger in technology reliant industries. Another study by Atasoy (2012)which examined the variation in ICT diffusion and labor market outcomes, found that increased access to ICT leads to an increase of 1.8% in employment rate in rural areas of US. Despite that, the overall employment effects were null.

Furthermore, few studies have analyzed the association between ICT diffusion and social capital. Aker (2011) found that mobile phones surges rural-urban migration and communication within social networks in Niger. Similarly, Muto (2012) used panel data of Ugandan households and finds that an individual is further prone to migrate from rural areas to seek employment, when the household owns a mobile phone.

Finally, another set of studies proposes that ICT diffusion leads to greater employability by endorsing the acquisition of ICT proficiencies which are comprehensively correlated with higher wages. Loh and Chib (2021) in their study in Singapore found that access and usage of higher order ICTs is linked to employment generation as it facilitates filling in the skills gap more quickly. A more recent study by Berquin and Mbongo (2019) conducted in 20 African countries over 1995-2015 also claims that ICT diffusion is favorable to employment in general, and to youth employment. Moreover, the impact of ICT on male unemployment is observed to be higher than female unemployment in a similar study by Ebaidalla (2017) in the MENA countries, indicating a gender variation in the response of youth unemployment to ICT facilities.

5.2.1.3 Inclusion effect of ICT diffusion

Poverty and social exclusion result in a self-spurring trap. It limits human-capital expansion and raises political instability, that further hurts the quality of institutions that regulate transactions in the market and coordinates political environment. Contrastingly, inclusive political establishments which stimulate public involvement and regulates the

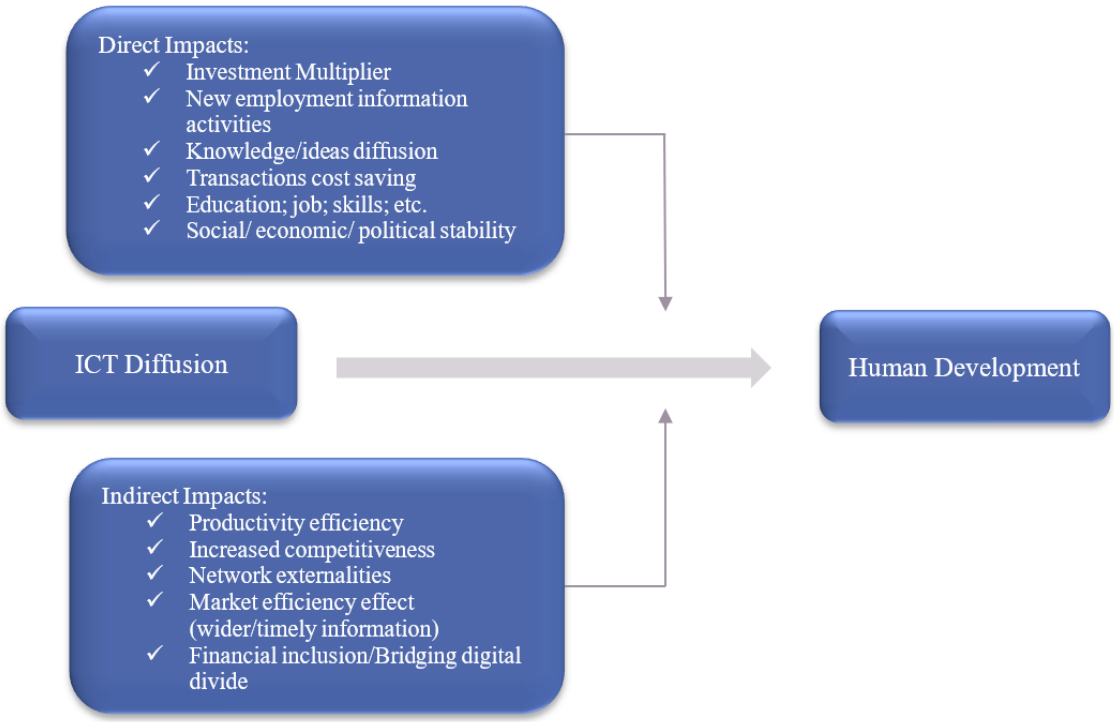
power of political leaders are crucial for economic welfare (North & Thomas, 1973). Henceforth, ICT diffusion promotes more inclusive political institutions by bringing in transparency, reducing corruption, improving resource allocation, uplifting political commitment and deployment, which warns political leaders, leading to extra alert administration. The combination of advanced tools for access and dissemination of information that induces the government to unveil data is conjectured to diminish chances of exploitation and increase awareness to the demands of the mainstream, thereby establishing more inclusive political as well as economic institutions.

The review puts forward two interdepended effects which suggest ambiguity in growth payoffs of ICT. Firstly, Human capital investment and organizational changes are a pre-condition to effective adoption of ICT. This gives well-trained workers and firms with sound innovative capacity and finances an edge over others. Secondly, because of the favorable impact of ICT diffusion on market harmonization and government institutions expand exponentially with increased usage levels. Therefore, while the evidence suggests substantial benefits of ICT diffusion to the developed economies, the returns for the developing countries like that of SAARC specifically for poverty alleviation remains uncertain. Owing to the gaps recognized in the literature, the study assesses the impact of ICT diffusion on poverty reduction for a panel of selected SAARC nations from 2005 to 2020, which has not received much attention in the existing literature.

5.2.2 ICT Diffusion and Human Development

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 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).



[Source: Author's compilation]

Figure 5.2: Impact of ICT diffusion on human development

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 5.2 summarizes the direct and indirect channels through which ICT diffusion leads to human development (Sarangi & Pradhan, 2020).

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). While some researchers (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 5.1 highlights the empirical evidence on the relationship between the diffusion of ICTs and human capital development.

Table 5.1: Summary of studies on ICT-HDI nexus

Author(s)	Study Area	Method	Findings
Ngwenyama et al. (2006)	West Africa	1993-2003; Regression analysis	Negative impact of ICT on Health component
Bollou and 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; SEM	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; MG estimator	HDI is influenced by mobile phone use, but not by internet use.
Maiti and Awasthi (2020)	67 countries	2000-2014; 2SLS	Less developed and developing countries have a slightly lower ICT impact.
Qureshi et al. (2020)	15 Advanced countries	1990-2017; QQ approach	FH between ICT and HDI
Farooqi et al. (2020)	67 Developing countries	2000-2018; ARDL	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

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 favorable relationship between ICT and human development in 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 FH, 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.

5.2.3 ICT Diffusion and Women Empowerment

Women empowerment is a multifaceted term that must be defined and assessed as a combination of factors. Several indicators have been examined while examining the complex idea of women empowerment, including the association between development and FLP, popularly known as the U-curve hypothesis (Lincove, 2008), educational attainment (Goldin, 1994), decision-making power (Amin & Lloyd, 2004) and the sex ratio (Sen, 1995).

The literature concerning the great potential that ICT diffusion may offer for women empowerment is robust as well as diverse. Women can benefit from the growth of ICT in a variety of different ways: (1) expanding social networks (Hossain & Samad, 2021); (2) increased access to information, particularly for education and health services (Handapangoda & Kumara, 2013); (3) improving women's status (Bayes, 2001);

(4) strengthening women's freedom of choice and action; (5) granting control over technology (Handapangoda & Kumara, 2013); (6) changing social, cultural, and religious norms over time (Hossain & Beresford, 2012); (7) overcoming spatial, physical, and temporal barriers (Nandi, 2021); and (8) liberating women from patriarchal restriction (Nandi, 2021). The most apparent has been the direct creation of employment opportunities for female specialists in the ICT sector. Additionally, ICT can help job markets become more transparent, adaptive, progressive, and equitable, making it even easier for women to find jobs and for hiring managers to locate competent female employees since increased access to job market information streamlines the job search process (Raja et al., 2013). Furthermore, ICT may help increase the number of women in the workforce by making it easier for them to engage in online contracting and giving them more access to online job exchanges and platforms. ICT's contribution to economic growth and development, and hence to the achievement of the SDGs, is expected to be one of the most apparent expressions of increased women employment.

The empirical evidence for causal and statistical linkages between technological advancement and FLP is developing but still scarce. Alves and Steiner (2017) investigate the causal links between women empowerment, globalization, and advancements resulting from knowledge transmission through ICT diffusion in twenty-three developed economies between 1986 and 2017. The study revealed that higher ICT use boosted women's labor force involved in the upper-middle-income economies, and thereby identified a link between increased female economic and political engagement and digital literacy. Nahtman and Jansson (2017) examined how ICT increases workforce participation and economic expansion by boosting knowledge acquisition and education using a classical growth model. They examined data from twenty-six European nations spanning 1981 to 2010 and discovered no statistically significant causal

relationship between technological progress, FLP, and GDP. Novák (2020) examined structural changes in European nations when it comes to technology transformation and labor markets using modern growth theories. He discovered that increasing FLP harmed overall employment growth across all sectors, together with the computerized industrial sector. Petrović and Radukić (2018) focused on the impact of macroeconomic conditions on women's participation in the labor market and entrepreneurial activities in post-transition nations. They discovered that while technical indicators have a role in increasing FLP in emerging economies, they are dependent on governmental assistance. Their findings corroborate the theoretical and empirical evidence presented by Puffer et al. (2010).

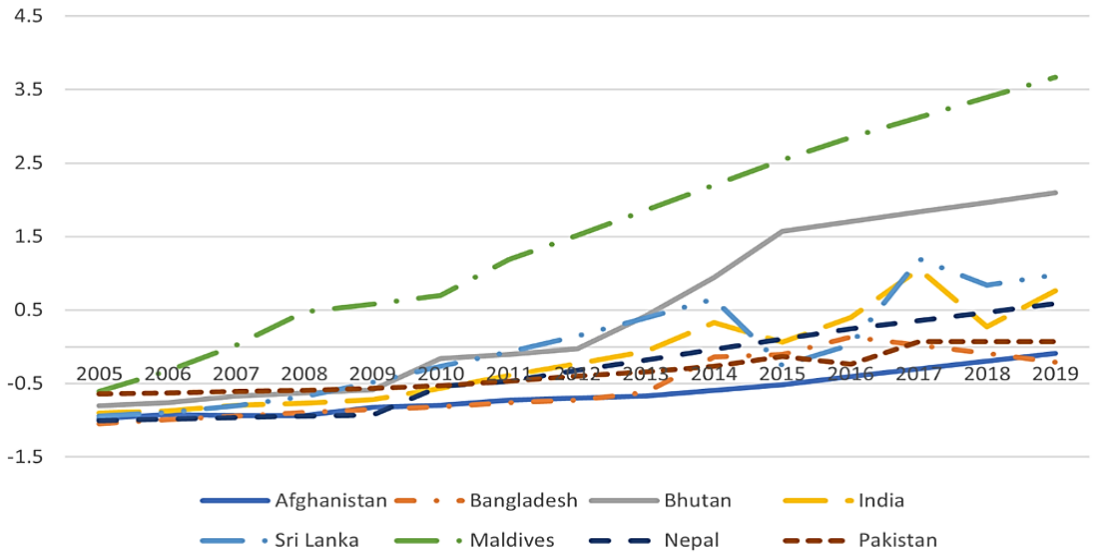
According to Pergelova et al. (2019), women-owned small and medium enterprises (SMEs) in Bulgaria have a significant impact on the country's economic growth and globalization when it comes to ICT diffusion. However, empirical analyses do not unambiguously support the concept that ICTs have a positive impact on the labor market, as evidenced by their research. While ICTs have the potential to increase male and female employment, they may also have unintended consequences for labor markets, such as job losses as a result of improved labor productivity enabled by ICT within the organizations (Kılıçaslan & Töngür, 2019). Therefore, assessing the overall impact of ICT on female empowerment is ambiguous and must be performed empirically.

5.3 Data and Model

5.3.1 Data

This study examines the link between ICT diffusion and inclusive growth i.e., poverty reduction (POV), human development (HDI), and women empowerment (FLP) from 2005 to 2020 for SAARC. The specified timeframe and extent of research is based on, the availability of data and the motivation stated in the above sections.

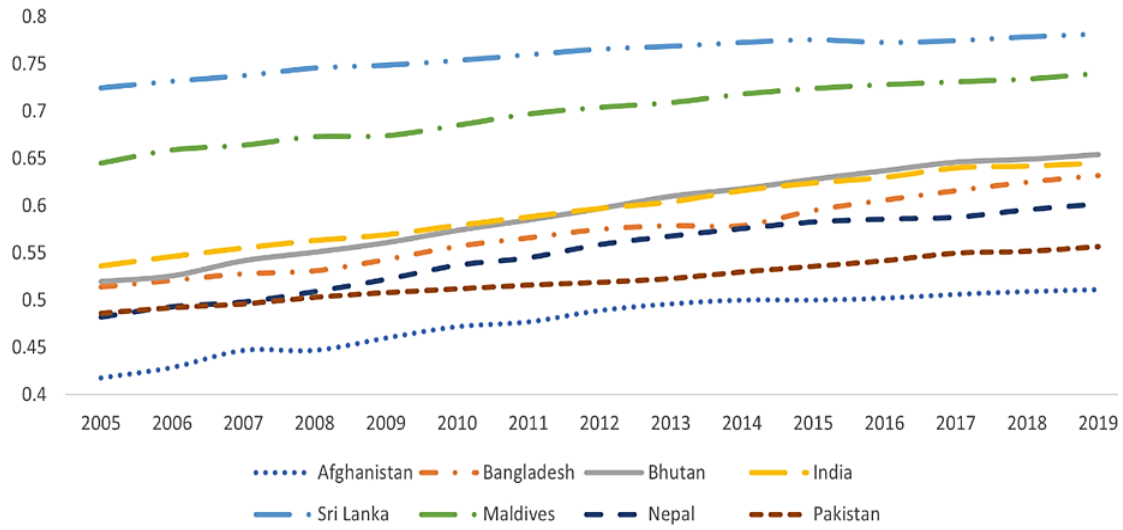
ICT diffusion (ICT) is a composite index constructed using PCA on five indicators: mobile phone subscriptions (per 100 people), fixed telephone subscriptions (per 100 people), fixed broadband subscriptions (per 100 people), Internet users (percentage of population), and international bandwidth per Internet user (bit/s). The first PC1 used as the index explains 61% variance contribution. The KMO test statistic 0.80 confirmed the sampling adequacy of each indicator in the model. The use of PCA to formulate an index is depicted in various panel studies [see, for example, Verma and Giri, 2020]. Figure 5.3 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.



[Source: ITU (2022) and Author calculations]

Figure 5.3: Trend of ICT diffusion in the SAARC economies

The variable poverty reduction (POV) is assessed by per capita household consumption expenditure because consumption expenditure is generally more accurately recorded and is more stable than income (Odhiambo, 2008). This statistic corresponds to the World Bank's concept of poverty, which is identified as "the inability to meet the basic living standard" in accordance with the basic consumption requirements (World Bank, 1989).



[Source: UNDP (2022) and Author Calculations]

Figure 5.4: 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 5.4 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.

Women empowerment is measured using female labor force participation (FLP) which is defined as employment to population ratio, 15+, female (%). Table 5.2 contains the description, data source, and definitions for the variables employed in this research. The selection of dependent, independent, and control variables is based on the latest research (Lechman & Popowska, 2020; Noor et al., 2021; Verma & Giri, 2020b).

Table 5.2: Descriptions of the variables

Variables	Symbols	Measurement	Data source
Dependent variable			
Poverty Reduction	POV	Households & NPISHs per capita final consumption expenditure (constant 2010 US$)	WDI
Human Development	HDI	Human Development Index	UNDP
Female Labor Force Participation	FLF	Employment to population ratio, 15+, female (%) (modeled ILO estimate)	WDI
Independent variable			
ICT Diffusion Index	ICT	It is a main independent variable and an important indicator of SDG goal 5(5b). The index is constructed using PCA on following indicators: i) Fixed telephone subscriptions (per 100 people) ii) Mobile cellular subscriptions (per 100 people) iii) Fixed broadband subscriptions (per 100 people) iv) Individuals using the Internet (percentage) v) International bandwidth per user (bit/s)	ITU
Control variables			
Economic growth	GDP	GDP per capita (constant 2010 US$)	WDI
Female Population	POP	Population, female (% of total population)	WDI
Financial development	FD	FD Index by IMF	IMF
Inflation	INF	Inflation, consumer prices (annual %)	WDI
Remittances	REM	Personal remittances, received (current US$)	WDI
Fertility Rate	FER	Fertility rate, total (births per woman)	WDI
Female Education	FED	School enrollment, primary, female (% gross)	WDI
Trade openness	TRD	Import plus export divided by GDP	WDI

To maximize the reliability of the findings and minimize the impact of any ambiguous or superfluous factors, the study includes various control variables which includes economic growth (GDP), trade openness (TRD) and inflation (INF) among others. GDP, has a direct impact development to the degree that it increases the options and capacities available to the government and the citizens (Ranis, 2000). Similarly, TRD influences 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.

5.3.2 Model specification

The purpose of this research is to analyse the role of ICT diffusion in poverty reduction, human capital development and women empowerment, considering economic growth, inflation, trade openness and other macro-economic control variables. As a result, an ICT-based theoretical model for the above variables can be derived as:

$$lnPOV_{it} = \alpha + \beta_1 lnICT_{it} + \beta_2 lnGDP_{it} + \beta_3 lnFD_{it} + \beta_4 lnREM_{it} + \beta_5 lnINF_{it} + \theta_i t + \varepsilon_{it} \quad (5.1)$$

$$lnHDI_{it} = \alpha + \beta_1 lnICT_{it} + \beta_2 lnGDP_{it} + \beta_3 lnINF_{it} + \beta_4 lnTRD_{it} + \theta_i t + \varepsilon_{it} \quad (5.2)$$

$$lnFLP_{it} = \alpha + \beta_1 lnICT_{it} + \beta_2 lnGDP_{it} + \beta_3 lnPOP_{it} + \beta_4 lnFER_{it} + \beta_5 lnFED_{it} + \beta_6 lnTRD_{it} + \theta_{it} + \varepsilon_{it} \quad (5.3)$$

where i = 1, 2,..., N represents the panel member, t = 1, 2,..., T indicates the timeframe, β denotes long-run elasticity estimates of dependent variables relative to ICT diffusion and other control variables, and αit & θit connotes the fixed country effect and the deterministic trend, and εit is the error term.

5.4 Results and Discussion

Recent studies in the domain of macroeconomic variables have piqued the interest of academicians all around the world. CSD among the economies is no more an expectation, but rather a rule in this globalized era (Turkay, 2017). Given the significance of CSD among cross sectional groups, we used four CSD tests to check if the series contains CSD. Table 5.3 indicates the existence of CSD in the variables. This suggests that the

existence of undetected common shocks across cross-section owing to economic interdependence is accounted for by the error terms. 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. The next step in the analysis is to determine if the variables are stationary.

Table 5.3: Cross-sectional dependence test

Series	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnPOV	212.988***	36.147***	35.947***	14.580***
lnHDI	405.739***	50.477***	50.191***	20.141***
lnFLP	142.153***	15.254***	14.968***	-1.359
lnICT	163.896***	27.184***	26.984***	12.650***
lnGDP	223.312***	38.032***	37.832***	14.936***
lnINF	51.839***	6.725***	6.525***	6.436***
lnREM	216.568***	36.801***	36.601***	14.707***
lnFD	82.459***	12.316***	12.116***	0.474
lnTRD	97.229***	9.251***	8.965***	2.378***
lnPOP	271.629***	32.556***	32.270***	1.6579***
lnFER	401.276***	49.881***	49.595***	20.026***
lnFED	130.708***	13.724***	13.439***	3.1296***

Note: *** Indicate levels of significance at 1%

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 5.4 shows that the null hypothesis of the absence of a unit root is rejected, and 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 relationship between the variables is tested using Westerlund cointegration test instead of the traditional Pedroni (2004), and Kao (1999) tests of cointegration. The findings of traditional tests could be factually inaccurate as they ignore several critical issues such as heteroskedasticity, serial correlation, structural breaks, and CSD among

the cross-sectional units. On the other hand, Westerlund (2007) cointegration test is an advanced test of cointegration between the variables as it considers all the above issues, resulting in more accurate results. Table 5.5 confirms that the p values of Ga, Gt, Pa, and Pt are significant, rejecting the null hypothesis of no cointegration and proving the existence of long run association between the variables.

Table 5.4: Panel unit root test

Variable	CIPS		CADF	
	Level	First difference	Level	First difference
lnPOV	-2.012	-2.324*	-1.735	-2.232**
lnHDI	-2.316	-3.938***	-1.904	-2.392**
lnICT	-2.283*	-4.070***	-1.390	-3.198***
lnGDP	-2.128	-4.340***	-1.419	-2.025**
lnINF	-3.089***	-4.132***	-2.601**	-4.060***
lnREM	-1.939	-2.828***	-2.391*	-2.246***
lnFD	-1.392	-3.783***	-1.627	-3.046***
lnTRD	-2.096	-3.066***	-2.252	-2.383**
lnPOP	-1.162	-2.843***	-5.632	-4.803***
lnFER	-2.612**	-2.999***	-2.348**	-2.984***
lnFED	-1.292	-2.948***	-1.108	-2.948***

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

Table 5.6 shows the long run elasticity estimates of lnPOV. The estimates of CS-ARDL test depict that a 1% increase in ICT diffusion will reduce poverty by 0.128 % in long run. This result is in contrast with studies Sujarwoto and Tampubolon (2016) Haider (2017) that argue that ICTs have no impact on poverty reduction. However, our results are inconsistent with the studies that strengthen the key idea vis-à-vis the positive effect of ICT diffusion on poverty alleviation in developing countries (Alimi & Adediran, 2020).

The results support the notion that economic progress reduces poverty. The coefficient of lnGDP is statistically significant. A 1% rise in GDP reduces poverty by 0.56% in the long run. This finding supports the idea that growth has a pro-poor effect, and it is consistent with the findings of Kraay (2006). This conclusion might be explained by the

fact that rising output improves the aggregate living standard. Furthermore, the significant coefficients of FD indicate that they promote poverty reduction. Statistically, a 1% rise in FD will reduce poverty by 0.10% in the long run. This demonstrates the significance of financial development in emerging nations for poverty alleviation and is consistent with the results of Peković (2017).

Table 5.5: Westerlund cointegration test

H0: no cointegration	Value	Z-value	Robust p-value
Dependent Variable: lnPOV			
Gt	-4.491	-5.520	0.000***
Ga	-5.234	2.070	0.000***
Pt	-7.763	-2.581	0.000***
Pa	-6.732	0.400	0.000***
Dependent Variable: lnHDI			
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
Dependent Variable: lnFLP			
Gt	-2.331	0.264	0.000***
Ga	-0.086	4.669	0.000***
Pt	-6.043	-0.026	0.000***
Pa	-0.079	3.702	0.000***

Note: *** indicate levels of significance at 1%.

Contrastingly, the results reveal that inflation upsurges poverty. A 1% rise in INF will increase poverty by 0.009% in the long run. Since inflation decreases the real income, expenditure on health and education decreases, which further increases the poverty level. The result is in agreement with the findings of Khan *et al.* (2021). The results of the DK tests presented in Table 5.6 are remarkably identical with those of the CS-ARDL. Except for INF, which has a negative value, all other coefficients are positive. The findings infer that ICT diffusion, economic growth, financial development, and remittances alleviate

poverty whereas inflation increases the poverty level in the economy.

Table 5.6: Long-run elasticity estimates (Dependent Variable: lnPOV)

Variables	CS-ARDL	DK Regression
lnICT	0.128**	0.181**
lnGDP	0.561***	0.142**
lnINF	-0.009	-0.047*
lnREM	0.054	0.159***
lnFD	0.105***	0.159***
R-squared	0.96	0.81
Prob>f	-	0.00
CD Statistic (p)	-1.77 (0.76)	-
F-stat (p)	12.75 (0.00)	-
Groups	6	6
Observation	96	96

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

Further, the elasticity estimates of lnHDI are presented in Table 5.7. Because all the variables are converted to logarithmic form, the long-run coefficient estimate of ICT, GDP, INF, and TRD are statistically equal to elasticities of HDI concerning ICT, GDP, INF, and TRD respectively. Table 5.7 shows that ICT diffusion has a favorable and significant impact on the HDI. A 1% increase in ICT leads to a 0.26% increase in HDI, which agrees with economic theories and is statistically significant. 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.

Table 5.7: Long-run elasticity estimates (Dependent Variable: lnHDI)

Variables	FMOLS	DCCE	DK Regression
lnICT	0.173***	0.268**	0.258***
lnGDP	0.024*	0.0215**	0.134**
lnINF	-0.003*	-0.001*	-0.011
lnTRD	0.025***	0.038*	0.050**
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

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

Further the positive impact of GDP is also 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).

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 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.

Table 5.8: Long-run elasticity estimates (Dependent Variable: lnFLP)

Variables	FMOLS	DCCE	DK Regression
lnICT	0.254**	0.638**	0.600***
lnGDP	0.119**	0.103**	0.041***
lnPOP	0.885**	0.149	0.221***
lnFER	-0.068***	-0.250*	-0.208***
lnFED	0.563*	0.732**	0.854***
lnTRD	-0.117***	-0.018**	-0.111***
R-squared	0.78	0.76	0.86
Root MSE	-	0.020	0.026
Prob>f	-	0.000	0.000
Groups	8	8	8
Observation	128	128	128

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

Further, Table 5.8 depicts the elasticity estimates of lnFLP. The results reveal that ICT diffusion has a favorable and statistically significant impact on FLP. The positive impact of ICT can strengthen the efforts for achieving SDG 5. The result of DCCE estimation shows that a 1% increase in ICT diffusion will increase female employment by 0.638 percent. The finding is also consistent with the studies of Alves and Steiner (2017), Mackey and Petrucka (2021), Nandi (2021), Noor et al. (2021), and Shirazi (2012).

Table 5.8 shows the expected signs of control variables; the GDP growth has a positive and significant impact on women's empowerment. The findings imply that economic

progress in developing nations is inclusive in terms of women's empowerment. Education also contributes to women's empowerment as a rise in female education enhances the likelihood of employment or employment retention, raises salary levels and widens job-search options for women in the workforce (Ahmed & Abdel, 2009). Even more intriguing is ICT's potential to boost women's education and thereby minimize gender imbalance in employment (Chen, 2004). As a result, it contributes to the achievement of SDG 4 in the long term.

Finally, in SAARC economies, FLP has a negative correlation with fertility. This is in accordance with the findings of previous research (Berniell et al., 2018; Noor et al., 2021), which show that motherhood leads to a decrease in labor supply, both in the extensive and intense margins, which may be interpreted in terms of the opportunity cost of remaining in the labor market. Indeed, when childcare services are scarce or pricey, the opportunity cost of remaining in the labor market forces one parent to focus on earning a living while the other focuses on childcare.

Trade openness, however, has a significant but detrimental effect on women's empowerment. Firstly, trade openness leads to an increase in capital accumulation that raises per capita GDP, and this increasing income discourages female participation. Secondly, higher imports indicate less domestic economic activity, which results in lower FLP. Thirdly, it increases the demand for skilled labor, which caused fewer job offers for females (Wood, 1998).

Moreover, to check the robustness of these results, the study also employed DK standard error approach. The results of the DK tests presented in Table 5.8 are remarkably identical to those of the DCCE test. Neal (2015) discovered that in the presence of CSD, the PMG, MG, DOLS, and FMOLS approaches yield inconsistent findings. Therefore, we rely on the results of DCCE and DK regression which are robust to CSD.

Table 5.9 Pairwise DH panel causality test

Null hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Remarks
lnICT ⇏ lnPOV	13.084	7.464	0.000***	ICT ↔ POV
lnPOV ⇏ lnICT	5.195	1.863	0.062*	
lnGDP ⇏ lnPOV	15.156	8.935	0.000***	GDP↔ POV
lnPOV ⇏ lnGDP	9.340	4.806	0.000***	
lnFD ⇏ lnPOV	3.782	0.859	0.390	FD ⇏ POV
lnPOV ⇏ lnFD	2.901	0.234	0.814	
lnREM⇏ lnPOV	4.777	1.561	0.118	REM ⇏ POV
lnPOV⇏ lnREM	3.009	0.310	0.755	
lnINF ⇏ lnPOV	4.990	1.717	0.085*	INF ↔ POV
lnPOV ⇏ lnINF	5.743	2.252	0.024**	
lnICT ⇏ lnHDI	5.945	2.459	0.013**	ICT↔HDI
lnHDI ⇏ lnICT	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*	
lnICT ⇏ lnFLP	11.992	14.745	0.000***	ICT ↔ FLP
lnFLP ⇏ lnICT	2.528	1.788	0.073*	
lnGDP ⇏ lnFLP	10.162	12.2400	0.000***	GDP↔ FLP
lnFLP ⇏ lnGDP	69.289	93.189	0.000***	
lnFER ⇏ lnFLP	1.998	1.062	0.288	FER ⇏ FLP
lnFLP ⇏ lnFER	1.565	0.470	0.638	
lnFED⇏ lnFLP	4.987	5.154	0.000***	FED → FLP
lnFLP⇏ lnFED	1.686	0.635	0.525	
lnPOP⇏ lnFLP	15.112	19.016	0.000***	POP ↔ FLP
lnFLP ⇏ lnPOP	140.144	190.195	0.000***	
lnTRD ⇏ lnFLP	1.826	0.827	0.408	TRD ⇏ FLP
lnFLP ⇏ lnTRD	1.968	1.022	0.306	

Note: ***, **, and * indicate levels of significance at 1%, 5%, and 10%, respectively and the symbol →, ↔ and ⇏ indicates unidirectional, bidirectional and no causality relationship, respectively.

Following the long run elasticity estimation, the study employs the DH causality test to investigate the causal relationships between the variables. Table 5.9 shows the results of the panel causality test. The association between ICT and POV lends credence to the feedback theory. This is in contrast with studies which argue that ICTs do not have a beneficial causal influence on poverty reduction (Haider, 2017; Sujarwoto & Tampubolon, 2016). Our findings, however, are consistent with Rodríguez and Sánchez-Riofrío (2017).

Similarly, a two-way causal linkage i.e., bidirectional causality between ICT and HDI and ICT and FLP was observed.

Furthermore, the results illustrate the bidirectional causality between GDP and POV. It implies that economic growth lowers poverty, and that poverty-reduction interventions will also have an impact on economic growth. The findings are consistent with the findings of Chinoda and Kwenda (2019) and Ghosh (2016).

Contrastingly, the causality findings further indicate that ICT granger causes GDP in the economy without any feedback, since ICT is now seen as a valuable component in combating global poverty. This finding is confirmed by Pénard and Poussing (2010), who claim that ICT presents emerging economies with unparalleled opportunity to achieve significant development objectives such as poverty alleviation, adequate healthcare, and education, much more efficiently than before.

Also, feedback effect was found between INF and POV. According to the feedback theory, inflation reduces the worth of an individual's cash holdings, real income, and the purchasing power of money, exposing them to higher degrees of poverty. Further, a unidirectional causality running from HDI to GDP, HDI to TRD and FED to FLP was observed. The study, however, found little evidence of a causal link between FD and POV. Similarly, there was no evidence of causal connection between REM and POV, HDI and INF, FER and FLP, and TRD and FLP.

5.5 Conclusion and Policy Implication

This research aims to examine the impact of ICT diffusion on inclusive growth measured through poverty reduction, human capital development and women empowerment in the SAARC economies for the period 2005-2020, using the most recent available data. The

study employed econometric methods robust to CSD such as CS-ARDL, DCCE, DK regression, and the DH causality test for the analysis.

The outcome of our study reveals that ICT can alleviate poverty and lead to human capital development as it helps the unprivileged to have better access to the market and healthcare services, as well as extend their usage of public services and microfinance. However, given the widespread illiteracy, high accessibility cost, and inadequate ICT infrastructure, the benefits of ICT remain confined in rural areas. Poor connectivity, as well as unstable power supplies, hinders the viability of several ICT-related initiatives. The poor in SAARC have extremely limited access to the ICT and the development of ICT infrastructures doesn't really ensure its use by the disadvantaged community. Therefore, the role of government in policy design is vital in achieving the objective of making ICT accessible to the poor.

Further, the empirical outcomes endorse the importance of ICT diffusion for women empowerment in SAARC economies. Using technology and ICTs to advance the rights of women and girls is explicitly addressed in SDG 5, which focuses on gender equality and women's empowerment. However, achieving gender equality goes well beyond any specific goal and is fundamental to the achievement of every SDG. Women empowerment through ICTs has a wide range of impacts even in informal labor settings: for example in Pakistan, a new food ordering system enables a safe virtual marketplace for home-based female food vendors to sell their meals to a wider audience (Hussain, 2016). ICTs provide enormous potential for women and girls, including the eradication of poverty, improvement of education and health, enhancement of agricultural productivity, and creation of decent jobs.

The results of the study resulted in various theoretical and practical contributions which

are shown below after an overview of the findings. 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 are 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.

Several policy recommendations can be derived from the findings in order to address the enormous challenges of ICT adoption in SAARC economies. The present research proposes the following initiatives could be implemented in SAARC to achieve inclusive growth:

- Participation in ICT projects can by encouraged by a diverse group of project operators and trainers, both in terms of caste and gender.
- Small business owners are interested in providing services in rural regions unlike the big operators in the market. Therefore, subsidies to these operators can be utilized to connect the poorest and most remote parts of the country.
- Applications for the poor should be offered in regional languages and, if feasible, visually oriented with audio interfacing.
- The contents of ICT applications should not be confined to external sources but should also incorporate information from disadvantaged people themselves.
- The success of ICT initiatives can be enhanced by training, especially when it is innovative and interactive.
- More emphasis should be placed on monitoring and assessment of ICT initiatives to determine if the returns outweigh the cost.
- Ensuring essential public services like health, education, and employment in a way that promotes gender equity and equitable access.
- Improving gender equality in the workforce by making labor markets more inclusive
- Improving access to ICT for reducing information asymmetries and eliminating the gender gap in decision-making
- Providing incentives like scholarships and awareness-raising initiatives to encourage girls to participate in ICT programmes.

Chapter-6

ICT Diffusion and Environmental Sustainability

6.1 Introduction

Development discourse nowadays is dominated by the objective of meeting the SDGs. However, many economies continue to confront obstacles or view the corresponding objectives with despair, particularly when their development efforts do not adhere to the desired/targeted time frames. Postponement of incremental milestones leading to the fulfillment of SDGs can be attributed to several factors, including the lack of a mechanism for disseminating information, which would help minimize ignorance of the procedures and methods required to achieve these goals (Latif et al., 2017). Advancements in information ICTs have made available a plethora of options for disseminating information (e.g., via the internet, mobile phones, fixed landlines, and other technological channels). Increasing ICT adoption in recent years has entailed a wide range of economic implications that differ by industry, including faster economic growth, financial sector development, educational efficiency, and ecological sustainability (Donou-Adonsou, 2019; Verma & Giri, 2020a). Meanwhile, the influence of ICT adoption on sustainable development has attracted significant academic attention. Globalization has led to a greater spread of ICTs

among geographically dispersed countries, creating new possibilities for inclusive and sustainable development (Pérez-Castro et al., 2021). It is essential, however, that the outputs of sustainable development be designed and built in such a way that the economic, social, as well as ecological dimensions of sustainable development are all addressed equitably. Additionally, economic activity has an environmental impact; therefore, policymakers must examine this and establish policies that favor ecologically sustainable technologies in order to reduce the environmental impact (Liu et al., 2021).

When it comes to the environment, ICT diffusion can have both positive and negative ecological repercussions. On the one hand, ICT can help households and businesses save money by lowering information asymmetries, transactional and transportation expenses associated with CO_2 emissions (Chien et al. 2021). Moreover, ICT minimizes the problem of asymmetric information linked with environmental conservation by reducing information costs related to CO_2 emissions. On the other hand, ICT diffusion increases energy consumption by households and corporations, resulting in increased CO_2 emissions (Avom et al., 2020). It can also contribute to changes in consumer behavior, such as a rise in energy consumption, since the digitization of services boosts their efficiency (Joyce et al., 2019). This is referred to as the rebound effect. According to estimates, the possible rebound effects of digitalization range between 10% to 30% greater energy consumption (Haldar & Sethi, 2022). However, global studies indicate that there exists a major infrastructural threshold over which the positive environmental impacts of ICT offsets these rebound effects (Higón et al., 2017). Given the complexity of ICT applications, it is essential to consider renewable energy (Batool et al., 2022a), innovation (Chaudhry et al., 2021), and the degree of liberalization (Asongu, 2018) in an economy in order to assess the net effect. Thus, depending on the circumstances, ICT may have either an adverse or favorable impact on environmental sustainability. This has prompted several researchers to conclude that

the two notions are connected through an inverted U-curve (Cheng et al. 2021; Khan et al. 2020).

Apart from ecological issues, ICT diffusion has a range of implications for social development. ICT, particularly smartphone technology, has revolutionized lives through advanced apps and services. As a result, current research has placed a strong emphasis on the economic and human developmental impact of ICT (Alimi & Adediran, 2020; Asongu et al., 2017b). Thus, owing to its favorable influence on globalization as well as CO_2 emissions, ICT has the potential to help accelerate human capital development (Asongu, 2021). Likewise, education can be used in conjunction with ICT and mobile technologies to promote inclusive human development. However, the favorable effects of ICT diffusion vary according to the ICT dynamics, the definition of human development, available resources, or even proximity to the sea (Nchofoung & Asongu, 2022).

Similarly, ICT diffusion has a range of economic repercussions. By increasing productivity and lowering transaction costs, ICT diffusion can boost growth in the economy (Aghaei & Nasab, 2009). It can also increase financial development (Chien et al., 2020), with positive externalities for economic expansion (Alshubiri et al., 2019; Verma & Giri, 2020a). The adoption of ICTs, which in turn boosts economic growth by improving economies of scale, might thus help to accelerate globalization (Haseeb et al., 2019; Pérez-Castro et al., 2021). However, without economic restructuring, ICT could be detrimental to economic growth (Verma & Giri, 2020a).

The literature frequently asserts that ICT exclusively benefits the economies of advanced countries but that the requisite human resources for managing ICT are lacking in emerging countries, particularly in low-income countries. Thus, ICT can be detrimental to overall development through its social, environmental, and economic elements. However, due to the interconnectedness of these factors, formulating sound economic

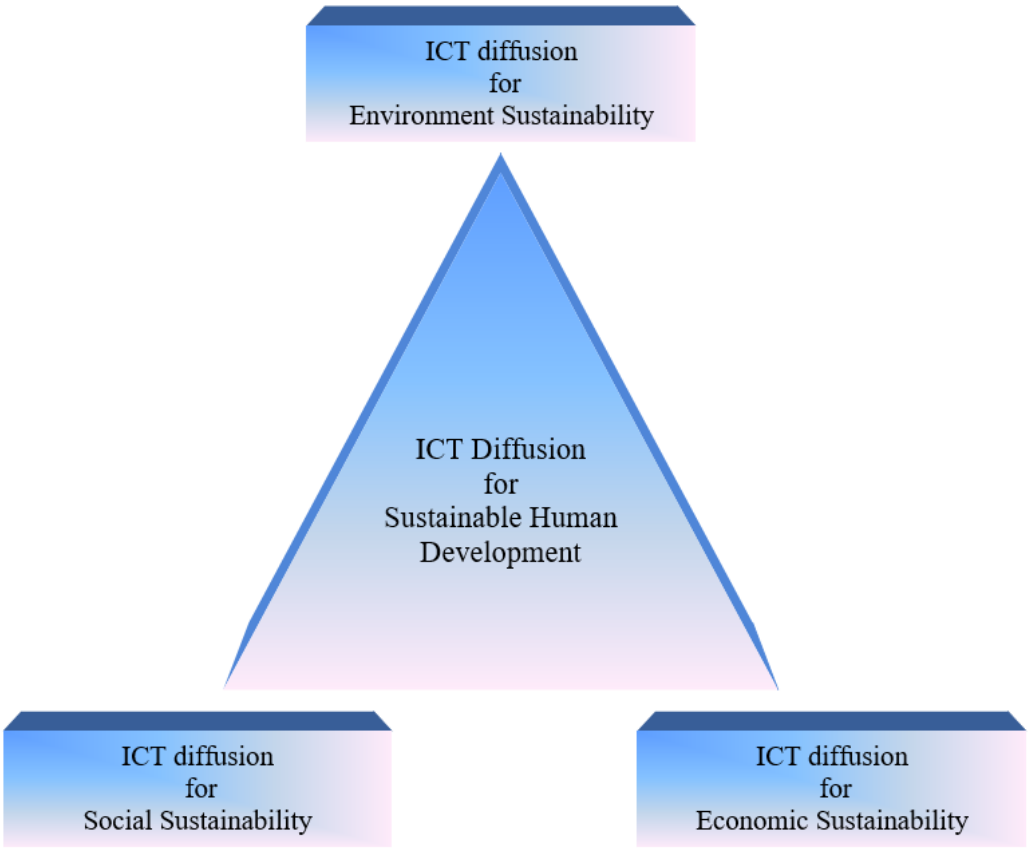
policy can be challenging at times. In light of the above issues, the study examines the impact of ICT diffusion, globalization, financial development, government effectiveness, and economic growth on sustainable human development (SHD) which is defined as the development of human capital adjusted against the human ecological footprint. It incorporates the concept of development that occurs without causing environmental deterioration. The fundamental linkages among ICT diffusion and various measures of sustainability demonstrated in the literature highlight the importance of studying this relationship. Further, it looks into the transmission mechanism through which ICT impacts sustainability. Given that ICT devices are ubiquitous, any attempt to mitigate climate change should address the carbon footprint of the ICT sector. Therefore, the study examines the direct impact of ICT on the environment and the indirect impact through interaction with energy consumption, financial development, and globalization in SAARC economies. It also examines the validity of EKC hypothesis. The EKC shows that environmental degradation first increases in tandem with per capita income. However, as the economy grows, the demand for environmental quality increases, resulting in a decline in environmental degradation (Dinda, 2004; Hussen, 2004). If there is an inverted U-shaped EKC, environmental benefits will occur as economies grow. Therefore, humanity may return to business as normal and still attain environmental sustainability without big changes.

The choice of the SAARC region is because this region is one of the world's most rapidly expanding economies. Increasing per capita income and better economic conditions have resulted in an increase in prime energy consumption, making it a hotbed for a growing middle-class populace. It accounts for around 4 percent of the global GDP, which totals USD 79.86 trillion (Abbas et al., 2018). The region is expected to develop by 6.6 percent in 2022 and 6.3 percent in 2023 (World Bank, 2022b). It is home to around 1.5 billion people, or approximately 24 percent of the worldwide people. Since the mid-1990s, ICT diffusion has

been growing in these developing nations. The problem is that SAARC economies have tried to advance without considering environmental quality, which is equally important for obtaining developed status. Because SAARC nations are economically open, they are seeing major increases in ICT adoption, energy use, globalization, and the unstructured financial sector, all of which have the potential to either reduce or accelerate environmental pollution. These economies have bright development potential. Fast-growing economies tend to have negative consequences for the environment. As a result, energy consumption and CO2 emissions are receiving more attention in SAARC economies. It is the world's most polluted region, where PM2.5 emissions from car exhaust, commerce, the burning of stalks and other crop debris during harvest season, and in-home cooking with solid fuels all combine to dangerously impair air quality. Therefore, it is vital to examine the environmental implications of ICT in these expanding countries to help policymakers make appropriate ICT infrastructure and foreign investment policies to protect the environment while encouraging economic growth and technology use. Besides, the extant ICT literature focuses mostly on advanced economies and substantially ignores developing economies (Akande et al., 2019; Salahuddin & Gow, 2016). Moreover, in prior research, ICT is typically quantified using either mobile phones or the internet, which cannot be extended to other indicators of ICT (Haldar & Sethi, 2022; Salahuddin & Gow, 2016). Furthermore, empirical investigations often overlook the possible issue of variable endogeneity (Higón et al., 2017b). Lastly, the existence of CSD in the data is constantly overlooked in the ICT research (Dabbous, 2018; Pradhan et al., 2017a). But, neglecting CSD can result in estimator inefficiency, which may lead to biased estimations. The need for this study was spurred by these gaps in ICT literature.

6.2 Literature Review

The "virtuous triangle" of ICT diffusion (Figure 6.1) extends well beyond the obvious cost-effective advantages, evolving the significance of ICT as a critical driver of sustainable human development. Therefore, this review of the literature is organized into three major pillars, namely, the social, economic, and environmental aspects of the goals. The environmental pillar is primarily concerned with the impact of ICT diffusion on CO2 emissions; the social pillar is concerned with the impact of ICT diffusion on different facets of human development, such as education, well-being, and inequality; and the economic pillar is concerned with the impact of ICT diffusion on economic development for growth and poverty alleviation purposes.



[Source: Author's compilation]

Figure 6.1: Virtuous triangle of ICT diffusion for sustainable human development

ICT has gradually spread, evolved, and penetrated different economic and sociological

domains, becoming a significant driver of worldwide economic growth in the contemporary industrial and technological revolution (Appiah-Otoo & Song, 2021; Arvin et al., 2021). Simultaneously, global warming and the degradation of the ecosystem continue to be major concerns. Scholars throughout the world are focusing on accurate identification and assessment of the links among ICT diffusion and CO_2 emissions (Haseeb et al., 2019). Theoretically, ICT diffusion impacts CO_2 emissions by increasing production, raising energy consumption efficiency, and reducing the cost of energy consumption (Moyer & Hughes, 2012). In the digital age, data acquisition and resource evaluation using ICT have become integral aspects of every corporate operation in terms of increasing production efficiency. May et al. (2017).

6.2.1 ICT diffusion and environmental sustainability

When it comes to the environment, ICT diffusion can have both positive and negative ecological repercussions. On the one hand, ICT can help households and businesses save money by lowering transactional and transportation expenses associated with CO_2 emissions. Moreover, ICT minimizes the problem of asymmetric information linked with environmental conservation by reducing information costs related to CO_2 emissions (Chien et al. 2021). It is further envisaged that ICT will help reduce carbon footprints through the establishment of smart cities, infrastructure, power stations, industrial operations, or emission reduction (Haseeb et al., 2019). On the other hand, ICT diffusion increases energy consumption by households and corporations, resulting in increased CO_2 emissions. In addition, although ICT strengthens the financial industry and dissemination of information, resulting in increased financial integration as well as boosting economic activity, it entails an increase in CO_2 emissions (Avom et al., 2020). Thus, depending on the circumstances, ICT may have either an adverse or favorable impact on environmental sustainability. This has prompted several researchers to conclude that the two notions are

connected through an inverted U-curve (Cheng et al. 2021; Khan et al. 2020).

Table 6.1: ICT diffusion and environmental sustainability

Author(s)	Area	Method	Main Finding
Avom et al. (2020)	Sub-Saharan Africa	1996-2014; Mediation analysis	ICT worsens environmental quality
Liu et al. (2021)	33 Asian	2000-2015; FMOLS, DOLS and PMG	ICT increases CO_2 emissions
Ahmed and Le (2021)	ASEAN-6 countries	1996-2017; CUP-FM	ICT improves environmental quality by mitigating CO_2 emissions
Chien et al. (2021)	BRICS countries	1995–2018; MMQR	ICT mitigates the level of CO_2 only at lower emissions quantiles
Haseeb et al. (2019)	BRICS countries	1994-2014; DSUR	ICT positively contributes towards environmental quality
Bhujabal et al. (2021)	Asia Pacific countries	1990-2018; PMG	ICT diffusion and FDI inflows decreases environmental pollution in the long run
Azam et al. (2021)	30 developing countries	1990-2017; VAR model	ICT mitigates CO_2 emissions
Esquivias et al. (2022)	Asian countries	1990-2019; QR	Investments in ICTs and human development reduce CO_2 emissions

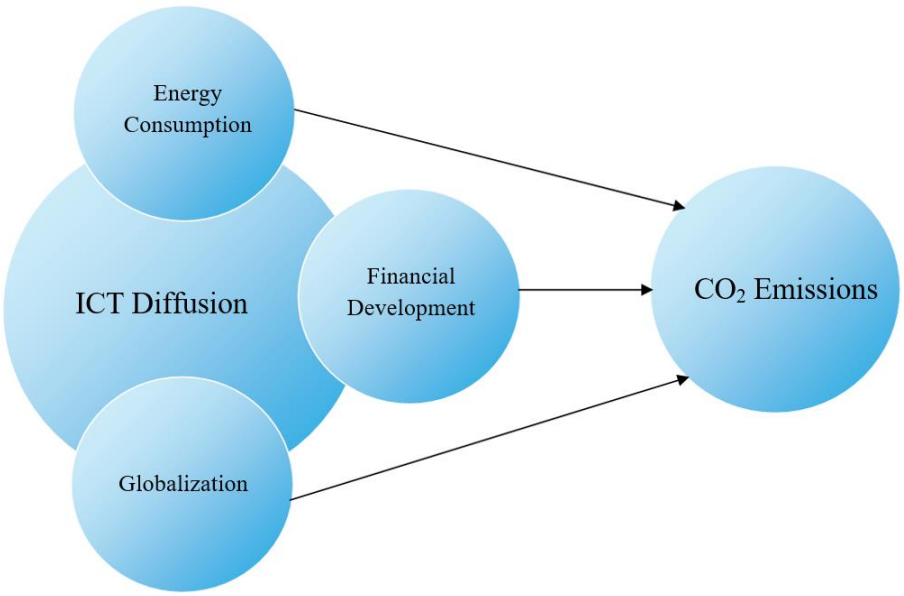
Table 6.1 presents a summary of the studies that have examined the relationship between ICT diffusion and environmental sustainability. Although significant progress has been made in the empirical investigation of the effect of ICT on environmental quality, existing studies have failed to empirically establish the mechanisms by which ICT hinders or improves environmental quality. The effect of ICT diffusion on the environment depends on several aspects like the integration of information technologies with energy (Batool et al., 2022a), innovation (Esquivias et al., 2022), trade (Arshad et al., 2020), FDI (Arain et al., 2019), population (Haldar & Sethi, 2022), and the level of financial development (Haldar & Sethi, 2022). Figure 6.2 presents the schematic representation of the direct and indirect impacts of ICT on CO_2 emissions.

Energy consumption is ubiquitously accepted as one of the major factors affecting CO_2 emissions. Numerous research has been conducted on the relationship between energy use and CO_2 emissions, and almost all of them indicate a positive impact of energy use

CO_2 emissions. In this context, ICT could help to minimize carbon emissions by improving energy efficiency and lowering the cost of renewable energy production (Moyer & Hughes, 2012). Contrarily, ICT may indirectly boost CO_2 emissions if gains in efficiency do not decrease the amount of energy consumed but instead increase it. This is commonly referred to as the rebound effect or the Jevons' Paradox. The rising demand for energy consumption necessitates the use of both renewable and nonrenewable energy sources. CO_2 emissions then increase due to increasing pressure to use non-renewable energy sources (Joyce et al., 2019; Vélez-Henao et al., 2019). This further encourages policymakers to move towards renewable energy alternatives to the conventional sources of energy. Rising prices of fossil fuels and the question of energy security has further strengthened the willingness of policymakers to shift to non-conventional sources of energy. Hence, the costs of renewable energy have been falling in many countries with emerging economies, thereby levelling the playing field and making renewable energy alternatives more competitive with the non-renewable ones (Haldar & Sethi, 2022). The cost-reduction combined with the need to protect themselves from volatile prices of non-renewable energy sources and the desire to reduce their environmental footprint has pushed ICT firms to invest heavily in renewable energy (Ahmed et al., 2017). Additionally, it can keep countering the detrimental impact caused by its own energy demand by incorporating renewable green energy to reduce its own CO_2 emissions.

The second channel is financial development. Many studies have found that financial development contributes to economic growth by stimulating economic activities, which increases energy demand and consequently positively contributes to environmental degradation (Ibrahim & Waziri, 2020; Sharma et al., 2021). However, the role of financial institutions in relaying the effects of ICT on environmental quality is still

unclear. From the theory standpoint, Asongu and Nwachukwu (2016) assert that ICT strengthens financial sector development by expanding the availability of credit to businesses and household, minimizing information asymmetry on the credentials of borrowers, and boosting competition between the formal and informal financial sectors. Financial prosperity in transitioning and emerging nations, when combined with ICT, worsens the environment by raising CO_2 emissions (Danish et al., 2018). However, other authors believe that financial development reduces environmental degradation as growth in financial services can promote innovation and increase energy efficiency (Haseeb et al., 2019; Raheem et al., 2020). These contrasting results across countries make it crucial to further explore the impact of this dynamic interaction between ICT and financial development on CO_2 emissions.



Source: Author's compilation

Figure 6.2: The direct and indirect impact of ICT diffusion on CO_2 emissions

The third channel from ICT to CO_2 emissions is trade openness. The indirect impact of ICT on the environment may result from the fact that ICT reduces the prices and restrictions involved with the trade of CO_2-emitting products. In addition, the Internet

makes available information on the location of manufacturing factors, which can facilitate the expansion of worldwide trade in these products. The literature also asserts that ICT commodities would ideally flow more easily into nations with relatively lower comparative advantages in manufacturing them if trade barriers are liberalized. In addition, increasing openness to ICT-trade contributes to the development of the ICT industry, particularly in emerging economies, which is expected to enhance their energy infrastructure to facilitate the adoption of green technology and reduce CO_2 emissions (Murshed, 2020). Dong et al. (2021) in a recent study that covered 15 major economies from 2000 to 2014, showed that while the total input of carbon emissions in the ICT sector shows a decreasing trend, the share of carbon emissions from trade shows an increasing trend. ICT can minimize emissions by tracking, optimizing, and regulating logistic operations (Danish, 2019; Haldar & Sethi, 2022), given that international trade requires extensive transport and logistics infrastructure.

Further, foreign direct investment (FDI) has an impact on the environment because it facilitates the interchange of information and expertise necessary to improve environmental quality through green technologies (Weili et al., 2022). The literature highlights two approaches to the relationship between FDI flows and CO_2 emissions i.e., the “pollution haven” and the “pollution halo” hypothesis. According to the “pollution haven” theory, developing countries have a relatively flexible policy to attract FDI and dirty sectors, which could have an impact on the environment and cause developing countries to become a pollution haven where FDI exacerbates pollution. (Mani & Wheeler, 1998). Such industries become a “pollution haven” for developing countries. Thus, it is concluded that FDI increases pollution in these countries. The "pollution halo" concept, on the other hand, claims that FDI and CO_2 emissions have positive externalities. This dynamic interplay between ICT and FDI must be further studied

considering these varied results across countries. As a result, this research examines whether this interaction has the potential to cut CO_2 emissions. Hence, how do ICT diffusion, energy consumption and economic openness influence emissions is an important question in the context of SAARC countries.

6.2.2 ICT diffusion and social sustainability

Apart from ecological issues, ICT diffusion has a range of implications for social development. ICT, particularly smartphone technology, has revolutionized lives through advanced apps and services. As a result, current research has placed a strong emphasis on the economic and human developmental impact of ICT (Alimi & Adediran, 2020; Asongu et al., 2017b). Thus, owing to its favorable influence on globalization as well as CO_2 emissions, ICT has the potential to help accelerate human capital development (Asongu, 2021). Likewise, education can be used in conjunction with ICT and mobile technologies to promote inclusive human development. However, the favorable effects of ICT diffusion vary according to the ICT dynamics, the definition of human development, available resources, or even proximity to the sea (Nchofoung & Asongu, 2022). Another line of research examines the idea of social development in the context of population health. In this context, various academics have investigated the impact of ICT on health status, finding that it has contributed to the regionalization of healthcare networks and bringing doctors and patients closer together (Dutta et al., 2019). According to Chib et al. (2008), digital inclusion is a key component of health initiatives. However, in efforts to improve lifestyle through ICT diffusion, the deployment model should be adapted to promote the basic rights, privacy, and security of individuals on the web (Hughes et al., 2017). Table 6.2 presents a summary of the studies that have examined the relationship between ICT diffusion and social sustainability.

Table 6.2: ICT diffusion and social sustainability

Author(s)	Area	Method	Main Finding
Dutta et al. (2019)	30 Asian countries	2000-2016; FMOLS and DOLS	Long run relationship between ICT and health outcome
Tchamyou et al. (2019)	48 African countries	1996-2014; GMM	ICT reduces income inequality through formal financial sector development
Adams and Akobeng (2021)	46 African countries	1984-2018; GMM	Internet, broadband and mobile subscriptions directly reduce inequality
Njangang et al. (2021)	45 countries	2000-2017; GMM	ICT increases wealth inequality
Asongu (2021)	Sub-Saharan Africa	2000-2012; Tobit regression	Mobile phone penetration boosts inclusive human development irrespective of level of income
Zhang and Danish (2019)	Asian countries	1990-2016; MG estimator	Mobile phones contribute to economic growth, but the internet does not seem to do.
Azam et al. (2021)	30 developing countries	1990-2017; VAR model	ICT and remittances stimulate the human development process
Farooqi et al. (2020)	67 countries	2000-2018; ARDL	ICT investment have different impacts on different components of human development

6.2.3 ICT diffusion and economic sustainability

The final body of research looks at the impact of ICT on economic development. ICT has become an integral part of the manufacturing process and technical advancement since it serves as both “an intermediate input and an investment good” (Hwang & Shin, 2017). Furthermore, ICT contributes to output through both neutral and non-neutral effects by altering the production function and lowering capital output elasticity as it promotes capital-intensive technology upgrades (Zhang & Danish, 2019).

Additionally, productivity improvements and economic growth enable emerging economies to benefit from an improved living standard as a result of ICT sector expansion (Appiah-Otoo & Song, 2021). Global investment in the ICT industry may have been boosted due to the proliferation of mobile phone technology (Lam & Shiu, 2010). Indeed, mobile devices have become ingrained in our daily lives and are altering the way businesses and markets operate, opening up new revenue streams (Asongu, 2021). As a

result, empirical research has consistently demonstrated that ICT has a favorable and significant impact on economic growth (Alshubiri et al., 2019; Appiah-Otoo & Song, 2021). However, some research indicates that as an economy develops, the influence of mobile phones gradually diminishes due to marginal returns and the emergence of the internet (Donou-Adonsou, 2019). Also, ICT may actually be detrimental to development in the absence of economic reform (Albiman & Sulong, 2017). Table 6.3 presents a summary of the studies that have examined the relationship between ICT diffusion and economic sustainability.

Table 6.3: ICT diffusion and economic sustainability

Author(s)	Area	Method	Main Finding
Cheng et al. (2021)	72 countries	2000-2015; GMM	ICT diffusion boosts economic growth in high-income countries, but the effect is ambiguous in middle & low-income countries.
Alshubiri et al. (2019)	6 GCC countries	2000-2016; fixed effects	A 1% increase in ICT increases money supply proxy by 0.40%
Chien et al. (2020)	81 countries	1990-2015; GMM	Internet positively influences financial development, whereas mobile phones cause a negative effect in high-income countries, but a positive effect in middle- & low-income countries.
Kurniawati (2020)	25 Asian countries	2000-2018; Panel cointegration estimators	Fixed telephone and mobile phone penetration promotes economic growth
Yilmaz et al. (2018)	182 countries	2000-2013; fixed effects	Internet usage has a strong positive is effect on all poverty indicators
Ben Lahouel et al. (2021)	Africa	1970-2018; logistic smooth transition regression	ICT boosts economic growth and mitigates climate change
Toader et al. (2018)	European Union	2000-2017; GMM	Positive and strongly effect of ICT on economic growth but the magnitude of the effect differs depending on the type of technology.
Appiah-Otoo and Song (2021)	123 countries	2002-2017; GMM	ICT increases economic growth; however, poor countries tend to gain more from the ICT revolution.
Ofori et al. (2021)	Sub-Saharan Africa	1980-2019; GMM	The results further revealed that, though ICT skills reduce poverty, the effect is more pronounced in the presence of enhanced financial development.

The highlighted literature examines the impact of ICT diffusion on environmental, social, and economic dimensions. However, no study has examined the impact of ICT diffusion

on sustainable human development using the SHD index. Also, the literature asserts that the relationship between ICT diffusion and the above dimensions follows an integral but dynamic construct that strongly relies on HDI dynamics, ICT indicators, country characteristics, and the adopted methodology. In addition, the existing literature typically operationalizes the idea of development solely in terms of human development and disregards the carbon footprint. Furthermore, existing studies have overlooked the causality nexus (the FH, no causality hypothesis, one-way ICT-led development hypothesis, and one-way development-led ICT hypothesis) between ICT diffusion and SHD. This necessitates a comprehensive examination of how ICT diffusion and Environmental Sustainability are intertwined, using advanced methodologies robust to CSD to ensure the transparency and reliability of the findings. Ipso facto, the main objective of the present study is to answer the following research questions (RQs) with respect to SAARC economies.

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

RQ2: What are the transmission mechanisms from ICT diffusion to environmental sustainability?

RQ3: What is the nature of the association (causal relationship) between ICT diffusion and environmental sustainability?

6.3 Data and Model

The primary aim of this study is to examine the impact of ICT diffusion on sustainable human development by incorporating the role of globalization in the SAARC economies for the time period 2005–2020. The periodicity of the variables is restricted by the available data at the time of this research. The dependent, independent, and control variables were selected based on existing literature (Asongu et al., 2017b; Nchofoung &

Asongu, 2022; Verma & Giri, 2020a). The data source includes World Bank, ITU, and Hickel (2020).

The SHD index, based on Hickel (2020), is the dependent variable in our study; it signifies the effectiveness of the economies in achieving SHD. The index is calculated as a quotient of two indices, namely, the HDI and the environmental impact index (EII). While the HDI is constructed as the geometric mean of indices of education, life expectancy, and modified income, the EII considers the extent to which the material footprint and CO_2 emissions from consumption-based activities exceed per capita shares of planetary boundaries. The computations are presented in equations (6.1), (6.2), and (6.3) for the SDH, HDI, and EII, respectively.

$$SDH_{it} = \frac{\text{Human Developmen t Index}_{it}}{\text{Ecological Impact Index}_{it}} \tag{6.1}$$

$$HDI_{it} = (\text{Life Expectancy Index} * \text{Eductaion Index} * \text{Income Index})^{\frac{1}{3}} \tag{6.2}$$

$$EII_{it} = 1 + \frac{e^{AO} - e^{1}}{e^{4} - e^{1}} \tag{6.3}$$

where ***AO*** denotes the average overshoot, which is defined as the proportion of the material footprint and each emission value to their corresponding per capita planetary boundaries.

ICT diffusion is the independent variable of interest, which is measured through an index constructed using PCA to avoid the problem of multicollinearity. The index is based on five indicators, which include fixed telephone subscriptions, mobile cellular subscriptions, fixed broadband subscriptions, individuals using the internet, and internet bandwidth (Arvin et al. 2021; Cheng et al. 2021; Khan et al. 2020). The index was further screened for sampling adequacy using the KMO test (Kaiser, 1974). The overall KMO score for the dataset is 0.80, indicating that our PCA produces accurate and reliable results.

The control variables are selected in light of existing literature on the factors affecting SHD and inclusive development. Financial development (FD), proxied by domestic credit to the private sector, is the first control variable, which is expected to have a favorable impact on SHD. ICT may have an impact on the environment through the growth of financial markets (Chien et al. 2021). In addition, globalization has a beneficial effect on SHD in the socio-economic and political domains (Nchofoung & Asongu, 2022). Therefore, globalization is proxied by trade openness (TRD) and foreign direct investment (FDI), which is likely to have a positive impact on SHD. Another variable that must be taken into consideration is good governance, which is a prerequisite to SHD. It is anticipated that the governance proxy of government effectiveness (GOV) will have a favorable impact in this study. Finally, the study also includes economic growth (GDP), proxied through per capita GDP. Indeed, no economic development is possible without growth. While growth is a proxy for development, it is also critical to social and environmental sustainability (Nchofoung & Asongu, 2022). This variable may have a beneficial or detrimental influence.

As a result, an ICT-based theoretical model for SHD can be derived, as in equation (6.4):

$$lnSHD_{it} = \alpha + \beta_1 lnICT_{it} + \beta_2 lnFD_{it} + \beta_3 lnTRD_{it} + \beta_4 lnFDI_{it} + \beta_5 lnGOV_{it} + \beta_6 lnGDP_{it} + \theta_{it} + \varepsilon_{it} \quad (6.4)$$

where i = 1, 2,..., N represents the economy in the panel, t = 1, 2,..., T indicates the time frame, β1, β2, β3, β4, β5, and β6 are the parameters indicating long-run elasticity estimates of SHD with respect to ICT diffusion and other control variables, and αit & θit denote the fixed country effects and the deterministic trend, respectively. Lastly, εit is the error term.

Further, the study examines the direct impact of ICT diffusion on CO_2 emission (expressed in metric tons per capita) along with the indirect impacts through interaction with energy consumption, financial development, and globalization. The study also examines the

existence of EKC hypothesis for ICT diffusion.

The choice of variables is based on a review of the relevant literature and theoretical justifications. The energy intensity of the ICT sector is currently developing at an unsustainable annual rate of 4 percent, while the emissions linked to digitalization is increasing at the rate of 8 percent (IEA, 2017). Considering the importance of ICT in the energy sector, this study explores the connection between ICT diffusion and CO2 emissions using renewable and nonrenewable energy usage as energy sector proxies.

In addition, the implications of ICT go far beyond the energy sector. Global economic productivity and consumption are being reshaped by ICTs, thanks to the advent of sophisticated newer technologies. Since ICT can facilitate "dematerialization" in varied sectors like housing, transportation, and commerce (Fagas et al., 2017), an indirect effect of ICT through economic openness may save more energy than its direct effect. The relationship between ICT and CO2 emissions is heavily influenced by economic openness measures such as globalization and financial development. Research shows that ICT facilitates globalization (through trade openness and boosting FDI) and reduces emissions in developing countries (Murshed, 2020), whereas ICT-led financial development has a direct impact on the economy and environment of these nations (Danish et al., 2018). As a result, the present research also considers financial development which is proxied by domestic credit to the private sector and globalization which is proxied by trade openness and FDI.

The following linear model to analyze the impact of ICT, economic growth, energy consumption, financial development, and globalization on CO_2 emission is constructed:

$$CO_2 = f(ICT_{it}, GDP_{it}, REC_{it}, FD_{it}, G11N_{it}) \quad (6.5)$$

$$lnCO_2 = \beta_0 + \beta_1 lnICT_{it} + \beta_2 lnGDP_{it} + \beta_3 lnGDP_{it}^2 + \beta_4 lnREC_{it} + \beta_5 lnFD_{it} + \beta_6 lnG11N_{it} + \varepsilon_{it} \quad (6.6)$$

$$lnCO_2 = \beta_0 + \beta_1 lnICT_{it} + \beta_2 lnICT_{it}^2 + \beta_3 lnGDP_{it} + \beta_4 lnGDP_{it}^2 + \beta_5 lnREC_{it} + \beta_6 lnFD_{it} + \beta_7 lnG11N_{it} + \varepsilon_{it} \quad (6.7)$$

where, equation (6.6) presents the general specification of the model, equation (6.7) is the expanded form of equation (6.6) depicting the linear effect of ICT diffusion on CO_2 emissions with and as the endogenous variables, while equation (6.8) is the non-linear formulation, incorporating ICT^2 to check for the existence of EKC hypothesis for ICT diffusion.

6.4 Results and Discussion

The analysis begins with a series of diagnostic tests. To begin, we check to see if the model has a multicollinearity problem. Although multicollinearity has no effect on the explanatory power of the model, it does lower the statistical significance of the variables under study. Therefore, it is important to detect multicollinearity before beginning the estimation. We use VIF as a diagnostic tool for potential multicollinearity issues. The results indicate that VIF spans between 1.47 and 4.35 and that the mean VIF score is 2.76, which is less than 5, indicating that our models are not susceptible to multicollinearity (Khan et al., 2020).

Subsequently, the tests for CSD were conducted using the Pesaran CD (Pesaran, 2004), Breusch-Pagan LM (Breusch & Pagan, 1980), Pesaran scaled LM (Pesaran, 2004), and bias-corrected scaled LM (Baltagi et al., 2012) tests for the SAARC economies. Table 6.4 shows the outcomes of the CSD tests, which strongly reject the null hypothesis stating the absence of CSD in the dataset. This indicates that our panel data exhibit CSD in the data. Thus, it is necessary to address the CSD problem to produce robust estimation findings.

Table 6.4: Cross-sectional dependence test

Series	Breusch-Pagan LM	Pesaran scaled LM	Bias-corrected scaled LM	Pesaran CD
lnSHD	193.010***	22.050***	21.765***	10.045***
$lnCO_2$	378.94***	46.89***	46.69***	18.92***
lnICT	378.594***	46.850***	46.564***	19.444***
lnGDP	340.633***	41.777***	41.492***	18.365***
lnNREC	465.92***	58.51***	58.31***	21.42***
lnREC	376.44***	46.56***	46.36***	19.14***
lnFD	190.878***	21.766***	21.480***	0.452
lnGOV	43.539***	2.077***	1.791***	0.427***
lnFDI	111.609***	11.173***	10.887***	1.349
lnTRD	177.065***	19.920***	19.634***	10.960***

Note: *** indicate levels of significance at 1%

The non-stationary nature of economic variables often leads to biased results. Therefore, to obtain valid and unbiased results, the study uses second-generation CIPS and CADF tests to examine the stationarity properties. Both tests are designed to address the issue of homogeneity in panel unit root testing. Additionally, these tests are unaffected by CSD or heterogeneity in the data. According to the results in Table 6.5, the variables fulfill the precondition of cointegration tests, i.e., the variables at stationarity at first difference I(1).

Table 6.5: Panel unit root test

Variable	CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)
lnSHD	-1.780***	-2.057***	-2.992***	-3.144***
lnCO2	-1.283	-3.939***	-1.283	-3.939***
lnICT	-1.599	-1.924**	-0.961	-1.794**
lnGDP	-0.311	-2.572***	-1.163	-3.102***
lnNREC	-1.695	-3.426***	-1.695	-3.426***
lnREC	-1.418	-3.648***	-1.418	-3.648***
lnFD	-1.487	-2.374***	-1.904	-2.724***
lnGOV	-2.743**	-3.324***	-2.512**	-3.195***
lnFDI	-2.162***	-3.899***	-2.944	-3.943***
lnTRD	-1.672**	-2.173***	-1.314	-2.354**

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

The cointegration test proposed by Westerlund (2007) has been used to examine whether or not the variables have a possible long-run equilibrium relationship since it generates

efficient outcomes even in small sample sizes. Additionally, the Westerlund cointegration test controls a substantial degree of panel heterogeneity in both the long run as well as the short run while assuming CSD among the panels. Table 6.6 displays the results of the Westerlund cointegration test. The null hypothesis of absence of cointegration is rejected because the robust p values are significant at the 1 percent.

Table 6.6: Westerlund cointegration test

	Value	Z value	Robust P value
Dependent Variable: lnSHD			
Gt	-1.763	1.839	0.000***
Ga	-0.449	4.546	0.000***
Pt	-4.814	1.004	1.000
Pa	-0.747	2.991	0.000***
Dependent Variable: lnCO2			
Gt	-1.408	-0.071	0.000***
Ga	-5.919	-0.049	0.000***
Pt	-6.846	-3.158	0.000***
Pa	-10.001	-4.330	0.000***

Note: *** indicate level of significance at 1%.

Table 6.7: Long-run elasticity estimates (Dependent Variable: lnSHD)

Variables	FMOLS-MG	DCCE-MG	DK Regression
lnICT	0.281	0.477***	0.349**
lnGDP	0.394***	0.702**	0.422***
lnFD	-0.136***	-0.112*	-0.122***
lnGOV	0.614	0.556	0.648
lnFDI	0.017**	0.018***	0.016**
lnTRD	0.028	0.035	0.014*
R-squared	0.79	0.79	0.77
Root MSE	-	0.03	0.02
Prob>f	-	0.00	0.00
Groups	8	8	8
Observation	128	128	128

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

Table 6.7 shows the long run elasticity estimates of lnSHD using FMOLS and DCCE. To ensure the results are robust, we additionally employ the DK standard error approach. The empirical evidence in Table 6.7 demonstrates that ICT has a considerable positive

influence on SHD, regardless of the estimation methodology used. The findings of the DK standard error approach show that a 1% growth in ICT diffusion induces a 0.34% increase in the SHD index. The results are consistent with existing literature, which asserts that ICT has the potential to promote inclusive human capital development (Asongu et al., 2017b), accelerate economic growth (Verma & Giri, 2020a), reduce environmental impacts (Haseeb et al., 2019), and alleviate inequality (Tchamyou et al., 2019). ICT contributes to SHD by enhancing the environmental and socio-economic components of sustainability. ICTs, such as the internet and telephone, provide the ideal medium for disseminating knowledge of the impact of achieving long-term development goals. They make trading and investing easier, boost economic activity, and allow for larger economies of scale. Consequently, the level of income in the economy rises, which may then be utilized to fund the SDGs outlined by the UN.

Additionally, the control variables (e.g., GDP, government effectiveness, FDI, and trade openness) all demonstrate a favorable and significant impact on SHD in the long run. It is now imperative for SAARC countries to become more open to global commerce and integration. Increased economic progress may contribute to improvements in health, education, and life expectancy. Health and education are more accessible to persons who have a higher income since they have more money to spend. SHD and globalization are intertwined as trade and commerce can improve standards of living, increase business possibilities, ensure sustainability, as well as boost production, all of which have an impact on human capital in one way or another. Mukherjee and Chakraborty (2010) demonstrate that trade openness and a decent standard of life are causally related. Financial development, on the other hand, has a detrimental effect on SHD.

Table 6.8: Long-run elasticity estimates (Dependent Variable: lnCO2)

	DK Regression				
Variables	**I**	**II**	**III**	**IV**	**V**
lnICT	0.2172**	0.3102***	0.3157***	0.0205**	0.3276***
	(0.0744)	(0.0575)	(0.0656)	(0.0813)	(0.0659)
ln(ICT)2		-0.0353**	-0.0361*	-0.0419*	-0.0344*
		(0.0188)	(0.0178)	(0.0201)	(0.0192)
lnGDP	0.0005**	0.0001**	0.0001**	0.0001**	0.0001*
	(0.0008)	(0.0005)	(0.0005)	(0.0005)	(0.0005)
ln(GDP)2	-0.0005**	-0.0001*	-0.0001*	0.0001*	0.0001*
	(0.0006)	(0.0007)	(0.0007)	(0.0007)	(0.0006)
lnNREC	0.0385***	0.0342***	0.0358***	0.0318***	0.0336***
	(0.0057)	(0.0055)	(0.0057)	(0.0056)	(0.0065)
lnREC	-0.0042*	-0.0028*	-0.0027*	-0.0040*	-0.0018**
	(0.0019)	(0.0020)	(0.0021)	(0.0020)	(0.0020)
lnFD	0.0127***	0.01163***	0.0114***	0.0098***	0.0110***
	(0.0022)	(0.0020)	(0.0021)	(0.0019)	(0.0020)
lnTRD	-0.0002*	-0.0003*	-0.0003*	-0.0001*	-0.0006*
	(0.0007)	(0.0007)	(0.0007)	(0.0007)	(0.0008)
lnFDI	-0.0069***	-0.0059***	-0.0059***	-0.0053***	-0.0053***
	(0.0018)	(0.0018)	(0.0018)	(0.0018)	(0.0017)
lnICT*lnREC			-0.0114*		
			(0.0271)		
lnICT*lnFD				-0.0026***	
				(0.0008)	
lnICT*lnTRD					-0.0020***
					(0.0011)
lnICT*lnFDI					-0.0083***
					(0.0015)
Constant	0.81948***	0.9501***	0.9490***	1.0196***	0.9544***
	(0.1474)	(0.1133)	(0.1103)	(0.0887)	(0.1148)
R-squared	0.7545	0.7600	0.7602	0.7669	0.7706
Prob > f	0.0000	0.0000	0.0000	0.0000	0.0000
Observations	168	168	168	168	168
Countries	8	8	8	8	8

Note: ***, **, and * indicate levels of significance at 1%, 5%, and 10%, respectively. Standard errors in parentheses.

Next, the DK standard error approach is used to estimate the long run coefficients of lnCO2 reported in Table 6.8. As previously noted, we use DK panel estimators to account for autocorrelation, heteroscedasticity, CSD, and non-normality in the dataset. In Table 6.8, the linear specification with ICT diffusion index as proxy for ICT (Model-

I) demonstrates that an increase in ICT usage significantly reduces CO_2 emissions. These results are consistent with existing research on developing countries (Danish et al., 2018; Salahuddin et al., 2018; Sharma et al., 2021). The influence of per capita GDP on CO_2 emissions is also found to significantly reduce CO_2 emissions, but the coefficient is quite small. Further, renewable energy, trade and FDI significantly reduces CO_2 emissions, but the use of nonrenewable energy sources and financial development is found to increase CO_2 emission for the panel. The rise in CO_2 emissions caused by GDP per capita is small but significant.

Further, the interaction effect between renewable energy and ICT diffusion as depicted in Model-III, significantly reduces CO_2 emissions for the sample under consideration. which is in accordance with Haldar and Sethi (2022). The ICT industry is at the forefront of the transition to more renewable energy use, which has helped the industry reduce emissions (Freitag et al., 2021). In addition, findings depict that financial development increases CO_2 emission. This is because in developing countries of Asia, the financial sector causes scale effects by increasing economic activity through the provision of loans. However, the interaction term between ICT and financial development in Model IV is significant and negative, asserting that the interaction between ICT and financial development might increase energy efficiency and decrease CO_2 emissions. For Model-V, the interaction between ICT diffusion and globalization proxied by trade and FDI have small interactions. This result supports the notion that the interaction effect between ICT diffusion and globalization is favorable for environment quality. This is owed to the fact that SAARC economies frequently imposes rigorous environmental laws on energy-intensive manufacturing activities and complies with all these regulations by outsourcing manufacturing lines and importing final energy-intensive products, which helps to

preserve environment. Our results are in line with Essandoh et al. (2020). Furthermore, the EKC hypothesis for ICT diffusion is supported by all of these models. Economic growth in developing countries is associated with increased use of nonrenewable energy sources and the loss of natural resources, including deforestation. These factors ultimately have a negative impact on environmental quality. However, in the long run, GDP squared has a negative sign, proving the validity of the inverted U-shaped EKC notion. Several regional and international studies also indicate the presence of EKC for the use of ICT (Higón et al., 2017b; Batool et al., 2022b; Danish et al., 2018; Haldar & Sethi, 2022; Liu et al., 2021).

The long-run panel data estimates do not offer extensive with respect to the causal association among the variables. The study uses the paired panel causality test proposed by Dumitrescu and Hurlin (2012) which is resistant to CSD and heterogeneity, in order to assess the causality. Table 6.9 presents the results of the DH causality test, which show a unidirectional causal relationship running from ICT diffusion to SHD, implying that an increase in ICT boosts SHD in an economy. The results also found unidirectional causality running from TRD to SHD, which implies that an increase in trade will increase SHD in these countries. Furthermore, the existence of a bidirectional causal relationship between GDP and SHD was observed, suggesting that economic growth and SHD influence each other in the SAARC countries. Likewise, bidirectional causality was observed between government effectiveness and SHD.

With respect to CO2 and ICT, Table 6.9 shows bidirectional causal relationship between ICT diffusion and CO2 emissions which is in line with Khan et al. (2020) and Chien et al. (2021). Similarly, a two-way causal link exists between GDP and CO2 emissions which is in line with Saidi and Rahman (2021) in OPEC countries. A unidirectional causality exists

running from energy consumption, financial development and FDI to CO2 emissions which is in accordance with the existing literature (Mbarek et al., 2014; Bui, 2020; Essandoh et al., 2020).

Table 6.9: Pairwise DH panel causality test

Null hypothesis:	W-Stat.	Zbar-Stat.	Prob.	Remarks
lnICT ⇎ lnSHD	6.775	3.066	0.002***	ICT→SHD
lnSHD ⇎ lnICT	3.031	0.273	0.784	
lnGDP ⇎ lnSHD	3.346	0.510	0.061*	GDP↔SHD
lnSHD ⇎ lnGDP	2.611	0.041	0.096*	
lnFD⇎ lnSHD	4.390	1.293	0.195	FD⇎SHD
lnSHD⇎ lnFD	3.685	0.764	0.447	
lnGOV ⇎ lnSHD	16.679	10.509	0.000***	GOV↔SHD
lnSHD ⇎ lnGOV	8.858	4.643	0.000***	
lnFDI⇎ lnSHD	4.390	1.293	0.195	FDI⇎SHD
lnSHD ⇎ lnFDI	3.685	0.764	0.447	
lnTRD ⇎ lnSHD	6.890	3.167	0.001***	TRD→SHD
lnSHD ⇎ lnTRD	4.028	1.021	0.307	
lnICT ⇎ $lnCO_2$	3.37186	3.56079	0.0004*	ICT↔CO2
$lnCO_2$ ⇎ lnICT	3.07611	3.09035	0.0020*	
lnGDP ⇎ lnCO2	3.20302	3.29222	0.0010*	GDP↔CO2
lnCO2 ⇎ lnGDP	2.83622	2.70875	0.0068**	
lnNREC ⇎ $lnCO_2$	3.00487	2.97703	0.0029*	NREC→CO2
$lnCO_2$ ⇎ lnNREC	1.52518	0.62330	0.5331	
lnREC ⇎ lnCO2	3.15877	3.22182	0.0013*	REC→CO2
$lnCO_2$ ⇎ lnREC	1.48323	0.55657	0.5778	
lnFD ⇎ $lnCO_2$	13.6847	19.9653	0.0000*	FD→CO2
$lnCO_2$ ⇎ lnFD	1.27802	0.23014	0.8180	
lnTRD ⇎ $lnCO_2$	0.99602	-0.21842	0.8271	TRD⇎CO2
$lnCO_2$ ⇎ lnTRD	1.78344	1.03412	0.3011	
lnFDI ⇎ $lnCO_2$	1.49551	0.57611	0.5645	FDI→CO2
$lnCO_2$ ⇎ lnFDI	3.38012	3.57393	0.0004*	

Note: ***, **, and * indicate levels of significance at 1%, 5%, and 10%, respectively and the symbol →, ↔ and ⇎ indicates unidirectional, bidirectional and no causality relationship, respectively.

6.5 Conclusion and Policy Recommendations

The primary objective of this study was to analyze the relationship between ICT diffusion and environmental sustainability. In light of this, the study examines the impact of ICT diffusion, globalization, financial development, government effectiveness, and

economic growth on sustainable human development (SHD) (i.e., the development of human capital adjusted against the human ecological footprint) in SAARC economies. To address the issue of CSD in the data, second-generation stationarity tests were utilized. The DCCE-MG and DK standard error approaches were used for empirical estimation, which yield robust results in the presence of CSD. Empirical findings suggest favorable and significant impacts of ICT diffusion on SHD. Moreover, economic growth and globalization through trade and FDI contribute significantly to SHD in SAARC economies. Furthermore, a unidirectional causal link running from ICT diffusion and globalization via trade has been detected toward SHD. Moreover, economic growth and SHD exhibit a bidirectional causal relationship.

Given that ICT devices are ubiquitous, any attempt to mitigate climate change should address the carbon footprint of the ICT sector. Therefore, the study analyzed the interaction impacts of ICT diffusion and some key variables highlighted in the existing literature, to analyze their moderating effect on environment quality measured through CO_2 emissions. With increasing digitalization in various sectors, including businesses, homes, and the financial sector, it is challenging to detect the direct and indirect consequences of ICT on the environment. Therefore, the environmental impacts of ICT diffusion were researched in conjunction with energy consumption, financial development, and globalization. This is in accordance with earlier studies that looked at the environmental impacts of ICT through different moderators or channels (Avom et al., 2020; Danish et al., 2018; Moyer & Hughes, 2012). Using econometric approaches robust to CSD, such as the DK estimator and the DH causality test, the study found that ICT, renewable energy consumption, and globalization significantly reduce CO_2 emission, whereas non-renewable energy consumption and financial development significantly increase emission. However, the interaction between financial development and ICT

jointly reduces CO_2 emissions Similarly, renewable energy and globalization reduce emissions from increased ICT usage. The study also confirms the validity of the environmental Kuznets curve hypothesis for ICT diffusion. The causality test indicates bidirectional causality between ICT and CO_2 emissions.

In light of the above, in the globalized era, in order to resolve the undesirable consequences of environmental degradation on human development, it is essential for SAARC economies to tackle challenges of adequate ICT infrastructure: particularly, access and affordability. By eliminating these significant barriers to ICT access, CO2 emissions can be reduced, and human development can be sustained simultaneously. Therefore, ICT is an ideal instrument for developing SHD projects. It is quite unlikely that many of the current global advantages would have been realized without the use of ICT. To this extent, developing economies can leverage ICT to their advantage. ICT can help businesses attain cost competitiveness by mitigating extenuating factors. Remote locations would have been unable to afford modern technologies without the use of ICT. Consequently, achieving SHD through ICT initiatives is a reality that those who truly desire more equitable societies need to embrace.

The policy implications of this study necessitate that policymakers include ICT diffusion in their pursuit of attaining the SDGs. It is recommended that policymakers in the SAARC countries promote investment in technological advancements, renewable energy generation, and the implementation of green growth policies to avoid future environmental problems. The authorities should propose legislation and enforce regulations that encourage the development and use of renewable energy and discourage production practices that rely on the burning of fossil fuels. Technological breakthroughs in these areas lessen environmental degradation, allowing these countries to invest more in the technology sector and import new technology to assist in improving environmental quality. Therefore, it is imperative that

(i) ICTs are accessible to all; (ii) greater investment is made in the promotion of ICT, (iii) e-culture is introduced to promote education, health, and higher standards of living; (iv) better connectivity is provided to all; and (v) ICT equipment at lower prices is made available so that the masses can benefit from technology. Hence, the timely implementation of green growth policies would establish the foundation for successful complementarity between economic expansion and healthy ecosystems. In this context, the following concrete suggestions will prove useful:

- Positive stimulus from ICT diffusion reduces CO_2 emissions, but negative shock raises them. Therefore, by boosting expenditures on scientific research and development, technological innovation will facilitate the introduction of more environmentally and energy-efficient technologies and equipment, thereby reducing CO_2 emissions. Priority should be given to the development of appropriate policy initiatives to increase investment in technological innovation.
- Renewable energy drastically reduces CO_2 emissions. Renewables and energy efficiency, backed by considerable electrification and technological innovation, have the potential to generate more than 90% of the required reductions in energy-related carbon emissions. Renewable energy reduces CO_2 emissions because solar, wind, and nuclear power have a much lower carbon footprint than coal or gas with carbon capture and storage (CCS). To reduce CO_2 emissions, it is necessary to prioritize the use of renewable energy over fossil fuels and non-renewable energy sources. In this context, additional investment is required to enhance renewable energy sources by supporting solar and wind power and by encouraging and incentivizing the widespread adoption of energy-saving devices and appliances. This can be achieved by developing and enforcing an appropriate energy policy.

- Economic expansion raises CO_2 emissions, but as environmental concerns are addressed, CO_2 emissions decrease at higher levels of growth. Therefore, the implementation of inclusive economic growth and development without affecting the environment is preeminently essential for reducing CO_2 emissions. Green growth, green technology adoption, green urbanization, and green industrialization will all be effective and favorable to assuring long-term economic growth. In this light, a relevant and effective policy initiative is essential.

However, the study has significant limitations. Future research in this field should incorporate additional mediators, such as institutional quality and governance. There are many ways in which institutional quality can serve as a mediator, for example, by ensuring that policies are implemented in all sectors of the economy. In addition, individual country-specific research might be conducted to provide policymakers with more detailed guidance. Accordingly, future research should investigate more inclusive and sustainable metrics in addition to the ones used in this study, which are not exhaustive.

Chapter-7

Summary and Conclusions

7.1 Summary of the Study

The 2030 Agenda for Sustainable Development recognizes the potential of ICTs to accelerate human advancement and overcome the digital divide. Even though none of the SDGs is specifically about ICT, most of the goals refer to ICT and technology, and ICT can serve as a foundation for accomplishing all of the SDGs. ICT, especially broadband, is vital for attaining all 17 SDGs and is essential for advancing the three pillars of sustainable development (economic growth, social inclusion, and environmental preservation). Even though ICTs are mentioned surprisingly infrequently in the SDG goals and targets list, the UN General Assembly emphasized their significance as crucial drivers for achieving the new goals. It urged all stakeholders to integrate ICTs into their work towards the SDGs. However, the connection between ICTs and the SDGs remained unclear. In light of this, the present study aims to examine the impact of ICT diffusion on financial, economic and sustainable development in SAARC economies.

The present study emphasizes that ICT provides a unique opportunity to resolve many of the challenges encountered by SAARC economies, including financial instability, economic volatility, digital divide, poverty, and environmental degradation. ICT may support sustainable development and enhance people's lives by improving access to

information, facilitating communication, and stimulating creativity. For instance, ICT has the potential to expand people's horizons by opening up new avenues for education, healthcare, financial inclusion, and employment. Additionally, it can help in the prevention and management of natural disasters, the mitigation of climate change, and the improvement of environmental monitoring and conservation initiatives. In addition, ICT may aid in the fight against inequality and advance social inclusion by expanding access to resources for previously excluded groups.

The rise of mobile network coverage and greater internet use have allowed SAARC nations to begin reaping the benefits of ICT dispersion. However, digitalization has yet to reach its full game-changing potential in the region. The catastrophic impacts of the COVID-19 pandemic and the evident implications of climate change have increased dependence on digital technologies while exposing the costs of the digital divide. Even though 4G mobile network coverage has expanded rapidly in most SAARC countries over the past five years, Afghanistan and Nepal stand out as significant outliers. Despite these advancements, the region still has the highest percentage of people (61%) who live within the range of a telecommunications network but do not use the internet. Reasons for these gaps include poor affordability, low digital skills, and a need for more relevant content and applications.

Hence the present study is initiated to examine some of the unresolved issues and some new issues associated with the relationship between ICT diffusion and development in the context of SAARC economies. ICT diffusion is measured by constructing a composite index using PCA on mobile, fixed broadband, internet and landline usage in SAARC economies. In many aspects of SAARC economies, such as healthcare, education, financial services, energy, and climate change mitigation, the diffusion of ICTs can be accelerated to support the SDGs. To show the potential of ICT to drive progress on the SDGs in SAARC, Chapters 4-6 of this study summarize the impact of ICT diffusion on some critical financial, economic,

social, and environmental issues using robust econometric techniques such as FMOLS, DOLS, DCCE, CS-ARDL and DK standard error approach.

The first issue of the present study is to investigate the relationship between ICT diffusion, financial development, and economic growth in SAARC economies. The subject is explored in Chapters 4 in accordance with SDGs 8 and 9 for 2030 set by the UN.

Chapter 4 of the study examines the ICT-finance-growth nexus in SAARC economies using data from 2000 to 2017. The study does this using econometric methods, which includes granger causality, cointegration, and panel data analysis. The analysis discovers a long-run association between the variables, and financial development, ICT diffusion, and trade openness are shown to boost economic growth. Inflation, on the other hand, has a negative impact on economic growth. The panel Granger causality test demonstrates a unidirectional causal relationship between ICT diffusion and financial sector development and economic growth. However, the result of causation between the financial sector development and ICT is statistically insignificant. This chapter focuses on the potential for ICT diffusion and financial development to promote economic growth in the SAARC region.

Overall, the study's findings emphasize the potential for ICT diffusion to promote financial development, foster economic growth, and advance financial inclusion and stability in SAARC nations.

The next issue of the present study is to examine the impact of ICT on inclusive growth. Chapters 5 emphasize that economic advancements and opportunities must be evenly distributed for inclusive growth.

In light of the aforementioned issue of poverty, Chapter 5 first examines the relationship between ICT diffusion and poverty reduction in SAARC nations from 2005 to 2020 using

panel data. The study's primary finding shows that ICT diffusion reduces poverty both in the long and short run, indicating the favorable impact of ICT on the development process in SAARC countries. Further, the causality test reveals bidirectional causation between ICT diffusion and poverty reduction. The study emphasizes the importance of ICT diffusion and specific economic variables in reducing poverty. The findings of this study will aid policymakers in formulating appropriate policies and programs to improve the well-being of people and boost macroeconomic performance, thereby influencing socioeconomic development in SAARC.

Further, Chapter 5 examines the significance of ICT diffusion in fostering human development in SAARC countries from 2005 to 2019. Utilizing econometric methods robust to CSD, the study highlights the strong positive relationship between ICT and HDI. In addition, GDP boosts HDI owing to productivity gains. Similarly, trade expansion and its direct effects also influence HDI by boosting economic growth. Inflation, on the other hand, has a negative impact on the HDI. Thus, the study recommends a cohesive setting that unites ICT with human development in this modern framework and identifies three factors that restrict human capital development: inequality of opportunities, poor service quality and effectiveness, and SAARC countries' increasing vulnerability to shocks and risks.

This brings to light another essential aspect of inclusiveness, namely gender equality, covered in Chapter 5. Labor market gender discrepancies are prevalent in SAARC. To alleviate extreme poverty and enhance shared prosperity, gender discrepancies in technology use must be closed. Thus, this section examines how ICT diffusion empowers women to achieve the SDGs in SAARC economies from 2005 to 2020. The findings indicate that the spread of ICTs and economic growth substantially and positively affect women's empowerment. However, the fertility rate and trade openness hinder women's

empowerment. The causality test shows a bidirectional causal link between ICT diffusion, economic growth, and women empowerment. In addition, there appears to be a unidirectional causal relationship between education and women's empowerment. Expanding ICT use and bridging the digital divide, particularly among women, can help SAARC countries.

SAARC nations have been grappling with severe economic challenges. However, the environmental crisis is one of the most significant and rapidly developing obstacles to SAARC's progress towards sustainability. The influence of ICT dissemination on sustainability has been studied extensively, but there has been little progress in defining the exact nature of that impact. For this reason, Chapters 6 investigate the effect of ICT on environmental sustainability and address this final issue.

Firstly, Chapter 6 examines the impact of ICT diffusion, globalization, financial development, government effectiveness, and economic growth on sustainable human development (SHD) (i.e., the development of human capital adjusted against the human ecological footprint) using 2005–2020 panel data of SAARC economies. The results show that ICT diffusion, globalization, and economic growth have significant positive impacts on SHD, while the impacts of government effectiveness and financial development are found to be insignificant. In addition, the DH causality test results show the presence of a unidirectional causality running from ICT diffusion to SHD and globalization to SHD. The study concludes that in order to resolve the undesirable consequences of environmental degradation on human development in the globalized era, it is essential for SAARC economies to tackle the challenges of adequate ICT infrastructure: particularly, access and affordability. By eliminating these significant barriers to ICT access, CO2 emissions can be reduced, and human development can be sustained simultaneously.

Further, Chapter 6 looks into the transmission mechanism through which ICT impacts sustainability. Given that ICT devices are ubiquitous, any attempt to mitigate climate change should address the carbon footprint of the ICT sector. Therefore, Chapter 6 examines the direct impact of ICT on the environment and the indirect impact through interaction with energy consumption, financial development, and globalization in SAARC economies from 2000 to 2020. The study found that ICT, renewable energy consumption, and globalization significantly reduce CO2 emission, whereas non-renewable energy consumption and financial development significantly increase emission. However, the interaction between financial development and ICT jointly reduces CO2 emissions. Similarly, renewable energy and globalization reduce emissions from increased ICT usage. The study also confirms the validity of the EKC hypothesis for ICT diffusion. The causality test indicates bidirectional causality between ICT and CO2 emissions. Results suggest that SAARC economies can safely boost ICT and related applications to minimize emissions. They should also use renewable energy and green innovations in telecommunications to reduce their adverse environmental repercussions.

According to the findings of the study, in order to fully realise the promise of ICT for sustainable development, collective effort and collaboration across various sectors and stakeholders are required. It necessitates a holistic and coordinated strategy for developing and deploying ICTs, one that considers the priorities and requirements of a wide range of people and settings. It also highlights the significance of being ethical, transparent, and accountable in deploying ICT and of doing so in a way that respects human rights and dignity. The paper concludes that the era of sustainable development presents a once-in-a-generation chance to use ICTs for social good and bring about a more equal and sustainable global society.

7.2 Specific Contributions of the Study

The present study empirically evaluated the complex relationship of ICT Diffusion with Financial Development, Economic Development, Inclusive Growth and Sustainable Development in the context of SAARC economies. According to the authors, this research represents a new effort to investigate the channels through which ICT diffusion can lead to achieving SDGs in SAARC economies. The research findings will undoubtedly aid policymakers in gaining a more precise grasp of the challenges surrounding the aforementioned relationships and providing direction towards achieving high and sustainable inclusive development.

This study aims to address the following gaps in the literature on this subject:

1. The future of humanity depends on sustainable development. As a result, determining how to best control sustainability has become an urgent issue for modern civilization. In order to guarantee a paradigm, change in addressing SDGs for the betterment of SAARC, the study has developed a revolutionary ICT framework for development. It is characterized by local and global considerations in the context of the economic, environmental, and social dimensions of sustainable development in SAARC.
2. This study fills a fundamental gap in the development literature by examining the trivariate relationship between ICT diffusion, financial development, and economic growth. So that effective policy measures for ensuring sustainable economic development can be introduced, this study also investigates the causal mechanism between these variables in SAARC economies - a group of nations that have not been studied before in this literature.
3. Given that one-fourth of the world's population and almost half of the world's poor live in SAARC, the challenge for SAARC is how to harness ICT to achieve inclusive development in the region, which also suffers from the digital divide, a complex issue

involving unequal access, use, and applications of ICT among and within economies. Economic advances and opportunities must be evenly dispersed for growth to be inclusive. Given this context, the study has attempted to investigate the effect of ICT on inclusive growth to alleviate poverty, foster human development, and, in particular, empower women in the region, which is extant in the existing literature.

4. The present research is the first study of the SAARC region examining the impact of ICT diffusion on sustainable human development (i.e., the development of human capital adjusted against the human ecological footprint). Hence, the empirical analysis is comprehensive and inclusive in terms of relevant variable selection.
5. Further, the study examines the environmental implications of ICT in the expanding economies of SAARC which has not been done before. This will help policymakers make appropriate ICT infrastructure and foreign investment policies to protect the environment while encouraging economic growth and ICT usage in these economies.
6. In addition, the study proposes the channels via which ICT impacts sustainability over time. Particularly, trade-induced-globalization and FDI were identified as potential transmission mechanisms. Given the current trend towards increased globalization and the subsequently increased importation of foreign technologies, ICT stands to boost industrial productivity and economic activities. The increased economic activity prompts domestic companies to seek out foreign markets for their goods. As a result, sustainable development's environmental, social, and economic components are impacted.
7. Previous research has conflated ICT with internet or mobile phone usage but has neglected to account for additional dimensions, such as broadband and telephone subscribers, providing an incomplete view of the ICT infrastructure. However, to get a comprehensive view and instead of focusing on just one indicator of ICT, this study

uses a composite index of ICT constructed using PCA on mobile, fixed broadband, internet and landline usage.

8. Also, since the 1970s, most empirical research has used two measures of financial depth to quantify financial development: the ratio of private credit to GDP and, to a lesser extent, the ratio of stock market capitalization to GDP. When analyzing the function of the financial system in economic growth, most researchers employ some combination of the two measures above. However, there are many facets to financial development. Therefore, in the context of measuring financial development in our study, the present study employs the composite index of financial development, which summarizes how developed financial institutions and financial markets are in terms of depth, access, and efficiency.

7.3 Policy Implications

The SDGs are an ambitious attempt to solve problems on a global scale, including people from all walks of life and all corners of the globe. With widespread support for the SDGs, it is time to put words into action by implementing these goals to benefit current and future generations through the rapid diffusion of ICTs. Policymakers must pursue a broader, more cohesive ICT policymaking strategy to spark ICT-enabled transformation and reap its benefits.

The policy recommendations of the study are for governments to invest in a comprehensive ICT infrastructure across all facets of the public sector, including the provision of financial, educational, health, energy, and transport services, to transition from the BAU trajectory to the SDG trajectory and realise the 2030 vision. In accordance with the policy recommendations set out in Chapter 4-Chapter 10, governments should focus on three key areas:

The government must ensure that the most vulnerable members of society benefit from any digitization initiatives. These efforts and initiatives would close rather than widen existing digital disparities. Countries in SAARC should make it a priority to ensure that their policies and programmes benefit everyone. Social security, healthcare, education, agriculture, and financial services are just a few examples of sectors where ICT must be used to improve and expand service provision. There is a need for improvement in the accessibility of public and private sector services and the affordability of broadband access and devices, particularly for women, people with disabilities, and underrepresented minorities. Countries in the region could also increase their efforts to comprehend the demand for digital skills and strengthen their supply while equipping small and medium-sized enterprises with digitalization incentives and tools.

The governments of the countries in the region might examine and reevaluate the regulations and institutions that are holding back the digital economy. Countries should explore lowering the regulatory risks faced by private and foreign investment in connectivity or e-commerce to make it simpler for firms to digitalize, innovate, and invest in new technologies. This would make it easier for businesses to digitalize, innovate, and invest. Regulatory changes that reduce entry barriers and encourage innovation and disruption in stale sectors might pave the way for a new services economy. In order to do this, regulatory institutions will likely need to increase their capacity, competency, and innovation, as well as better coordinate governmental systems and interfaces. Better performance of digital government programs and the delivery of improved and integrated services to the public and businesses requires the establishment of plenary bodies with clear mandates and the authority to make and enforce policies, standards, and strategies. Platforms can be effectively linked to form digital stacks using open interfaces and standards. This would allow for unified designs for digital payments, digital identification,

and trusted data. The digital stacks might offer the railroads for the digital economy by permitting and integrating cashless, presence-less, paperless, and data-empowered transactions in both the public and private sectors. In addition, regulatory sandboxes might be used to try out new financial products and services.

As SAARC experiences a digital transition, the governments in the area will benefit from constructing the required legal frameworks to encourage confidence in the digital domain. These frameworks should comprise enablers and safeguards to ensure the integrity of digital transactions. Enablers bestow legal legitimacy and equivalence onto digital identification and authentication, as well as upon transactions, signatures, and contracts. Safeguards prevent cyberattacks, data breaches, and other negative consequences of digitalization for individuals, organizations, and governments. In general, the countries of South Asia have implemented stronger enablers than safeguards in their legal systems. To fill this void, the government must hasten the creation of data protection and cybersecurity regulations and the necessary systems for supervision and responsibility. In addition to retaining the benefits of digitalization, safeguards have become an increasingly significant factor in digital trade (for instance, data protection adequacy judgements to authorize data transfers with other areas such as the European Union).

7.4 Limitations of the Study

1. The current study has taken only four indicators of ICT, i.e., mobile, fixed broadband, internet and fixed landline usage. It fails to incorporate indicators essential to capture the capabilities or skills for ICTs, such as mean years of schooling, gross enrolment ratio etc.

2. Socio-economic factors (education, employment, rural-urban composition etc.) which may play an important role in making ICT successful in developing countries have been less focused.
3. Finally, the scope of the current analysis is limited since the data were only collected up to 2019 (covering the pre-COVID era), limiting the amount of information gleaned from the findings.

7.5 Future Scope of Work

1. Future studies should consider additional mediators, such as institutional quality and governance, to progress the subject. To ensure that policies are appropriately implemented throughout all sectors of the economy, for example, institutional quality can serve as a mediator in many ways.
2. Independent country-specific research may be required to fully comprehend the consequences of ICT diffusion and its policy implications. The advantages of ICT dissemination may be maximized if researchers consider each country's specific conditions, therefore identifying unique problems and possibilities.
3. A comparative analysis across other emerging economies, considering a longer time frame, could help shed more light on the issue of ICT diffusion and sustainable development.
4. Scholars might investigate different econometric techniques and approaches to further our knowledge of the ICT-development nexus. Using multiple lenses, we can better grasp the complexities of the connection between ICT spread and development outcomes.
5. New and more appropriate proxies for quantifying the effects of ICT diffusion might be helpful for future research.

6. Inequality, a key component of inclusive growth, may be investigated further concerning the spread of ICTs. However, the current study could not address this issue due to a lack of data.

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A. Publications from the Ph.D. thesis

1. Verma, A., & Giri, A. K. (2022). ICT diffusion, financial development, and economic growth: Panel evidence from SAARC countries. **Journal of Public Affairs**, 22(3), e2557. https://doi.org/10.1002/pa.2557
2. Verma, A., Giri, A. K., & Debata, B. (2022). The role of ICT diffusion in sustainable human development: an empirical analysis from SAARC economies. **Environmental Science and Pollution Research**, 1-15. https://doi.org/10.1007/s11356-022-23174-7
3. Verma, A., Giri, A. K., & Debata, B. (2022). Leapfrogging into knowledge economy: Information and communication technology for human development. **Australasian Journal of Information Systems**, 26. https://doi.org/10.3127/ajis.v26i0.3883
4. Verma, A., Giri, A. K., & Debata, B. (2022). ICT diffusion, women empowerment, and sustainable development in SAARC countries. **Journal of Economic and Administrative Sciences**, (ahead-of-print). https://doi.org/10.1108/JEAS-03-2022-0073
5. Verma, A., Giri, A. K., & Debata, B. (2023). Does ICT Diffusion Reduce Poverty? Evidence from SAARC Countries. **Poverty & Public Policy**, 1–21. https://doi.org/10.1002/pop4.360
6. Verma, A., Kumari, A., & Giri, A. K. (2023). Environmental effects of ICT diffusion, energy consumption, financial development, and globalization: panel evidence from SAARC economies. **Environmental Science and Pollution Research**, 30(13), 38349-38362. http://dx.doi.org/10.1007/s11356-022-25049-3

B. Peer reviewed paper presentations

1. Verma, A., & Giri, A. K. (2023, Mar 23-25). ICT Diffusion, Financial Instability and Shadow Economy: Panel Evidence from SAARC. International Conference on Sustainable Business Management (SBM 2023), IIT Roorkee.
2. Verma, A., & Giri, A. K. (2023, Jan 4-6). ICT diffusion, energy consumption, financial development, and globalization: A cross-sectional study of SAARC

economies. 57th Annual Conference of the Indian Econometric Society (TIES), University of Hyderabad, Hyderabad.

3. Verma, A., Chhabra, M., & Giri, A. K (2023, Feb 4-5). Role of ICT Diffusion, Energy Consumption, and Institutional Quality on Environmental Sustainability in Emerging Economies. 6th SANEM Annual Economists' Conference (SAEC) 2023, Dhaka, Bangladesh.
4. Verma, A., Giri, A. K., & Debata, B (2019, Jan 23-25). Leapfrogging into Knowledge Economy: Information and Communication Technology for Human Development, AIB-South Asia Chapter Conference on Role of International Business and Sustainable Development in South Asian Economies, IIM Visakhapatna

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Prof. Arun Kumar Giri is a Macroeconomics and Financial Economics Professor at the Department of Economics and Finance, Birla Institute of Technology & Science (BITS Pilani, Pilani Campus). He obtained his Ph.D. in Economics, M.Phil. and MA in Economics Department of Economics, University, Hyderabad. He completed his Ph.D. in the year 1998 and joined BITS Pilani in the year 1999. He has published several research articles in the reputed national and international journals. His research interests lie in the areas of Macroeconomics, Financial Economics, Development Economics and Green Finance, Resources and Environmental Economics. He has over 24 years of teaching and research experience in Economics and Finance at the Post Graduate level.

Brief Biography of the Co-Supervisor

Dr. Byomakesh Debata is an Assistant Professor in the Department of Economics & Finance at Birla Institute of Technology & Science (BITS Pilani, Pilani Campus). He obtained his Ph.D. in Finance from Indian Institute of Technology (IIT) Kharagpur. He has research publications in the reputed journal like Finance Research Letters, Journal of Financial Economic Policy, Applied Economics, IIMB Management Review, International Review of Finance, and Review of Behavioral Finance to his credit, and a few papers are under review in reputed journals. In addition to his area of specialization in financial economics, he has a scholarly interest in computational finance and behavioral finance.

Brief Biography of the Candidate

Anushka Verma is a doctoral candidate in the Department of Economics & Finance at Birla Institute of Technology & Science (BITS Pilani, Pilani Campus). Her thesis revolves around analyzing the impact of ICT diffusion on financial and economic development in SAARC countries, using quantitative methods and econometric models. Her research interests lie in development finance, particularly ICT diffusion, financial inclusion, growth, and sustainable development issues. Her research has appeared in reputed international journals like the Australasian Journal of Information Systems, Environmental Science and Pollution Research, Journal of Public Affairs, Poverty & Public Policy, etc. She has also assisted in various finance and economics teaching responsibilities during her PhD journey at BITS Pilani. Before pursuing her PhD, she completed her B.Com (Hons.) from the University of Delhi and her M.Com from Panjab University. She cleared the UGC NET-JRF (Commerce) in her first attempt in 2019. Apart from her academic endeavors, she has a passion for charcoal sketching and enjoys exploring her artistic side in her free time.