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Driving Sustainable Development in South Asia: Unleashing the Power of Microfinance and ICT

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Abstract: This study examines the impact of Information and Communication Technology (ICT) and Microfinance Institutions (MFIs) on sustainable development in South Asian countries. ICT can help reduce financial barriers and improve the efficient allocation of financial resources by enhancing information access for the poor. Additionally, MFIs provide sustainable economic opportunities for the impoverished, fostering inclusive growth and reducing poverty in the region. The aim of this paper is to analyze the threshold effects of ICT on MFIs and sustainable development using a threshold regression and system GMM. Furthermore, by introducing the interaction term between MFIs and ICT, this study offers a new perspective on analyzing the key factors influencing sustainable development. The empirical results indicate that there is indeed a non-linear relationship between MFIs and sustainable development, with ICT as the threshold variable. Moreover, the interaction between ICT and MFIs significantly promotes the level of sustainable development in South Asia. The empirical findings underscore the importance of further leveraging the advantages of microfinance and ICT to effectively drive high-quality socio-economic development in the South Asian region. Therefore, it is recommended that relevant policies be implemented in South Asia to support and encourage the widespread adoption of ICT and microfinance in impoverished areas, thus aiding in the improvement of living standards and environmental conditions for the poor.

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1. Introduction

Currently, there is a significant focus on enhancing the effectiveness of promoting sustainable development. In 2015, during the Sustainable Development Conference, 193 member states of the United Nations unanimously adopted 17 Sustainable Development Goals (SDGs). These goals encompass various areas such as eradicating hunger, improving sanitation, promoting gender equality, ensuring universal education, fostering economic growth, and developing social infrastructure. The SDGs aim to promote social development by harnessing the synergies and externalities among society, economy, and the environment.

The significance of the SDGs cannot be underestimated for South Asian countries. Despite making notable progress in achieving the Millennium Development Goals (MDGs), the region still faces challenges including rapid population growth, poverty, and existing gaps in development and infrastructure. Enhancing living standards, ensuring food and nutritional security, and improving public health are areas that require particular attention. In the past, the South Asian region has underutilized these externalities, leading to significant structural imbalances in development. The region grapples with substantial disparities in physical and social infrastructure, high unemployment rates, pervasive inequality, and widespread hunger. Additionally, Driven by extreme weather, the region accounts for half of disaster deaths in Asia and the Asia-Pacific region. Addressing these disparities necessitates inclusive and expedited economic development, while simultaneously minimizing resource wastage and carbon emissions. South Asia must align its economic and social development agendas with the principles of sustainable development, and the SDGs serve as a guiding framework and pathway for achieving this objective. Figure 1.1 illustrates the planned reforms undertaken by South Asian countries to advance the 17 SDGs.

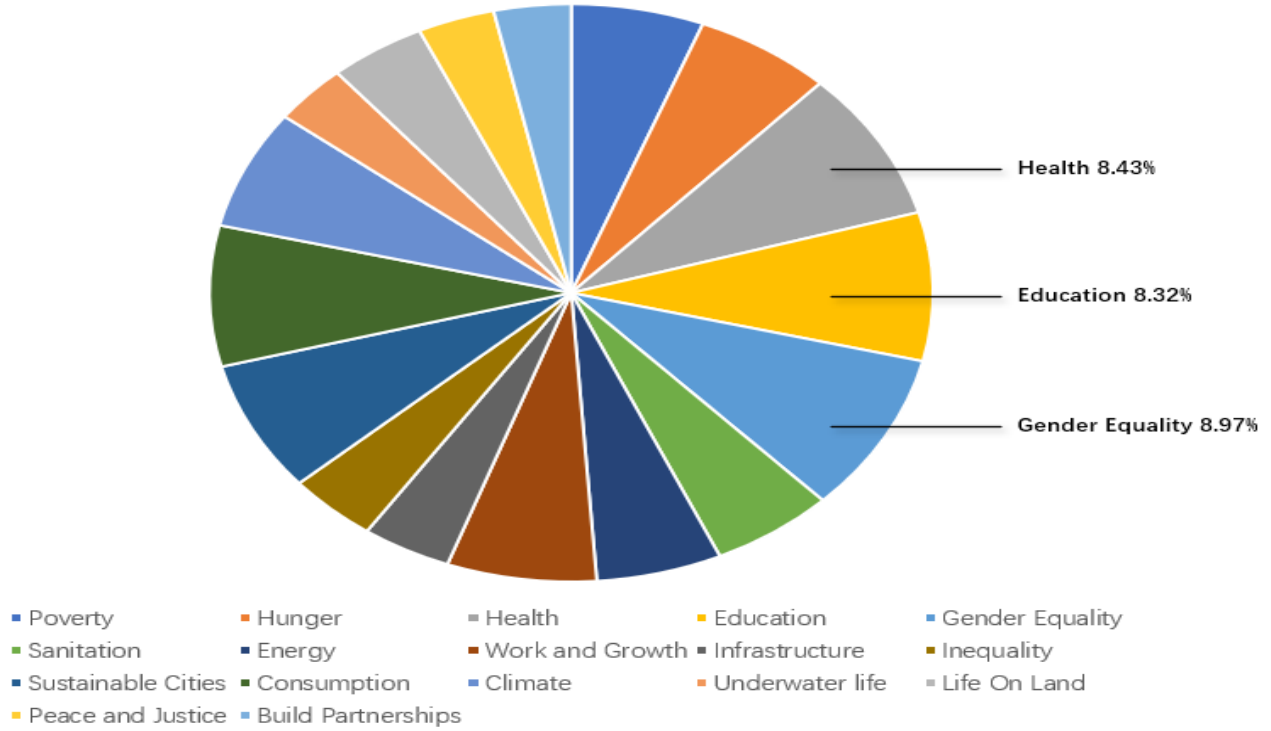

Figure 1.1: South Asian countries advance programme reforms in SDGs
(Source: United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), 2021)

Figure 1.1 highlights education, health, and gender equality as the primary targets for South Asian countries in their pursuit of the SDGs. It is important to note that while the region has made progress in achieving universal primary education enrollment, with a net enrollment ratio of 59%, it still lags behind the global average of 65%. Specifically, girls in Pakistan and children in impoverished areas of other countries face significant challenges in accessing and continuing their primary education. Moreover, the quality of teaching in underserved and remote areas is notably poor, leading to unsatisfactory student performance. This result is partly due to the low ratio of public expenditure on education to GDP, 3.9% in India, 2% in Bangladesh, 2.5% in Pakistan, and 1.7% in Sri Lanka, well below the recommended target of 6% (UNESCAP, 2018).

In terms of the environment, carbon dioxide emissions in South Asia have continued to rise, nearly fivefold between 1990 and 2020, reaching 2.4 billion tons (World Bank, 2020). In short, there is still a significant disparity in sustainable development among countries and between urban and rural areas in South Asia, and efforts are still needed from South Asian countries. But what means to promote sustainable development is more important. In other words, which variables can make a greater contribution to the sustainable development of South Asia? Over the past few decades, the development of microfinance in South Asia has provided sustainable economic opportunities for the poor, contributing to inclusive growth and poverty reduction in the region. The mission of microfinance's existence and development is to increase social welfare, improve equity, and promote sustainable development (Yemelyanov et al., 2020). The vigorous development of microfinance can enhance the coverage, availability, and fairness of financial services, catering to the financial needs of the poor (Zhang, Chi, & Zhang, 2018). Microfinance, in particular, emphasizes attention to vulnerable groups, effectively enhancing their

ability to participate in social production and contributing to social welfare equity (Quayes, 2012). However, existing literature primarily focuses on the financial sustainability of MFIs (Fall, Akim, & Wassongma, 2018; García-Pérez, Muñoz-Torres, & Fernández-Izquierdo, 2017; Gutierrez, 2007; Qayyum, 2006). It has been noted that research on microfinance lacks analysis from the perspective of social sustainable development (Perez-Moreno, 2011; Saint-Supéry Ceano-Vivas, Rivera Lirio, & Muñoz-Torres, 2014). This study aims to address this gap by examining the extent to which microfinance integrates social, environmental, and governance factors into its performance for sustainable development.

Technological innovation is widely recognized as a significant catalyst for socio-economic growth (Azadnia, Zahedi, Majjedin, & Reza, 2017), and it plays a crucial role in supporting the successful attainment of the Sustainable Development Goals (SDGs). When harnessed effectively, technology can provide viable solutions to development challenges at various levels, ranging from local to global (Ameyed, Cheriet, Samson, & Corninck, 2018). Information and Communication Technology (ICT) has particularly exerted a profound impact on the development of countries and societies in recent decades, especially in terms of driving innovation, efficiency, and effectiveness in today's world (Tjoa & Tjoa, 2016). ICT offers a wide array of foundational and methodological contributions that facilitate the implementation of the SDGs through advanced tools and comprehensive models. For instance, it can foster the digital advancement of sectors such as finance, education, and healthcare. ICTs possess immense potential to accelerate, expand, and enhance the diffusion of cutting-edge technologies, applications, and platforms across various sectors (Leidig, Teeuw, & Gibson, 2016). Additionally, it can substantially reduce the cost of financial services, enabling low-income countries to achieve crucial developmental milestones while contributing to economic growth and social well-being.

If finance serves as the driving force for sustainable development, then ICT acts as the lubricant that facilitates sustainable development. ICT plays a crucial role in promoting high-quality social development by facilitating capital circulation, improving the efficiency of capital allocation, reducing information costs, and diversifying risks. Furthermore, finance can provide ongoing financial support for technological innovation. In order to promote the achievement of the Millennium Development Goals, the United Nations advocates for the vigorous development of microfinance in all countries. This approach aims to eradicate poverty and achieve sustainable economic and social development by leveraging the resource allocation capabilities of microfinance. But what impact does microfinance have on sustainable development? What kind of positive and negative effects it has, how it is realized and produced, and how to seek advantages and avoid disadvantages are issues that need to be explored.

The main purpose of this paper is to examine the effect of ICT and microfinance on the sustainable development of South Asian countries. The advancement of ICT can enhance the information access efficiency for impoverished individuals and small-scale enterprises, consequently diminishing financial barriers. This, in turn, leads to a more effective allocation of resources in the credit market and a reduction in external financing costs. Hence, the development of ICT can enhance the role of microfinance in promoting sustainable development by diminishing information asymmetry and financial friction to a certain extent.

Due to the late start of ICT development in South Asia, there are differences in microfinance and ICT levels in different regions. Therefore, studying the impact of microfinance and ICT on sustainable development can provide valuable insights for further leveraging the advantages of inclusive finance and ICT to drive high-quality socio-economic development. The main contribution of this paper is twofold. Firstly, building upon the foundation laid by a few scholars who have proposed the role of microfinance in social sustainable development, it analyzes the threshold effect of ICT on the relationship between microfinance and sustainable development, offering a reference for studying key factors influencing sustainable development. Additionally, this paper introduces an interaction term between microfinance and ICT in the model variables to examine its impact on sustainable development, reducing the bias caused by endogeneity of variables in the estimation results.

2. Literature Review

2.1 The impact of Microfinance on Sustainable Development

In order to examine the relationship between microfinance and sustainable development, it is crucial to adopt a theoretical framework that considers the balance among fiscal, environmental, social, and governance (FESG) dimensions. As proposed by García-Pérez, Fernández-Izquierdo, and Muñoz-Torres (2020), a balanced approach to the sustainability of microfinance institutions (MFIs) takes into account financial, environmental, social, and governance aspects within the performance evaluation system of microfinance. Through a clustering process, García-Pérez, Muñoz-Torres, and Fernández-Izquierdo (2018) establishes the interrelationship among various sustainability indicators. The findings suggest that microfinance not only contributes significantly to the formal financial system but also plays a vital role in promoting sustainable development. By incorporating the FESG framework, this paper aims to provide a comprehensive analysis of the impact of microfinance on sustainable development, considering the multidimensional aspects of sustainability.

According to Warnecke (2015), microfinance is considered a crucial component of social, economic, and legal institutions. While it may not address all the global challenges related to sustainable development, it has a significant effect on issues such as gender inequality and climate change. Additionally, microfinance contributes to promoting sustainable agriculture, reducing deforestation, protecting clean water resources, and addressing biodiversity concerns. However, existing literature primarily focuses on the relationship between microfinance and economic growth, inequality, income, and education, neglecting the comprehensive analysis of microfinance's impact on sustainable development. In a study conducted by Ayodele and Arogundade (2014) on Nigeria, the authors examined the effect of microfinance on economic growth using proxy variables such as assets, deposit liabilities, and loans and advances. The findings indicate that assets and deposit liabilities have less impact on economic growth, whereas loans provided to the impoverished population have a significant effect on economic growth.

Klapper, Laeven, and Rajan (2006) argue that the development of microfinance can encourage talented individuals from low-income backgrounds to start their own businesses. By fostering entrepreneurship among the poor, microfinance not only increases productivity but also generates employment opportunities, thereby promoting

inclusive economic growth. Bruhn and Love (2014) suggest that expanding access to financial services has the potential to not only boost the income of low-income groups but also stimulate overall employment rates. Their research highlights the positive relationship between the availability of financial services and employment outcomes. Zhang et al. (2018) conducted research on China's microfinance impact on the income gap between urban and rural areas using the PSTR model. The findings indicate that the relationship between microfinance and the income gap is closely linked to the level of economic development. Specifically, as economic development progresses, the impact of microfinance on the income gap initially expands and then diminishes, exhibiting an inverted U-shaped pattern.

Bansal (2010) conducted an assessment of the impact of microfinance on employment and empowerment among rural women. Through the application of multiple regression analysis and a comparison between program participants and non-participants, the research findings indicate that microfinance plays a successful role in diversifying economic activities in rural areas and increasing employment opportunities. Furthermore, microcredit programs have been shown to empower women economically, psychologically, socially, and politically, leading to positive outcomes for women's empowerment. Similarly, Pathak and Gyawali (2010) conducted research on microfinance programs and their effects on job creation and socioeconomic empowerment. The study revealed that microfinance programs have a significant impact on generating employment opportunities and can contribute to socioeconomic empowerment among the rural poor. Additionally, these programs have the potential to mobilize internal resources, raise awareness, and foster self-employment for individuals in rural areas.

These studies highlight the potential of microfinance to empower individuals, drive economic growth, reduce income disparities, and create jobs, while also highlighting the positive impact of microfinance on employment, economic empowerment, and overall development.

2.2 The impact of ICT on sustainable development

Jayaprakash and Radhakrishna Pillai (2022) defined sustainable development as having three dimensions: economy, society, and environment. They conducted an analysis using panel data to examine the relationship between ICT and these three dimensions. The research findings indicate that the use of ICT has positive effects on economic growth, human development, and environmental performance. However, ICT alone cannot mitigate the negative impacts of environmental performance on economic growth and human development. In a related study, Gouvea, Kapelianis, and Kassicieh (2018) proposed a connection between environmental sustainability, ICT, and human development. The study revealed that ICT and human development have significant primary and interactive effects on environmental sustainability. Specifically, ICT can influence water and habitat utilization, energy consumption, as well as remediation and improvement efforts, particularly in the context of monitoring and reversing degradation that affects sustainability.

Nchofoung and Asongu (2022) conducted research on the impact of ICT on sustainable development and found that this relationship can be influenced by trade openness and foreign direct investment (FDI). They also observed that mobile phone penetration interacts with trade openness and FDI, leading to positive direct effects and negative indirect effects. In a study by Asongu, Le Roux, and Biekpe (2018) focusing on sub-Saharan Africa (SSA), the researchers explored the potential of increasing ICT penetration to reduce CO2 emissions and promote environmental sustainability. The results indicated that when the Internet penetration rate per 100 people exceeds 42.5, it contributes to ensuring the sustainable development of the environment by reducing carbon dioxide emissions. To achieve sustainable reductions in per capita CO2 emissions, policymakers are advised to adopt Internet penetration policies that encourage adoption, access, and increased ICT penetration.

Santarius, Pohl, and Lange (2020) argue that the contribution of ICTs to sustainable development can be enhanced through political measures that promote the savings potential of ICTs, while simultaneously addressing the energy- and resource-intensive nature of hardware production. In contrast, Ramasubramanian, Shaikh, and Sharma (2021) hold the belief that with the widespread adoption of ICT, carbon dioxide emissions will increase and employment in sustainable energy sectors will decrease. This implies that the growth in ICT development does not necessarily lead to increased income in low-income economies unless other external factors are taken into consideration. In a study conducted by Latif et al. (2017) on the relationship between the proliferation of ICTs and environmental sustainability, it was found that significant changes in culture, education, human behavior, and the environment are necessary for ICT to have a positive impact on environmental sustainability. However, when these changes are in place, ICT can greatly contribute to regional sustainable development and economic growth.

According to Azadnia et al. (2017), ICT has a significant impact on contemporary society, particularly in addressing sustainable development challenges that directly impact people's lives, such as illiteracy, unemployment, forest degradation, poverty, and pollution. ICT plays an effective role in tackling these issues and driving sustainable development. Suryawanshi and Narkhede (2015) argue that green ICT represents the future direction of ICT development, as it can effectively contribute to the sustainable development of the environment. They suggest that actively formulating green policies to promote the widespread adoption of environmentally friendly ICT can bring multiple benefits to the community, the country, and the field of education.

Overall, these studies provide insights into the relationship between ICT and sustainable development, highlighting its potential benefits in economic, social, and environmental dimensions. They also underscore the importance of considering external factors, policy interventions, and sustainable practices to maximize the positive impact of ICT on sustainable development.

2.3 The Relationship between Microfinance and ICT

Many scholars recognize the significant role of ICT in promoting microfinance. As the microfinance industry evolves, ICT is increasingly seen as a crucial tool for expanding the reach of microfinance and ensuring its sustainable operations (Hishigsuren, 2006; Kauffman & Riggins, 2012; Mathison, 2006; Mwashiuya & Mbamba, 2019; Ssewanyana, 2009). Although limited literature exists on the relationship between microfinance and ICT, most studies confirm the positive impact of integrating ICT and microfinance on social and economic development.

Mwashiuya and Mbamba (2019) conducted a survey of 322 microfinance institutions in Tanzania to analyze the effects of adopting ICT equipment on operational performance. The study revealed that most microfinance institutions

utilize information and communication technologies such as the Internet, computers, fixed-line phones, and mobile phones to enhance customers' access to financial services. Adoption of ICT not only improves savings and customer numbers but also reduces operating costs and interest rates, ultimately enhancing the overall operational performance of microfinance institutions. Kauffman and Riggins (2012) argue that ICT can enhance the operational efficiency and management of microfinance institutions, reducing overhead costs and enabling flexible service delivery to the underprivileged.

Mushtaq and Bruneau (2019) analyze the role of the ICT-microfinance relationship in poverty reduction and inequality. Their findings indicate that increased ICT usage in microfinance institutions effectively accelerates economic growth while reducing poverty and inequality. Strengthening the collaboration between ICT and inclusive finance can bridge financial infrastructure gaps, foster digital inclusive finance development, and enhance the poverty reduction impact of inclusive finance. Singh and Padhi (2015) highlight that the integration of ICT and microfinance institutions not only expands access to financial services for the poor but also enables microcredit provision in remote areas. ICT adoption has also helped reduce service costs and enhance customer management efficiency in microfinance systems. However, successful ICT adoption in microfinance institutions requires policy reforms addressing infrastructure and regulations that consider the interests of all stakeholders.

Stuart (2007) identifies limitations in the utilization of ICT equipment in microfinance. Existing regulatory systems often impede, rather than facilitate, the integration of ICT and microfinance. Additionally, the current management systems have yet to fully adapt to the changes in business processes brought about by ICT innovation. Moya Mosa et al. (2017) conducted a study on the adoption of ICT equipment by microfinance institutions in Uganda. Their research revealed that investing in ICT equipment led to a 19% performance increase in microfinance institutions. It effectively minimized customer attrition, increased marginal income, and allowed for sustainable provision of financial services at lower costs, enhancing the competitiveness of microfinance institutions in the market.

ICT plays a vital role in promoting microfinance, with the potential to expand its reach and ensure sustainable operations. Various studies highlight the positive impact of integrating ICT and microfinance on social and economic development. The adoption of ICT equipment by microfinance institutions enhances customer access, increases savings, reduces operating costs and interest rates, and improves overall performance. Furthermore, ICT usage in microfinance contributes to economic growth, poverty reduction, and inequality alleviation. However, challenges exist, such as regulatory barriers and the need for policy reforms. Nonetheless, investing in ICT equipment enables microfinance institutions to provide financial services efficiently and competitively while benefiting both the institutions and their customers.

3. Methodology

3.1 The Method

First, in order to study the relationship between MFI and sustainable development, this paper takes ICT as the threshold variable, draws on the panel threshold model proposed by Hansen (1999), and studies the nonlinear relationship between the two by estimating the threshold of the threshold variable. When there is a single threshold effect, the establishment of the threshold model is shown in formula 3.1:

$$Y_{it} = \alpha_i + \beta_1 X_{it} I(q_{it} \le \gamma) + \beta_2 X_{it} I(q_{it} > \gamma) + \varepsilon_{it} \quad 3.1$$

Among them, $I(\cdot)$ represents an indicator function. When the expression conditions in the brackets are satisfied, the function takes a value of 1; if the expression in the brackets is not satisfied, the function takes a value of 0. Among them, q_{it} is the threshold variable, γ is the threshold value to be estimated, α_i reflects the individual fixed effect, and ε_{it} is the random interference item. Further, the expansion of the model can be extended as shown in Formula 3.2:

$$Y_{it} = \begin{cases} \alpha_i + \beta_1 X_{it} + \varepsilon_{it}, q_{it} \le \gamma \\ \alpha_i + \beta_2 X_{it} + \varepsilon_{it}, q_{it} > \gamma \end{cases} \quad 3.2$$

In specific studies, it is often found that there is not only a single-threshold effect, but also a double-threshold or triple-threshold effect between the explanatory variable and the explained variable. Therefore, it is necessary to continue to test the threshold effect of the model. In the empirical analysis of this study, the threshold effect test will be carried out first to determine the threshold interval. At present, it is assumed that there is a single threshold effect between MFI and sustainable development, so the model is set as shown in formula 3.3:

$$SDI_{it} = \alpha_i + \beta_1 MFI_{it} I(ICT_{it} \le \gamma) + \beta_2 MFI_{it} I(ICT_{it} > \gamma) + \beta_3 X_{it} I + \varepsilon_{it} \quad 3.3$$

In the equation, $I(\cdot)$ represents an indicator function, and its value is 1 if the expression in brackets is true, otherwise it is 0. γ is the threshold threshold. SDI_{it}means sustainable development level. β_1 and $\beta_2$are respectively the elastic coefficients of microfinance variable (MFI_{it}). X_{it} represents the control variables, including MFI*ICT (the interaction item of microfinance and ICT), WAT (healthy drinking water), STA (political stability), and FDI (foreign direct investment).

Secondly, in order to analyze the impact of the interaction between MFI and ICT on sustainable development, this paper adopts the system GMM two-step method to analyze it. And a lag period of the explained variable HSDI is introduced into the model to make the model more capable of dynamic explanation. Although the differential GMM proposed by Arellano and Bond (1991) can eliminate the endogenous problem of the model by calling instrumental variables, it usually leads to the emergence of weak instrumental variables when the sample size is limited. The system GMM two-step method can estimate both the original model and the difference model, thereby reducing the estimation bias. Therefore, this paper refers to Roodman (2009) and uses the system GMM two-step method to analyze the effect of the interaction term of MFI and ICT on sustainable development. The model is set up as shown in formula 3.4:

$$SDI_{it} = SDI_{it-1} + \beta_1 MFI_{it} + \beta_2 ICT_{it} + \beta_3 MFI * ICT_{it} + \beta_4 X_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad 3.4$$

Among them, SDI_{it} represents the level of sustainable development, and SDI_{it-1} is its lagging period. MFI_{it} stands for microfinance. ICT_{it} means information and communication technology index. $MFI * ICT_{it}$ is an interaction item between microfinance and information communication technology. X_{it} represents other control variables, including WAT (healthy drinking water), STA (political stability), and FDI (foreign direct investment). μ_i is an individual fixed effect, λ_t is a time fixed effect, and ε_{it} represents a random error term.

3.2 Data Source

In order to analyze the relationship between microfinance and sustainable development, as well as the effect of the

interaction between MFI and ICT on sustainable development, this paper will use six countries in South Asia (India, Pakistan, Bangladesh, Sri Lanka, Nepal and Bhutan) 2000-2000 Panel data for 2018. Maldives is excluded because there is no MFI data. The data of microfinance mainly comes from MIX Market, and the data of other indicators mainly comes from WORLD BANK.

3.3 Variable Description

Sustainability Indicators (SDI)

Sustainable development is a concept that aims to ensure present and future generations can meet their needs without compromising the ability of future generations to do the same. It encompasses economic, social, and environmental dimensions, including factors such as education, income, health, sanitation, inequality, and environmental sustainability. This paper draws inspiration from Bravo (2015) and adopts the Human Sustainable Development Index (HSDI) as a measurement tool for sustainable development. The HSDI builds upon the Human Development Index (HDI) by incorporating environmental indicators, specifically carbon dioxide emissions, in addition to education, health, and income. The HSDI underscores the importance of focusing on people and their capabilities as the fundamental criteria for assessing a country's development, going beyond mere economic growth.

Microfinance (MFI)

The primary goal of microfinance is to advance social welfare, progress, and sustainable development. By enhancing the accessibility, inclusivity, and equity of financial services, microfinance contributes to meeting the financial needs of the underprivileged. Drawing from the empirical research conducted by Yemelyanov et al. (2020), this article focuses on the per capita gross loan portfolio as an indicator of microfinance. It is anticipated that a positive relationship exists, indicating that higher per capita loan amounts are conducive to fostering sustainable development.

Information and Communication Technology (ICT)

ICT encompasses a wide range of communication devices and software applications, including radios, televisions, mobile phones, computers, network hardware and software, and satellite systems. It also includes various services and application software associated with these technologies. Beyond its technical significance, ICT plays a crucial role in providing economically disadvantaged countries with opportunities to access advanced production and service technologies. This article draws upon the empirical research conducted by Islam (2015), where the ICT indicator chosen is the number of mobile cellular subscriptions per 100 people.

Access to Safe drinking Water (WAT)

Access to safe drinking water is a crucial aspect of sustainable development as it ensures that people have access to clean and uncontaminated water sources. The World Health Organization (WHO) classifies safe water sources as deep boreholes, taps, uncontaminated natural springs, rainwater harvested water, and dug wells separated from contaminants. This article focuses on access to safe drinking water as an environmental health indicator to empirically investigate its relationship with sustainable development. A positive effect is anticipated, highlighting that improved access to safe drinking water contributes to sustainable development and helps achieve the goals outlined in the Sustainable Development Goals (SDGs). Expected positive effect between WAT and sustainable development

Governance (GOV)

The World Governance Index (WGI) is employed as an index to assess governance, encompassing corruption control, government effectiveness, regulatory quality, and legal provisions. This index serves as a measure of the quality of governance within a country. Government effectiveness reflects aspects such as the civil service system, the quality of public services, the implementation of policy formulation, and the government's commitment to maintaining a high level of credibility. Regulatory quality promotes and upholds safety, peace, and security, which are fundamental elements in fostering sustainable human development. In the model utilized, this variable is employed to determine the influence of government governance on environmental pollution and sustainable development. It is anticipated that there will be a positive relationship between governance and sustainable development. This study predicts that the relationship between governance and sustainable development is expected to be positive.

Foreign Direct Investment (FDI)

In order to achieve the United Nations Sustainable Development Goals (SDGs), significant resources are required, and foreign direct investment (FDI) can be seen as a primary source of financing for sustainable development. However, the potential contribution of FDI to sustainable development in the South Asian region can only be realized under specific conditions and policies, coupled with an increase in both the quantity and quality of FDI inward, outward, and within the region. This necessitates the identification and prioritization of FDI projects in key sustainable development sectors like renewable energy, education, health, water and sanitation, among others. Additionally, the development and implementation of FDI policies, legal frameworks, and regulatory structures at national and international levels are crucial to maximize the sustainable development impact of FDI on the local economy. The paper expects a positive relationship between FDI and sustainable development.

Table 1: variables measurements and source

Variable	Measurements	Source
Sustainable Development (SDI)	Human Sustainable Development Index	Development Indicators(WDI)
Microfinance(MFI)	Gross loans portfolio of microfinance	MIX Market
Information and Communication Technology (ICT)	Mobile cellular subscriptions per hundred population	WDI
Access to Safe drinking Water (WAT)	Proportion of population access to safe water	WDI
Governance (GOV)	Worldwide Governance Indicators	WDI
Foreign Direct Investment (FDI)	Total annual FDI inflows to South Asian countries	World Bank

4. Empirical analysis

4.1 Regression results

In this section, before the main regression analysis, descriptive statistics and correlation analysis are carried out among the variables. The analysis results are shown in Table 2 and Table 3 below. The findings indicate a positive correlation between microfinance, ICT, and sustainable development, suggesting that these variables are related. There is no significant issue of collinearity among these variables. However, it is worth noting that the correlation between the interaction terms of microfinance, ICT, and the main explanatory variables exceeds 0.7, indicating a certain degree of collinearity. This finding is consistent with the study conducted by Balli and Sørensen (2013), which suggests that there will be a correlation between the interaction terms and the main explanatory variables. Although collinearity is present, it is not considered a severe problem in general interaction models, and it is typically unnecessary to address it. Moreover, there is no significant collinearity issue observed among the other independent variables utilized in this study.

Table 2: descriptive statistics

Variable	Mean	Std. Dev.	Min.	Max
SDI	.6190526	0.0967013	0.482	0.836
Ln.MFI	8.69682	1.008031	6.126716	10.51886
ICT	48.592	40.380	0.042	142.650
WAT	47.05869	21.04454	19.17831	93.7023
GOV	-0.992534	1.030058	-2.810035	1.284487
Ln.FDI	10.64465	1.212711	7.94444	12.67685

Table 3: results of correlation test

Variable	SDI	MFI	ICT	MFI*ICT	WAT	STA	FDI
SDI	1.000						
MFI	0.400	1.000					
ICT	0.598	0.522	1.000				
MFI*ICT	0.596	0.720	0.795	1.000			
WAT	0.634	0.194	0.229	0.232	1.000		
STA	0.216	0.257	0.246	0.280	-0.019	1.000	
FDI	0.190	0.315	0.117	0.125	0.313	-0.479	1.000

In addition to conducting the threshold model regression, it is essential to perform threshold effect tests and threshold value tests. The threshold effect test examines whether there is a significant threshold effect between microfinance and sustainable development using ICT as the threshold variable. Once the threshold effect test is successfully passed, the threshold value test is conducted to determine whether the model exhibits a single threshold, double threshold, or triple threshold. This process continues until the test results support the null hypothesis. The findings of these tests are presented in Table 4.

Table 4: threshold effect test

Test for single threshold	
F_1	29.42
p-Value	0.0200
(10%; 5%; 1% Critical Values)	(22.1636, 25.7122, 31.6722)
Test for double threshold	
F_1	15.34
p-Value	0.3315
(10%; 5%; 1% Critical Values)	(36.0597, 45.2505, 61.1215)

Based on the results presented in Table 4, several observations can be made. The P-value associated with the single threshold effect is found to be 0.02, indicating that the model rejects the null hypothesis and passes the significance test. On the other hand, the P-value for the double-threshold effect is 0.33, failing the significance test. These findings suggest that the model exhibits a single-threshold effect rather than a double-threshold effect. Consequently, there exists a nonlinear relationship between microfinance and sustainable development, characterized by a single threshold effect. Therefore, this study employs a single threshold model to estimate the relationship between microfinance and sustainable development.

Through empirical analysis utilizing the single-threshold effect model, it is observed that the association between MFI and sustainable development is not a simple linear relationship but rather exhibits a critical threshold characteristic. This indicates that the extent of ICT development in each South Asian country influences the role of MFI in promoting sustainable development within the region. As the level of ICT development varies, the impact of MFI on sustainable development also differs across the region. The regression results are presented in Table 5.

Table 5: results for the threshold regression results.

Variable	(1)	(2)	(3)
Threshold level			101.86**
MFI	-0.0124106**(-2.10)	0.0224939***(6.47)	
ICT	0.0016176*(1.73)	0.000857*(1.85)	
MFI*ICT	-0.00005(-0.48)	0.000159***(3.22)	0.0000836***(11.76)
WAT	0.0034306***(21.92)	-0.0005061(-1.14)	-0.0004338(-1.22)
GOV	0.0153193***(3.72)	-0.0075308**(-2.45)	0.0001478(0.05)
FDI	0.0016826(0.47)	0.0080483**(2.20)	0.0057816*(1.89)
$MFI_{it}I(ICT_{it} \leq \gamma)$			0.0201986***(6.49)
$MFI_{it}I(ICT_{it} > \gamma)$			0.0163565***(5.00)
Constant	0.5068338***(10.96)	0.3239296***(8.09)	0.3671182***(10.19)
Obs	114	114	114
F-statistics(p-value)	0.0000	0.0000	0.0000
Hausman test(P>chi2)	0.0000		
Linearity test (p-value)			0.0000

Note: In this table, (1) is a random effect model, (2) is a fixed effect model, and (3) is a threshold effect model. The Hausman test was carried out through random effects and fixed effects, and the test results rejected the null hypothesis, indicating that the model was more in line with fixed effects. t statistics are given in parentheses. ***, **and * represent significance levels of 1, 5 and 10, respectively.

Based on the regression results presented in Table 5, several findings can be observed. Firstly, when the estimated value of the threshold variable ICT ≤ 101.86, the model rejects the null hypothesis, indicating a significant

relationship between MFI and sustainable development at a 1% significance level. In this case, the regression coefficient of MFI is 0.0202, suggesting that when the mobile cellular network penetration rate is below 101.86, MFI has a positive and significant impact on sustainable development. This implies that the development of MFI is beneficial for improving sustainable development in the region when ICT penetration is relatively low.

On the other hand, when the threshold variable ICT > 101.86, the model also rejects the null hypothesis with a significant P-value of 0. At this point, the regression coefficient of MFI is 0.016, indicating that although MFI continues to have a positive impact on sustainable development, the strength of this impact diminishes as the mobile cellular network penetration rate increases beyond 101.86. This suggests that the relationship between MFI and sustainable development weakens when the level of ICT penetration is high. Among the other control variables, the results indicate that WAT and STA are not statistically significant, suggesting that they do not have explanatory power in the model. However, the interaction items of MFI and ICT, as well as FDI, are significant at the 1% and 10% levels, respectively. This implies that the interaction between MFI and ICT, as well as FDI, also have a positive impact on sustainable development. Overall, the findings highlight the importance of ICT development and its interaction with MFI and FDI in promoting sustainable development in the South Asian region.

In order to address potential endogeneity issues that could affect the regression results, the paper employs a dynamic panel model to analyze the relationship between the interaction items of MFI and ICT and sustainable development. The results of this analysis are presented in Table 6. The P value of AR(2) in the results is 0.396, suggesting that there is no second-order serial correlation present in the model. This indicates that the error terms in the model do not exhibit a systematic pattern of correlation over time. Additionally, the P value of the Hansen test indicates that the instrumental variables used in the model are not over-identified. This suggests that the instruments used to address endogeneity are valid and do not introduce biases into the regression results. By using a dynamic panel model and assessing the serial correlation and instrument validity, the paper strengthens the reliability of the regression results and provides more robust evidence regarding the relationship between the interaction items of MFI and ICT and sustainable development.

Table 6: results for the dynamic effect regression results.

Variable	GMM
L1.SDI	0.8080*(2.03)
MFI	0.0641***(18.33)
ICT	0.0018***(6.06)
MFI*ICT	0.0006**(2.73)
WAT	0.0099***(5.11)
GOV	0.0721***(26.34)
FDI	0.0219***(10.88)
Constant	0.3857***(9.98)
Obs	114
F-statistics(p-value)	0.000
AR(2)(p-value)	0.396
Hansen (p-value)	0.553

Note: t statistics are given in parentheses. ***, **and * represent significance levels of 1, 5 and 10, respectively.

The regression results indicate that the interaction term of MFI and ICT has a significant positive effect on sustainable development at a 5% level, with a regression coefficient of 0.0006. This suggests that the integration of ICT in microfinance has a beneficial impact on sustainable development. The use of ICT tools in microfinance, such as internet, computers, fixed telephones, and mobile phones, enhances access to financial services for customers. ICT adoption facilitates increased savings, customer base expansion, and reduction in operating costs and interest rates. These findings align with the research of Kauffman and Riggins (2012) that highlights the role of ICT in improving operational efficiency and cost-effectiveness of microfinance institutions, enabling them to better serve the poor.

Furthermore, strengthening the collaboration between ICT and microfinance helps bridge the gaps in financial infrastructure. This collaboration not only extends access to financial services for the poor but also reduces information asymmetry among them, enabling micro-entrepreneurs to receive favorable market information. Additionally, ICT enables microfinance institutions to promote environmentally friendly and sustainable business opportunities, provide information services for entrepreneurship, and contribute to the overall sustainable development of the economy. Overall, the positive relationship between the interaction of MFI and ICT and sustainable development highlights the potential of ICT in enhancing financial inclusion, reducing poverty, and promoting sustainable economic growth.

4.2 Robustness Test

In order to enhance the credibility of the regression results in this study, an additional analysis is provided to validate the aforementioned findings. Drawing from the research conducted by Nchofoung and Asongu (2022), it is suggested that the impact of ICT on sustainable development can be influenced by trade openness and foreign direct investment (FDI), with potential positive direct or indirect effects arising from their interaction.

Hence, as part of the robustness test in this study, ICT is employed as the primary explanatory variable, while microfinance institutions (MFI) are utilized as the threshold variable to examine the threshold effect between ICT and sustainable development. Prior to conducting the threshold model regression, a threshold effect test is conducted using MFI as the threshold variable to ascertain the presence of a significant threshold effect between ICT and sustainable development. The corresponding results are presented in Table 7.

Table 7: threshold effect test

Test for single threshold	
F_1	34.71
p-Value	0.0085
(10%; 5%; 1% Critical Values)	(19.2332, 23.0043, 31.6722)
Test for double threshold	
F_1	10.80
p-Value	0.3569
(10%; 5%; 1% Critical Values)	(17.0463, 19.7137, 25.0826)

The results presented in Table 7 reveal that the P-value associated with the single threshold effect is 0.0085, indicating that the null hypothesis is rejected, and the model demonstrates statistical significance at the 1% level. Conversely, the P-value corresponding to the double threshold effect is 0.3569, signifying a failure to meet the significance test. These findings suggest that a single-threshold effect exists between ICT and sustainable development within the model. As a result, the robustness test in this study employs a single-threshold model to estimate the relationship between ICT and sustainable

development. The regression results of the threshold model are depicted in Table 8.

Table 8: robustness test

Variable	(3)
Threshold level	9.7137**
MFI*ICT	0. 000033*(0.53)
WAT	-0.0006471(-1.60)
GOV	0. .010814***(3.56)
FDI	0. 0109789***(2.98)
$ICT_{it}I(MFI_{it} \leq \gamma)$	0. 0011948**(2.08)
$ICT_{it}I(MFI_{it} > \gamma)$	0. 0016053***(2.61)
Constant	0. 4127784***(10.67)
Obs	114
F-statistics(p-value)	0.0000
Linearity test (p-value)	0.0000

Note: t statistics are given in parentheses. ***, **and * represent significance levels of 1, 5 and 10, respectively.

Upon analyzing the regression results, it is observed that when the estimated value of the threshold variable MFI ≤ 9.71, ICT exhibits a significant positive effect on promoting sustainable development, with a regression coefficient of 0.0012. Similarly, when the threshold variable MFI > 9.71, the model's outcome remains significant, rejecting the null hypothesis, and yielding a regression coefficient of 0.0016. These findings indicate that as the total amount of MFI loans increases, the positive impact of ICT on sustainable development is further amplified. Moreover, the interaction terms among the control variables, FDI, and STA also significantly influence the level of sustainable development in South Asia, with consistent signs. Consequently, the regression results affirm the robustness of the primary findings in this study.

5. Conclusion

This study examines the threshold effect between microfinance (MFI) and sustainable development in South Asia using panel data from 2000 to 2018. It also investigates the impact of the interaction between MFI and information and communication technology (ICT) on sustainable development in the region. The paper employs the threshold model and dynamic system GMM model to address two key questions: firstly, at what threshold does ICT weaken the positive impact of MFI on sustainable development? And secondly, does the interaction between ICT and MFI contribute to the advancement of sustainable development in South Asia? Given that microfinance plays a vital role in poverty alleviation, education, and socio-economic development in South Asia, improving the efficiency of microfinance utilization and reducing the cost of accessing financial services for the poor are crucial factors. The research findings indicate that MFI exhibits a significant threshold effect on sustainable development in South Asia. Specifically, when the level of ICT development is below the identified threshold, increasing ICT usage can further enhance the positive impact of MFI on sustainable development in the region.

Moreover, the interactive use of MFI and ICT demonstrates a significant improvement in the level of sustainable development in South Asia. These findings not only align with the hypothesis of this paper but also contribute new empirical evidence to the existing literature. In light of these results, it is imperative for governments to prioritize enhancing areas where ICT development has not yet surpassed the threshold. This ensures that the poor in these regions are not excluded from accessing financial services, helps narrow the wealth gap, and enables the economically disadvantaged to benefit from the dividends of economic growth. To achieve these goals, governments should focus on reducing barriers to financial services, providing increased financial support to rural finance and small-scale enterprises, and expediting the establishment of inclusive digital finance initiatives. Additionally, offering financial subsidies, tax relief, and other supportive policies to microfinance institutions that serve the poor will be instrumental. It is essential to facilitate the flow of financial services and promote environmental awareness in rural areas, providing sustainable, stable, and high-quality investments in impoverished regions. These measures will not only drive sustainable economic development in impoverished areas but also contribute to gradually reducing income disparities.

In general, there are three key strategies to enhance the impact of microfinance and ICT on sustainable development in poverty-stricken areas. Firstly, it is important to increase the business coverage of microfinance institutions in these regions. Utilizing ICT, microfinance-related knowledge should be disseminated to rural residents, enabling the poor to understand the concept of sustainable development. Through the use of ICT and financial tools, individuals can make informed decisions and select suitable entrepreneurial opportunities. Secondly, improving the construction of digital credit reporting systems in poverty-stricken areas is crucial. By incorporating information such as the user's industrial operation status, quality, education level, and credit status into the credit evaluation system, the operational efficiency of microfinance can be enhanced. This enables a better understanding of the lives and entrepreneurship status of the poor. Lastly, it is essential to tailor microfinance products and services to the needs of the poor. By understanding the financial and commercial requirements of poverty-stricken areas, innovative financial service models can be developed using technologies like big data, cloud computing, and other information technologies. This enables the development of personalized financial products based on local resource endowments and industrial characteristics. These strategies aim to increase the business reach of microfinance institutions, strengthen digital credit reporting systems, and provide customized financial solutions to promote sustainable development in impoverished regions.

The study has several limitations that should be acknowledged. Firstly, the data samples used in this study are limited to South Asia, which may not fully represent the diverse microfinance landscapes in other countries and regions. Therefore, future research could consider expanding the research area to include a broader range of countries and regions to enhance the generalizability of the findings. Secondly, the study focuses on a specific aspect of ICT, namely the coverage of the mobile network, as a proxy for ICT development. Future research could explore a wider range of ICT infrastructure indicators to capture the multidimensionality of ICT and its impact on microfinance and sustainable development. Thirdly, the study does not account for the potential negative effects of the commercial nature of microfinance institutions on the well-being of the poor. It is important to consider the profitability and social responsibility of microfinance institutions in future research to provide a more comprehensive analysis of their impact on sustainable development. Addressing these limitations will contribute to a more robust understanding of the relationship between microfinance, ICT, and sustainable development, and provide valuable insights for policymakers and

practitioners in designing effective strategies to alleviate poverty and promote sustainable economic growth.

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