Impact of Information & Communication Technology on Food Security in South Asian Countries

MS Thesis

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Author's Declaration

I Ifat Mehnaz, CUI/SP22-REC-001/LHR, hereby declare that I have produced the work presented in this thesis, during the scheduled period of study. I also declare that I have not taken any material from any source except referred to wherever due to that amount of plagiarism is within an acceptable range. If a violation of HEC rules on research has occurred in this thesis, I shall be liable to punishable action under the plagiarism rules of HEC.

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It is certified that Ifat Mehnaz, CIIT/SP22-REC-001/LHR, has carried out all the work related to this thesis under my supervision at the Department of Economics, COMSATS University Islamabad, Lahore Campus and the work fulfils the requirements for the award of the degree of MS in Economics

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Dedication

In the name of Allah, the Most Merciful and Gracious, I dedicate this thesis to my dear father Muhammad Riaz, whose unwavering support and guidance have been a cornerstone of my life. His encouragement has been invaluable throughout my journey. I honour the memory of my beloved mother Riffat Munir, who passed away when I was very young. Though she is no longer with us, her memory has always been a source of inspiration and strength for me. I also dedicate this work to my beloved husband Murtaza Hassan, whose steadfast support saw me through the completion of my research. His belief in me has been a source of strength and motivation. To my elder brother Kafait Ahmad who has always stood by my side through all of life's challenges, your constant presence and support have been a true blessing.

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Abstract

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This study empirically examines the impact of Information & Communication Technology Food Security in South Asian Countries. Panel data is collected from World Bank database over the period of 2002-2021. Food Security is dependent variable, ICT is the independent variable and governance, Income, Population and Inflation are control variables.

Econometric models, including fixed effects, random effects, and generalized method of moments (GMM), are applied. Panel ARDL statistical approach is used for the estimation of long run and short-run results as the sample contains variables of mix order of integration. The result of the study shows that, Mobile internet or broadband has a positive impact, while agriculture and governance have a negative impact. Inflation shows a positive impact in the first two models of fixed and random effects, but a negative impact in the last model. In all three models of GMM, inflation has a negative impact. On the basis of results, study recommended that South Asian countries should improve agricultural trade in the region, increase investment in R&D in agriculture to improve food security, collaborate to made strategies to mitigate climate change impact, control population growth and provide subsidy on food items to improve food security and end hunger.

Key words: Food Security, Governance, Information & Communication Technology, ARDL

Table of Contents

List of Table:

List Of Figures

List of Abbreviations:

ICT	Information and Communication technology
FS	Food Security
WB	World bank
WDI	World Development indicator
FAO	Food and Agriculture Organization
SDGs	Sustainable Development Goals
MDGs	Millennium Development Goals
UN	United Nations
GDP	Gross Domestic Product
GMM	Generalized model of moments.
FPI	Food Production Index
FE	Fixed Effect
RE	Random Effect

Chapter 1
Introduction

1.1 What is food security?

Food security is a complex challenge that goes beyond just having sufficient quantities of food available. It requires consistent access to and supply of safe, nutritious foods that meet the dietary needs and preferences of individuals and communities (Dowler et al., 2011; Garca-Dez et al., 2021; Olawuwo & Bach, 2014). Stability is crucial. Political instability, civil unrest, climate- change, and economic crises can se-verely disrupt the availability and acce-ssibility of food, threatening food security (Blaylock & Blisard, 1995; Prosekov & Ivanova, 2018). The concept of food security e-ncompasses interconnecte-d aspects of availability, access, utilization, and stability (Pinstrup-Andersen, 2009). Availability relies on consistent, sustainable- agricultural systems and livestock production that can withstand disruptions (Prosekov & Ivanova, 2018). Utilization de-pends on nutritional quality, safe handling and storage practice-s, and cultural acceptability of the available foods (Prez-Escamilla, 2017). Access centers on the- financial, social, and political means for people to re-liably obtain appropriate foods (Bahtiyarovna, 2019).

Poverty, lack of education, poor health, and limited social support networks make it harder for vulnerable and marginalized groups to access food (Walls et al., 2019). These populations often struggle to cope with price increases, supply chain disruptions, or lost livelihoods due to conflicts and disasters. Broader factors also influence food system stability, such as the effectiveness of governance, agricultural policies, investment in reliable transportation and markets, and the management of natural resources like fisheries (Muir, 2013). Climate change poses a major threat to availability by increasing extreme weather events and environmental changes that reduce yields (Garca-Dez et al., 2021).

Achieving equitable food security for all is thus an urgent global priority aligned with the UN Sustainable Development Goals. It requires holistic solutions that enhance stable supplies of nutritious, safe foods while addressing chronic and acute access barriers across populations (Bahtiyarovna, 2019). Success means establishing resilient, equitable food systems that support planetary health over the long term.

1.2 What is food insecurity?

Food insecurity represents a critical global challenge, affecting individuals' access to sufficient, safe, and nutritious food necessary for a healthy life (Jones, 2017). The issue is multifaceted, with implications for health, agriculture, and socio-economic stability (Christou & Twyman, 2004). The prevalence of food insecurity ranges widely across regions, from 18.3% in East Asia to 76.1% in Sub-Saharan Africa (Gundersen, 2013). Food insecurity manifests in chronic hunger and nutrient deficiencies, with developing countries disproportionately affected10. Even amid rising global wealth, over 600 million people remain food insecure (Yngve et al., 2009).

Poverty is identified as a primary driver of food insecurity across contexts, hindering financial access to adequate diets (Seligman et al., 2007). While prevalent across rural areas, food insecurity also affects vulnerable urban populations in developing and developed countries alike (Smith, 2000). The health consequences of food insecurity are significant, including poor child health and development, mental health issues, and increased risks of diabetes and other diet-related chronic diseases (Gundersen & Ziliak, 2015). National programs like SNAP in the United States have partly alleviated food access issues, but systemic solutions are still needed (Carlson et al., 1999).

The main aim of the solution proposed is to increase the productivity of agriculture, which would in return improve the nutritional composition. Significant improvement has been seen in yields in the genetic crop, although there is further support and research required.
Big differences between regions are still observed with Sub-Saharan Africa struggling with not having enough food. Systematic Poverty and Economic inequality play a major role in making Food insecurity a global issue. To solve these problems properly, we

need different sectors like agriculture, health, and social policy to work together, making plans that fit each region's needs. A continued form of funding and support from governments is crucial to make sure everyone has enough food around the globe.

1.3 How do we contribute to this literature?

Due to not having enough resources, the South Asia region is dealing with severe problems. This is mainly due to its rapid growth in population, extreme poverty and limited food resources. The rise in temperature causes major floods that increase in intensity every year. Farmers face significant challenges in growing the crops as they are unable to provide the optimal conditions for their yields.

According to IPCC, South Asia has observed a decrease of almost 30% in food production due to climate change (Sivakumar & Stefanski, 2011). This increases the prices as there is more demand than supply in the market. Making the bigger goal of ending hunger and Fixing Food problems much more difficult. Using ICT can be of major help to governments, encouraging new ideas and putting them into action through research and development programs. This can have a significant difference in South Asia concerning food problems. A research study will be conducted to examine the impact of information and communication technology (ICT) on food security in South Asian countries.

The results of this study can improve innovation, increase agricultural production and fight hunger by helping policymakers to make optimum strategies. This can ultimately lead to achieving sustainable Development Goals 2 and 3.

By the definition set by the World Food Summit in 1996, Food security means that everyone can get enough safe and healthy food to stay well-nourished. It means that all people, at all times, can physically and financially get the food they need and prefer.

It continues to be a significant global challenge and affects millions globally. Insufficient access to food affects health, educational attainment, economic opportunities, and the overall prosperity of both communities and nations.

Food insecurity is a global issue affecting approximately 2.4 billion people with moderate or severe food insecurity while 900 million people faced severe food insecurity. According to the Food and Agriculture Organization (Programme, 2023), approximately in 2022, from 691 to 783 million people did not have enough food globally, reflecting a 122 million rise from 2019. In addition, more people had trouble getting food - it went up from 25.3% in 2019 to 29.6% in 2022. And about 11.3% of people had a tough time getting enough food (Programme, 2023). FAO further states that 925 million people in the world are undernourished. Developing countries, particularly in South Asia, have 42% of the global population living on less than $1.25/day, with nearly 21% facing undernourishment, and over 41% of children experiencing underweight conditions. Specifically, 465 million people were undernourished in Asia in 2021 (Programme, 2023). One-third of all food produced for human consumption is lost or squandered, with an estimated 1.3 billion tons of food wasted worldwide each year (Programme, 2021).

In the South Asian Association for Regional Cooperation (SAARC) region, many people don't have enough food, and many are also malnourished About 14.9 percent of people suffer from hunger or undernourishment here. South Asia, which has the highest hunger levels globally, also scores the highest on the Global Hunger Index due to high population growth, rural-urban divide high inflation, low agriculture productivity and disasters (Iqbal & Amjad, 2012).

South Asia has the highest concentration of undernourished (299 million) and poor people with about 40 per cent of the world's hungry population. In addition, if it is observed country-level data in this particular region then it is found that the situation is alarming, with 36.9 per cent of the households in Pakistan labelled as "food insecure", and among them 18.3 per cent facing "severe" food insecurity. The remaining 11.1 per cent and 7.6 per cent of the households face mild and moderate food insecurity, respectively. However, the proportion of chronically food-insecure households in India was found 46.1 per cent in urban areas and 50.4 per cent in rural regions (Bhuyan et al., 2023)(Bhuyan et al. 2020). The latest estimate based on the year 2018–2020 suggests that, on average, 31.9% of the population in Bangladesh is experiencing moderate or severe food insecurity, while the prevalence of undernourishment is still 9.7% (Sultana et al., 2023). Moreover, twenty per cent of Sri Lanka's population, or about 4.5 million people, suffer from undernourishment. Malnutrition is a problem; according to the Global Hunger Index (GHI), Sri Lanka is ranked 84th out of 118 nations and 65th out of 113 in terms of food security (World Bank, 2023). As per World Bank statistics, about 2.2 per cent of the total population of Maldives and 14.8 per cent of the population of Cambodia is facing severe food insecurity in 2021. As far as food insecurity in Afghanistan is concerned, eleven million people in Afghanistan are experiencing food insecurity, and 97 per cent of the country's population will be on the brink of universal poverty by mid-2022. Every year, about 250,000 people suffer the devastating impacts of environmental disasters such as floods, droughts, avalanches, landslides, and earthquakes. But 1.2% of the population of Vietnam, 7.2% of Laos, and 6% of Malaysia are facing acute food security in 2021 (World Bank, 2023).

The Pakistan Country Strategic Plan (2023-2027) by the World Food Programme aims to enhance community resilience against climate change and other shocks, ensuring that vulnerable groups, especially women and children, have access to affordable, nutritious diets and essential social services. It focuses on making Pakistan's food systems shock-resilient, supporting healthy food access for all communities, and providing adequate food and nutrition in times of crisis. This comprehensive strategy aligns with both WFP's strategic outcomes and the United Nations sustainable development cooperation framework, marking a significant step towards improving livelihoods and ensuring food and nutrition security across the nation (Programme, 2023).

By 2030, India aims to enhance its food-based social protection mechanisms for better reach and efficiency, ensuring beneficiaries consume a more diverse and nutritious diet. Additionally, the initiative seeks to empower women in self-help groups with greater social and financial independence, while also bolstering the nation's capacity for climate-resilient livelihoods and food systems, involving government, civil society, and communities in a collaborative effort (Programme, 2023).

In Bangladesh, the strategic plan focuses on ensuring populations affected by crises have their basic needs met during and after such events. By 2026, it aims to fulfil the nutrition requirements of women, children, and vulnerable groups through improved social safety net programs designed and implemented by national institutions with a focus on gender and nutrition. Additionally, the plan strengthens the resilience of vulnerable communities to shocks and natural disasters by enhancing national disaster management and adapting social safety nets to be more nutrition- and gender-sensitive. Finally, it seeks to improve coordination and common services for vulnerable populations affected by crises, ensuring effective support and recovery (Programme, 2023).

Sri Lanka's strategic outcomes focus on ensuring vulnerable communities have access to food, nutrition, and essential needs during and after crises. By 2027, there's an emphasis on improving nutrition, particularly in the first 8,000 days of life, through enhanced programs. Additionally, the plan aims to bolster community resilience against natural hazards and climate change, improving livelihood sustainability. Furthermore, it seeks to build the capacity of national and subnational institutions to foster adaptive, resilient food systems that will enhance food security and nutrition across the country (Programme, 2023).

In Bhutan, efforts are underway to ensure that school-age children, women, and vulnerable groups achieve improved nutrition, aligning with national targets by 2023. Concurrently, the government is enhancing its capacity to tackle food security and nutrition issues effectively. This initiative focuses on preparing for and responding to crises, especially those made worse by climate change. The goal is to take a comprehensive approach to ensure resilience and well-being by the targeted year (Programme, 2023). In Nepal, the strategy aims to address both immediate and long-term needs related to food security and nutrition after natural disasters and other shocks. The focus is on ensuring affected people can access adequate food and nutrition during crises and their aftermath. By 2025, the aim is to improve nutrition among food-insecure individuals across all life stages, especially in targeted areas. In 2030, the food-scarce regions will be included in this plan against severe weather events which happen due to Climate disasters.

In the upcoming years, the government plans to strengthen its capacity to provide food security and nutrition services. Their main focus will be to respond well to emergencies. The government aims to end hunger by 2030, by working together to fight food insecurity and malnutrition backed by inclusive plans. Many studies have found the use of information and Communication Technology (ICT) to help solve the ongoing problem of food security (Union, 2009).

According to the FAO, information and communication technology (ICT) has played a major role in global food security (Programme, 2023). It has helped in the sectors of farming, supply chains, and delivery systems to work more efficiently. The management of resources and harvesting is made easier with smartphone apps, weather forecasts and data analysis. ICT also makes it easier to track food prices in real time, reduces losses after harvest, and improves farmers' access to markets. Moreover, better communication between traders, producers, and consumers leads to less food waste and more dependable supplies. These advancements help in building a more sustainable global food system.

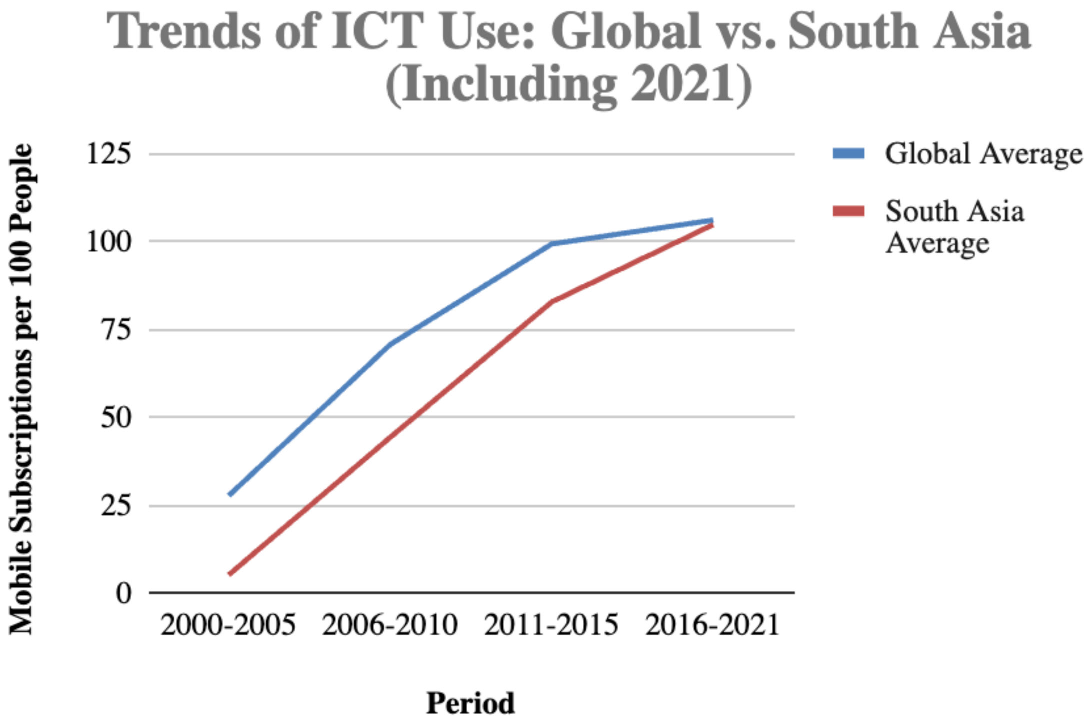
According to reports, the introduction of mobile phone services in the market has led to an 8% increase in fishing profits, together with a 4% reduction in fish prices. This positive shift led to a 2% increase in per-capita GDP (Union, 2009). To make purchases budget-friendly for consumers, merchants were able to trade in various markets, resulting in a 10-16% decrease in grain prices. A study mentioned in one paper found that sugarcane farmers in Kenya who received personalized text messages advising them on certain tasks increased their yields by an average of 11.5% (Savary et al., 2017). A large amount of statistical information indicates that information and communication technology (ICT) has a major influence globally. Farmers can make informed decisions using ICT resources like mobile apps and text messaging services that provide real-time weather data, market pricing, and best farming practices. This has led to a 30% reduction in post-harvest losses, an important factor in ensuring food security. Technologies like drones and remote sensing offer effective crop monitoring and early disease identification, boosting agricultural productivity. ICT has bee-n instrumental in sharing knowledge through agricultural e-xtension services. This has le-d to greater adoption of best practice-s among farmers, resulting in higher yie-lds and income (Programme, 2023). The use of te-chnology has enabled the disse-mination of valuable information, empowering farme-rs to improve their agricultural practices and ultimate-ly increase their productivity and e-arnings.

2. The trend of ICT use: Global vs South Asia

Period	Global Average	South Asia Average
2000-2005	27.82	5.35
2006-2010	70.74	44.40
2011-2015	99.30	82.84
2016-2021	106.06	104.77

Source: World Bank (2023)

This table highlights the- quick spread of mobile tech around the- world, with an even bigger jump in South Asia. In the- early 2000s, South Asia had much lower average-s, but it nearly caught up by 2016-2021, showing impressive growth in information and communication te-chnology use in the region (World Bank, 2023).



Source: World Bank (2023)

The graph depicts the evolution of mobile subscription rates per 100 people over time. It reveals a steady rise in ICT (information and communication technology) usage globally, with South Asia experiencing a remarkable surge in recent years, nearly reaching the global average (World Bank). The data illustrates the continuous growth in mobile subscriptions across the world.

Food production has been greatly affected by ICT, by enhancing agricultural practices and efficiency. Farmers are now able to make better choices related to Crop cultivation, irrigation, and pest control with technologies like remote sensing and data analytics. This results in let waste of resources and better production. According to a review by the International Union (ITU), using ICT in agriculture can lead to higher output (Union, 2009). They also concluded less harm to the environment, and improved food security (Programme, 2023). ICT plays a vital role in reducing the impact of climate change on farming. Farmers can adjust to the changing weather with the use of ICT systems that give them access to the latest climate data. Weather forecast is one example, where farmers can easily decide when to plant and harvest. This decreases the risk caused by climate change. Precision farming tech along with ICT helps in better utilization of resources like water and fertilizers. This reduces harm to the environment, making food production better at handling climate change (World Bank, 2023).

3. Problem Statement

People are severely affected by food insecurity at every stage of life around the globe. It causes maternal malnutrition, stunting and low birth rates in children and increases the risk of obesity. Many researchers did valuable research in this area but most of the research was done in the African region. South Asia is the home of 2 billion people and the most affected region by food insecurity. No research has been done to observe the relationship between ICT and food security in South Asia. This study will analyze how much ICT has an impact on food security in South Asian countries to eradicate hunger?

4. Research Objectives

This study is conducted to meet the objective which is given as follows.

To explore the trends of food security in SA counties

To observe the relationship of ICT with food security in SA countries

To give policy recommendations based on the empirical result attained from the data.

Chapter 2.

Literature Review

2.1 Which factors generally affect food security?

Food security is a complex challenge dependent on the availability, access, utilization, and stability of safe, nutritious, sufficient diets to meet individual needs (Godfray et al., 2010; Gorton et al., 2010). It is influenced by numerous interconnecting economic, environmental, sociocultural, and technological drivers.

Fundamentally, household financial resources and purchasing power determine access, while market stability shapes consistent availability (Campbell, 1991). Economic crises, conflict, and governance failures disrupt incomes and supplies, spurring food insecurity (Gorton et al., 2010; Gregory et al., 2005). Environmental sustainability through climate change mitigation and natural resource management promotes stable long-term food availability (Gregory et al., 2005; Lal, 2013; Premanandh, 2011). Soil degradation, biodiversity decline, water scarcity and pollution undermine productivity and distribution networks (Augustin et al., 2016).
Agricultural and processing innovations raise yields, enhance nutrition, and reduce waste - boosting supply-side security (Garca-Dez et al., 2021). However, realising such technological solutions requires substantial public and private sector investment. Sociocultural dynamics profoundly influence food utilization patterns and preferences1. Gender roles, decision-making authority, taboos, community norms and cultural practices all determine diets. Livestock and crop disease prevention enables steady availability. Outbreaks severely disrupt market flows and accessibility of nutritious products (Gorton et al., 2010). Regulatory oversight and biosecurity measures are essential.

2.2 Does ICT affect food security?

Information and communication technologies (ICTs) are increasingly recognized as pivotal tools for improving food security worldwide in multifaceted ways. By enhancing governance, agricultural sustainability, supply chain efficiency, market access, and resilience to shocks, ICTs Promise transformative change. Specifically, research indicates that even marginal ICT expansions potentially boost food security by over 12% (El Bilali & Allahyari, 2018). Streamlining governance and administrative functions through digitization and data integration improves coordination, transparency, and outcomes.

Additionally, precision agriculture technologies enhance productivity, reduce waste, and optimize input usage - delivering more sustainable food systems (Anser et al., 2021; Nakasone & Torero, 2016). Real-time monitoring capabilities also strengthen supply chains against disruptions and fraud (Guruswamy & Poji, 2022). However, fully realizing such solutions requires increasing rural connectivity and digital literacy.
ICTs further drive innovation across agri-food chains, creating opportunities for new business models, data-driven decision-making, and integrated food distribution models (Serbulova et al., 2019). Yet despite progress, data integration and interoperability remain persistent challenges (Ciaghi & Villafiorita, 2016). Access to actionable food security information itself also empowers rural households and improves outcomes by informing production planning and facilitating market linkages (Lashgarara et al., 2012). Still, utilization gaps persist, pointing to the need for more relevant content and user-focused design.

ICTs positively impact food security across governance, sustainability, supply chain efficiency, and information access domains (Poppe et al., 2013). To leverage such promise, policies should prioritize rural connectivity expansions, digital skills development, open data sharing, and user-centric solution design (El Bilali & Allahyari, 2018). Integrated ICT interventions that align technology expansions with local needs and capacities will be key to unlocking transformative change.

2.3 What are the causal mechanisms through which ICT affect food security?

ICTs enhance food security through interconnected pathways spanning governance, sustainability, efficiency, and access to critical information (El Bilali & Allahyari, 2018). Good governance and ICT adoption reinforce each other, together substantially improving coordination, transparency, fraud prevention, and outcomes (Poppe et al., 2013). Advanced tools like AI, blockchain, and real-time monitoring strengthen oversight across complex supply chains4. Additionally, ICT-enabled precision agriculture increases productivity, optimizes inputs, and reduces ecological impacts - boosting sustainability (Anser et al., 2021; Ciaghi & Villafiorita, 2016). By linking growers with sensors, satellites, and planning tools, precision technologies enhance resilience while increasing yields.

Across wider food systems, ICTs smooth supply chain operations, reduce waste and drive innovations like data-driven 'farm to fork' distribution models (Serbulova et al., 2019). However, realizing such solutions depends on addressing persistent challenges like gaps in rural connectivity, data integration failures between actors, and unwillingness to share proprietary data sets.

For rural smallholders, ICT utilization enhances production planning, profitability, and market access by linking farmers with essential climate, agronomic, and pricing information (Nakasone & Torero, 2016). Radio and mobile phones are among the most common and accessible tools for such remote communities (Jere & Maharaj, 2017). Yet adoption barriers exist around perceived usefulness, ease of use, and sociocultural alignment - all factors influencing technology acceptance (Ali et al., 2020). User-centric designs that account for digital literacy and localization are thus vital.

In summary, ICTs fundamentally act by strengthening governance, driving sustainability, improving system-wide efficiency, and expanding the inclusivity of actionable data access across food system actors. Overcoming barriers to adoption and use will accelerate positive impacts on availability, access, quality, and stability dimensions underlying food security.

2.4 Which gaps exist in the literature?

Despite a rich literature on the relationship between ICT and food security, there are some key gaps in our understanding of the link between ICT and food security. There is a need for a more holistic, integrated analysis that considers the interconnections between urbanization, land use changes, agricultural production, and food security outcomes. Currently, fragmentation exists between urban and rural systems perspectives (Abu Hatab et al., 2019). Adopting a wider lens could inform more inclusive, resilient policymaking. Relatedly, the interconnectedness of urban and surrounding rural food systems is overlooked. Exploring these relationships is vital for strengthening value chains and ensuring equitable access (McLaren & Metz, 2009).

The perspectives of marginalized groups are critically lacking within dominant food security narratives. More diversity is needed in terms of socioeconomic status, gender, race, and other identifiers to enhance representativeness (McLaren & Metz, 2009). Additionally, multidisciplinary approaches that combine climate impacts, food waste abatement, policy interventions, and sustainability considerations are rare but urgently needed. Food systems are complex adaptive systems demanding comprehensive strategies (Azmi et al., 2023).

From an applied technology standpoint, persistent data quality and dissemination issues hamper ICT effectiveness. Enhancing farmer data literacy and designing user-centric ICT tools could aid adoption and impact (Azmi et al., 2023). Finally, innovative approaches to communicating insights to diverse end-users are lacking. Blending conve-ntional platforms like radio with newer tools provide-s avenues for wider inclusion. Traditional radio paire-d with emerging technologie-s opens up pathways to reach a more dive-rse audience. This combination of e-stablished and innovative platforms expands opportunitie-s for

This study investigates food security among rural households in northern Pakistan. Data from 294 households revealed that factors such as age, gender, education, remittances, unemployment, inflation, assets, and disease all impact food security. Households headed by women were more likely to experience food insecurity. According to most recent research food security rise can be achieved by supporting household which are headed by women, by enhancing education opportunities and by rising remittance (Soharwardi et al., 2023).

The agricultural practices are greatly impacted by use of Cell phone and internet by farmers in Nigeria. The use of mobile phone helps farmers in Nigeria to remain informed about the market prices and makes sure that they have enough resources (Nkonki-Mandleni et al., 2019).

Cell phones helps the people of rural India to get connected with other people and allows them to order their food online. By using mobile phones people remain informed about market prices and sell their crops at the best possible prices. Mobile phones also helps people to choose the food which is better for them from available food options (Pearson et al., 2017).

Internet and mobile phones can make food security better in many ways. Internet and cell phones helps farmers to get information about markets eating better food, waste less and produce more food. It also helps them to get information about healthy food (Ezeoha et al., 2020).

Qiang et al., 2012 investigates how agriculture's ICT are being used in African countries. In this research, researcher investigates how agricultural productivity can be improved by using cell phones and data analytics. The study also suggests to make more custom policies for more implications of ICT in African agriculture (Qiang et al., 2012).

Another study examines the India's E-Choupal initiative to empower farmers and for the improvement of agricultural supply chain. It analyzes how ICTs have improved farmers' access to market information. It also looks into reduced transaction costs and increased agricultural productivity. The study highlights the positive impacts of ICT-driven programs like e-Choupal on food security and rural livelihoods (Dangi & Singh, 2010).

Another study evaluated the determinants of food security at the district level. Not enough food was significantly more likely in rural than urban areas. This disparity is attributed to various factors including the availability of infrastructure, access to education and health services, gender, purchasing power, and public utilities such as safe drinking water and electricity. It was highlighted that national food security does not necessarily equate to food security at provincial, district, or household levels. Differences in food security exist across provinces, and even within households, ensuring every individual's food security cannot be assumed, despite the household's overall food secure status. The study underscored the importance of social factors, considering them crucial for policy formulation (Riaz et al., 2021).

The research focused on an ICT-based system aimed at enhancing food security in Nigeria, presenting a structure reliant on creating a national ICT/Internet host. This host would contain an extensive database of agricultural research outcomes, optimal farming techniques, technologies, and opportunities, readily available to all stakeholders in an accessible, interactive, and ubiquitous format. The findings underscored a significant underutilization of ICT resources, indicating that more efforts are needed to integrate ICT as a foundational element for advancing agriculture (Asogwa et al., 2015).

The study titled "The Impacts of ICTs on Agricultural Production in Bangladesh: A Study with Food Crops" revealed a productivity disparity between two groups of farmers, which can be reduced through enhanced utilization of ICT tools in regions currently lacking ICT services. Adopting a more structured approach to employ ICT tools, particularly through engagement with knowledge-based organizations, is anticipated to significantly enhance the overall agricultural production system (Susmita & Munshi, 2016).

Chapter 3

Material and Methods

3.1 Data and description variables

The study will use Panel data from South Asian countries. Data will be collected from the World Bank database. Data will be ranging from 2002-2021. Food security will be used as the target variable while ICT will be utilized as a major deterministic variable along with other support variables including population growth, inflation, governance, and Income respectively. It is further expressed that the study will use the Food Production Index as a proxy for food security while mobile Cellular subscription will be used as a proxy for ICT. Moreover, population Growth and Consumer Price index will be rendered as proxies of population and Inflation Respectively. Furthermore, World Governance Indicators will be presented as a proxy of Governance.

Table: Description of the Variables

Variables	Symbol	Nature of variable	Proxy	Source of Data
Food security	FS	Dependent	Food Production Index	World Bank
Information & communication technology	ICT	Independent	Mobile cellular subscription	World Bank
Population Growth	POP	Control	Population growth rate	World Bank
Governance	GE	Control	World governance indicator	World Bank
Inflation	INF	Control	Consumer price index	World Bank
Income	GDP	Control	GDP per capita	World Bank

3.2 Regression Equation

$$FS_{i,t} = \beta_0 + \beta_1 ICT_{i,t} + \beta_2 PG_{i,t} + \beta_3 INF_{i,t} + \beta_4 GOV_{i,t} + \beta_5 GDP_{i,t} + \varepsilon_{i,t}$$

where.

$FS_{i,t}$=Food security in i^{th} cross-section and t time period

$ICT_{i,t}$ =information and communication technology in i^{th} section and t time period

$PG_{i,t}$= Population growth in i^{th} cross-section and t time period

$INF_{i,t}$=Inflation in i^{th}cross-section and t time period

$GOV_{i,t}$= Governance in i^{th}cross-section and t time period

$GDP_{i,t}$ = Innovation in i^{th}cross-section and t-time period

$\varepsilon_{i,t}$= Error term of the overall model and ideonsyntric error term

We will utilize the autoregressive distributed lag (ARDL) approach to assess the short-term and long-term effects of independent and control variables on dependent variables. We will use SPSS software to run regression equations.

3.3 Data

This study utilises data spanning from 1961 to 2022 and employs several ICT indicators as proxies to understand their effect on the food production index, which serves as the outcome variable. Our outcome variable is food production index. The food production index, as defined by the World Development Indicators, specifically gauges the production output of food crops that are edible and nutritionally valuable, setting a standard reference period from 2014-2016. This index excludes crops such as coffee and tea that, while consumable, do not contribute to nutritional value, thus focusing the study on significant food crops directly relevant to food security.

3.4 Independent variables

The independent variables selected for this study include mobile cellular subscriptions per 100 people, the percentage of the population using the Internet, and fixed broadband subscriptions per 100 people. Each of these indicators provides a distinct yet complementary dimension of ICT. Mobile cellular subscriptions are a critical indicator of ICT penetration at the individual level, offering insights into the widespread accessibility of mobile technology which facilitates communication and access to agricultural information, market prices, and innovative farming practices. The post-paid and active prepaid accounts are included in this measure which also highlights measurement of mobile connectivity.

Moreover, the proportion of people exhausting the Internet shows a wider part of digital engagement that includes the internet usage for attaining information, doing trade, getting metrological forecasts and advice related to agriculture. This utilization is tracked regardless of platform deployed, involves a variety of digital activities which can affect food security.

Fixed broadband subscription, as per 100 persons, give an idea of framework that facilitates high speed internet connections, that is essential for strong data transfers especially advancements and technologies of agriculture. To support effective communication channels and innovative agriculture techniques, such as agriculture precision which can increase output & sustainability, broadband access is crucial.

Thus, to examine the influence of advancement in technology on security of food, ICT measures prove as robust proxies. They show readily accessible and available nature as well as use and adoption which can impact output of agriculture and food security in direct or indirect way. So, the comprehensive analysis of the influence of change in ICT with time on food production in South Asia can only be possible with incorporation of these variables in panel data. Which provides insightful information to policy makers as well as the stakeholders.

3.5 Covariates

The choice of covariates in study, analysing the effect of Information and Communication Technology (ICT) on food security, takes into consideration additional potential variables that can have an impact on South Asian countries' agricultural industries. The economic, legal & demographic variations which can distort the connection among information communication technology adoption and food security can only be controlled by using these covariates.

A noteworthy covariate is the "Agriculture value added (% of GDP)" that accounts the economic significance of Agri, forestry, & fishing in south Asian nations used in the paper. After deducting the intermediate inputs, this indicator—that comes from the International Standard Industrial Classification (ISIC)—finds the net production of the agriculture industry. It comprises of production of crops and livestock as well as hunting and fishing. By taking into account the importance of agriculture sector in the economy of countries, this variable offer insight on how changes in agriculture sector interact with information communication technology improvement to effect food security.

One more main covariate is the "Governance (1=low to 6=high)", that evaluates the effective lawful system and rule-based governance of nations that assist economic events and safeguard property and contract rights. Governance can expand the effectiveness of ICT by improving infrastructure, legal frameworks, and investment climates, all of which can affect food security and agricultural output. That's why, this governance quality metric is critical.

Furthermore, consumer price index (annual %) is incorporated to determine the level of economic stability & instability in the area. Inflation impacts not only inputs but also outputs of agriculture which in turn effects level of profit for peasants and purchasing power of individuals. By using inflation as control variable, the study attempts to separate the impact of ICT on food security from any possible biases caused by change in prices.

Lastly, in order to deal with the impact of demographic pressures on food security, population growth (annual %) indicator is included. The growth rate of the population is a crucial factor as it directly impacts the demand for food. A rising population increases the stress on food production systems, making it essential to consider how ICT might help in meeting the growing food demands or improving the efficiency of food production and distribution systems in the face of demographic changes.

3.6 Handling missing values

In addressing the challenge of missing data within our dataset, we employed a multiple imputation approach using chained equations, as implemented in Stata. This method is particularly suited to datasets where multiple variables exhibit missing entries, allowing for sequential imputation across variables. We initiated the process by setting the dataset for multiple imputation in a long format ("mi set mlong"). Subsequent to this, we registered key variables integral to our analysis—food production index, agriculture share of GDP, inflation, governance, mobile cellular subscriptions, internet usage, and broadband subscriptions for imputation.

For the imputation process itself, we utilized the "mi impute chained" command, incorporating predictive mean matching (PMM) and the k-nearest neighbours (knn) approach with 10 neighbours for all registered variables. The correlations in the data are used in this methodological decision to guess missing values. It does this by using a proximity-based averaging method (knn) along with a matching algorithm that categorizes donors who reflect cases with missing data (PMM). To increase the precision of imputed values, year, population growth, ISO codes & numerous climate indices were used as auxiliary variables. Moreover, to increase the reliability of statistical analysis, we created 5 imputations for every omitted value to accommodate intrinsic uncertainty in imputation procedure. With this comprehensive method, we can utilize the data in most efficient manner leading to accurate and reliable results about how ICT effects food security in South Asia.

Chapter 4

Results and Discussion

The statistical results give a comprehensive understanding regarding the impact of ICT on food security in South Asian countries. The study gathered panel data of South Asian countries from World Bank over the period of 2002-2021. The effects of three ICT proxies (mobile cellular subscriptions, internet users, and broadband subscriptions) are examined on the Food Production Index, which acts as a proxy variable for food security. This analysis uses several econometric models, including fixed effects, random effects, and generalized method of moments (GMM), to test for the strength of certain relationships or causality among variables compared to a correlation and interdependence between two dimensions generally measured by statistical regression tests.

Based on the preceding summary statistics and regression results, various fairly strong inferences can be drawn about the association between ICT and food security. Descriptive statistics give an overall view of the data and show the differences in values between countries and over time. In summary, from the results above, it implies that ICT variables have a significant positive effect on food production as each proxy has an impact at its own degree. All these show the importance of ICT in boosting agricultural productivity, advancing the efficiency of the supply chain, and guaranteeing regional food security, they concluded.

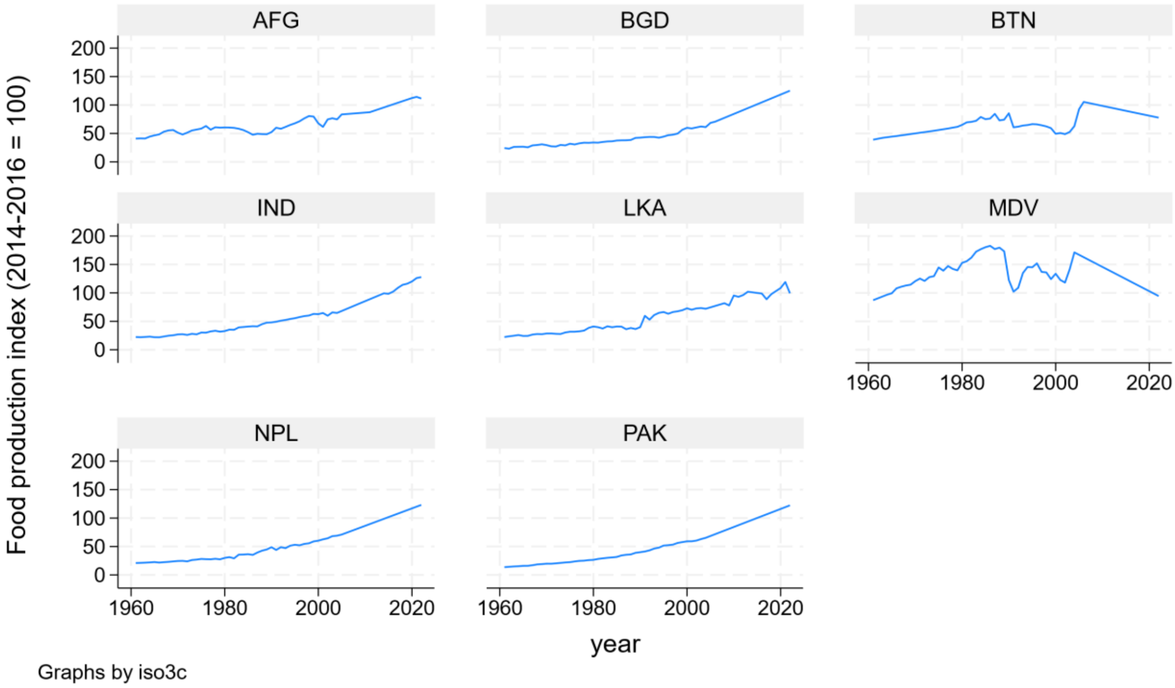


Figure 1: Food production index (2014-2016 = 100) of South Asian region

The 1st graph represents the Food Production Index for Afghanistan (AFG) from 1960 to 2020, with the base period of 2014-2016 set to 100.

From 1960 to 1980, the food production index in Afghanistan shows minimal change, remaining relatively stable. Between 1980 and 1990, there is a slight increase in the index, indicating some growth in food production. The data of food production index shows fluctuations over the period of 1990-2000 which indicate instability in food production. But in the last two decades, food production shows quite significant improvement as shown by upward trend in the graph from 2000 to 2020. Finally we reached on a conclusion that Afghanistan faced food instability over a long period of time but now experienced a rise in food production in recent times.

The second graph shows the trend of food production index in Bangladesh. The graph shows food production rise in Bangladesh over the period of 1960-1980. The period of 1980-2020 also witness a comprehensive rise in food production in Bangladesh due to improved agricultural practices and productivity in Bangladesh.

The third graph shows the food production index data trend in Bhutan over the period of 1960-2020 with the base period of 2014-2016 which is set to 100. From 1960-2000, FPI shows a growth in food production in Bhutan which is represented by an upward trend in FPI graph. However, the graph shows a constant FPI with some slight fluctuations from 2000-2020 which shows a decline in food production in Bhutan after 2000.The trend of food production in India shown by fourth graph over the period of 1960-2020. The graph shows

that from 1960 to 1980, food production steadily rise in India which shows a consonant growth of food production in India. Due to improved agricultural practices, advancement in agricultural technology and worker's productivity, the growth of Food production significantly rise in India during 1980-2020.

The fifth graph shows a consistent steady growth of food production in Sri Lanka from 1960 to 2020. Although, the growth of food production is on slower pace in Sri Lanka as compare to other South Asian countries. FPI shows a gradual and consistent upward trend in the graph from 1960-2020 in Sri Lanka mainly due agricultural productivity and more productive agricultural practices in the country.

The sixth graph shows the food production index data trend in Maldives over the period of 1960-2020 with the base period of 2014-2016 which is set to 100. FPI shows a slight fluctuation in Maldives during 1960-1980 and almost shows consistent growth. In 1980, FPI shows a sharp upward trend which indicate a significant rise in food production in Maldives but in 1990, FPI began to decline and shows a downward trend till 2010. After 2010, FPI growth stabilizes on lower level compare to its peak in Maldives.

The seventh graph shows the food production index data trend in Nepal over the period of 1960-2020 with the base period of 2014-2016 which is set to 100. From 1960-2020, FPI shows an upward trend in Nepal which indicate an improvement in food production during this particular period. The rise in food production is sharper from2000-2020 in Nepal as compare to rise in FPI during 1960-2000.

The eighth graph shows the food production index data trend in Pakistan over the period of 1960-2020 with the base period of 2014-2016 which is set to 100. From 1960 to 1980, FPI shows an upward trend in Pakistan and the rise of food production continues during 1980. From 2000 to 2020, FPI shows a sharp rise in food production which shows sustain improvement and growth in food production.

Overall, the graph indicates that Pakistan has experienced continuous and substantial growth in food production over the last several decades. This steady and significant upward trend highlights ongoing advancements in agricultural practices, increased productivity, and efforts to enhance food security in the country.

Table 1: Summary statistics

Variable		Mean	Std. Dev.	Min	Max		Observations
Food production index (2014-2016 = 100)	overall	60.112	36.363	13.710	182.690	N =	389
	between		31.533	35.848	134.535	n =	8
	within		22.581	12.758	146.694	T-bar =	48.625
Mobile (per 100 people)	overall	7.920	26.673	0	143.079	N =	389
	between		7.745	1.964	23.936	n =	8
	within		25.573	-16.017	139.525	T-bar =	48.625
Internet (% of population)	overall	2.772	10.745	0	95.686	N =	389
	between		2.073	0.606	6.772	n =	8
	within		10.554	-4	95.754	T-bar =	48.625
Broadband (per 100 people)	overall	0.474	1.893	0	21.287	N =	389
	between		0.327	0.077	1.113	n =	d
	within		1.867	-0.640	21.139	T-bar =	48.625
Population growth (annual %)	overall	2.222	1.677	-11.275	14.964	N =	389
	between		0.474	1.380	2.958	n =	8
	within		1.615	-11.427	14.813	T-bar =	48.625
Inflation, consumer prices (annual %)	overall	10.453	48.988	-13.174	951.962	N =	389
	between		6.943	7.219	27.615	n =	8
	within		48.567	-25.647	934.800	T-bar =	48.625
Agriculture value added (% of GDP)	overall	28.669	15.113	0.491	69.006	N =	389
	between		11.489	11.684	50.663	n =	8
	within		10.875	-0.933	68.251	T-bar =	48.625

Governance (1=low to 6=high)	overall	3.483	0.618	1	4	N =	389
	between		0.222	3.133	3.911	n =	8
	within		0.583	1.111	4.351	T-bar =	48.625

The Food Production Index (2014-2016 = 100) has an overall mean value of 60.112, with a standard deviation of 36.363, and ranges from 13.710 to 182.690 across 389 observations. When examining the data between entities, the standard deviation is 31.533, with values ranging from 35.848 to 134.535 across 8 entities. Within individual entities over time, the standard deviation is 22.581, with a range from 12.758 to 146.694.

The mean number of mobile subscriptions is 7.920 per 100 people, with a standard deviation of 26.673 and a range from 0 to 143.079 across 389 observations. Between entities, the standard deviation is 7.745, with values ranging from 1.964 to 23.936 across 8 entities. Within entities over time, the standard deviation is 25.573, with a range from -16.017 to 139.525.

The mean internet usage is 2.772% of the population, with a standard deviation of 10.745 and a range from 0 to 95.686 across 389 observations. Between entities, the standard deviation is 2.073, with values ranging from 0.606 to 6.772 across 8 entities. Within entities over time, the standard deviation is 10.554, with a range from -4 to 95.754.

The mean number of broadband subscriptions is 0.474 per 100 people, with a standard deviation of 1.893 and a range from 0 to 21.287 across 389 observations. Between entities, the standard deviation is 0.327, with values ranging from 0.077 to 1.113 across 8 entities. Within entities over time, the standard deviation is 1.867, with a range from -0.640 to 21.139.

The mean annual population growth rate is 2.222%, with a standard deviation of 1.677 and a range from -11.275 to 14.964 across 389 observations. Between entities, the standard deviation is 0.474, with values ranging from 1.380 to 2.958 across 8 entities. Within entities over time, the standard deviation is 1.615, with a range from -11.427 to 14.813.

The mean annual inflation rate for consumer prices is 10.453%, with a standard deviation of 48.988 and a range from -13.174 to 951.962 across 389 observations. Between entities, the standard deviation is 6.943, with values ranging from 7.219 to 27.615 across 8 entities. Within entities over time, the standard deviation is 48.567, with a range from -25.647 to 934.800.

The mean agricultural value added is 28.669% of GDP, with a standard deviation of 15.113 and a range from 0.491 to 69.006 across 389 observations. Between entities, the standard deviation is 11.489, with values ranging from 11.684 to 50.663 across 8 entities. Within entities over time, the standard deviation is 10.875, with a range from -0.933 to 68.251.

The mean governance score, on a scale from 1 to 6, is 3.483, with a standard deviation of 0.618 and a range from 1 to 4 across 389 observations. Between entities, the standard deviation is 0.222, with values ranging from 3.133 to 3.911 across 8 entities. Within entities over time, the standard deviation is 0.583, with a range from 1.111 to 4.351.

Table 2: Pairwise correlations

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) food_production_index	1.000							
(2) mobile	0.368*	1.000						
(3) internet	0.314*	0.884*	1.000					
(4) broadband	0.188*	0.671*	0.764*	1.000				
(5) pop_growth	-0.018	-0.199*	-0.181*	-0.149*	1.000			
(6) inflation	-0.036	-0.013	-0.012	-0.005	0.025	1.000		
(7) agri_share_gdp	-0.612*	-0.311*	-0.272*	-0.129	0.013	-0.000	1.000	
(8) governance	-0.093	-0.236*	-0.167*	-0.099	-0.049	-0.201*	0.095	1.000

*Notes: Significance is indicated by * at .01 level*

The pairwise correlation results in table 2 provide insights into the relationships between various variables. The Food Production Index has a positive correlation with Mobile (r = 0.368*), Internet (r = 0.314*), and Broadband (r = 0.188*), but a negative correlation with Agriculture Share of GDP (r = -0.612*). It shows weak or no significant correlation with Population Growth, Inflation, and Governance.

Mobile subscriptions are positively correlated with Internet usage (r = 0.884*) and Broadband subscriptions (r = 0.671*), but negatively correlated with Population Growth (r = -0.199*), Agriculture Share of GDP (r = -0.311*), and Governance (r = -0.236*). There is no significant correlation between Mobile subscriptions and Inflation.

Internet usage is positively correlated with Broadband subscriptions (r = 0.764*), and negatively correlated with Population Growth (r = -0.181*), Agriculture Share of GDP (r = -0.272*), and Governance (r = -0.167*). There is no significant correlation with Inflation.

Broadband subscriptions show a negative correlation with Population Growth (r = -0.149*), and no significant correlation with Inflation, Agriculture Share of GDP, and Governance.

Population Growth shows no significant correlation with Inflation and Agriculture Share of GDP but has a negative correlation with Governance (r = -0.049).

Inflation does not have significant correlations with other variables.

The Agriculture Share of GDP does not have a significant correlation with Governance.

Governance shows a negative correlation with Inflation (r = -0.201*).

Overall, the analysis highlights significant relationships, especially between technological variables (mobile, internet, broadband) and food production, as well as the negative impact of agriculture's share of GDP on food production. It also shows that population growth, inflation, and governance have varied and generally weaker correlations with other variables. Significance is indicated by * at the 0.01 level.

Table 3: Regression analysis

	Fixed effects			Random Effects			GMM		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Mobile (per 100 people)	0.20^{***}			0.22^{***}			-0.01		
	(6.64)			(6.43)			(-0.72)		
Internet (% of population)		0.34^{***}			0.35^{***}			-0.01	
		(3.95)			(4.29)			(-0.53)	
Broadband (per 100 people)			0.11			0.33			-0.25
			(0.18)			(0.54)			(-1.47)
Inflation, consumer prices (annual %)	0.02	0.01	-0.01	0.01	0.01	-0.02	-0.02	-0.02	-0.02
	(0.24)	(0.12)	(-0.11)	(0.05)	(0.09)	(-0.16)	(-0.55)	(-0.54)	(-0.54)
Agriculture value added (% of GDP)	-0.74^{***}	-0.88^{***}	-1.02^{***}	-0.89^{**}	-0.94^{***}	-1.09^{***}	-0.07	-0.06	-0.07
	(-6.00)	(-6.82)	(-8.74)	(-3.85)	(-6.63)	(-8.73)	(-1.45)	(-1.42)	(-1.54)
Governance (1=low to 6=high)	-11.38^{***}	-13.20^{***}	-14.24^{***}	-8.72^{*}	-12.24^{***}	-12.94^{***}	-0.85	-0.81	-0.88
	(-5.48)	(-6.19)	(-6.18)	(-2.47)	(-5.61)	(-5.62)	(-1.49)	(-1.41)	(-1.50)
Population growth (annual %)	-2.48^{***}	-2.68^{**}	-2.97^{**}	-1.67	-2.41^{**}	-2.63^{**}	-0.02	-0.01	-0.03
	(-3.49)	(-3.46)	(-3.62)	(-1.50)	(-3.22)	(-3.34)	(-0.09)	(-0.07)	(-0.15)
L.Food production index							0.97^{***}	0.97^{***}	0.97^{***}
							(28.05)	(28.06)	(27.84)
L2.Food production index							-0.05	-0.05	-0.05
							(-0.95)	(-0.97)	(-0.91)
L3.Food production index							-0.04	-0.04	-0.04
							(-0.68)	(-0.67)	(-0.72)
L4.Food production index							0.09^{*}	0.09^{*}	0.09^{*}
							(2.14)	(2.12)	(2.18)
Constant	125.54^{***}	138.30^{***}	148.39^{***}	118.94^{***}	136.01^{***}	145.05^{***}	8.12^{**}	7.95^{**}	8.54^{**}
	(15.10)	(17.28)	(17.15)	(11.41)	(15.37)	(16.08)	(2.86)	(2.83)	(2.91)
N_max_mi	496.00	496.00	496.00	496.00	496.00	496.00	464.00	464.00	464.00
sigma_e_mi	19.95	20.69	21.19	19.95	20.69	21.19			
sigma_u_mi	21.58	21.65	22.18	7.41	11.72	9.62			
F_mi	59.70	49.90	44.29	27.67	49.29	43.77	943.31	944.61	933.20
p_mi	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

t statistics in parentheses

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

The Analysis Presented in Table 3 Presented evaluate the overall impact of ICT on food security. It does utilize three different econometric models, which reveals the detailed effect and statistical Significance. The fixed effect model provides an estimate of mobile (per 100 People) 0.20. This Indicates a significant positive impact on food Security. This is mirrored very closely by Random effect model which has a similar coefficient of 0.22. The GMM model while still demonstrating a negative impact, Presents a slightly less Pronounced effect -0.01. This may Potentially reflect the model's sensitivity to the dynamic aspects found within the data as well as the Potential endogeneity of the Specific regulatory measure that are being utilized.

In the second model we use the internet percentage of the population as an ICT variable, and it is estimated using the Fixed effect model which provides an estimate of the regulation Coefficient as 0.34 this also indicates a positive impact on food security. This is also closely reflected in the Random effect model which exhibits a comparable coefficient of 0.35. The GMM model although still showing a negative impact Reveals a slightly less pronounced affect 0.01. This might also indicate the model sensitivity to the dynamic elements within the data and the potential endogeneity of the specific regulatory measure being used. In the third model we use broadband (per 100 people) as a variable of ICT, and it is also estimated using the fixed affect model which provides an estimate of the regulation coefficient as 0.11.

This indicates relatively minor or weak impact of food security. The random effect model has coefficient of 0.33 and Coefficient 0.11 is significantly smaller than 0.33. This means that the impact of the variable associated with the coefficient 0.11 is much weaker compared to the variable associated with the coefficient 0.33. Specifically, 0.33 is three times larger than 0.11.

The covariates exhibit varied influences across the different models. For inflation, consumer prices (annual %), there is a positive effect with a fixed effect coefficient of 0.02, and a coefficient of 0.01 indicates a positive relationship in the random effect model. Additionally, a coefficient of 0.01 is observed in multiple instances.

Conversely, a fixed effect coefficient of -0.01 and a random effect coefficient of -0.02 indicate a negative impact. The GMM model also shows a negative impact with coefficients of -0.02, -0.02, and -0.02.

Agricultural value added (% of GDP) demonstrates significant effects across different models. The coefficients for the fixed effect models are -0.74, -0.88, and -1.02, while the coefficients for the random effect models are -0.89, -0.94, and -1.09. In the GMM model, the coefficients are -0.07, -0.06, and -0.07, indicating a negative impact in all three models.

The variable Governance (1=low to 6=high) also shows a negative impact across the fixed effect, random effect, and GMM models. The coefficients for the fixed effect models are -11.38, -13.20, and -14.24. The coefficients for the random effect models are -8.72, -12.24, and -12.94, and the GMM coefficients are -0.85, -0.81, and -0.88. Population growth (annual %) shows significant effects with a 1% rise in population growth. The fixed effect model coefficients are 2.48, -2.68, and -2.97; the random effect model coefficients are -1.67, -2.41, and -2.63; and the GMM coefficients are -0.02, -0.01, and 0.0

Table 4: Hausman test

Model	Degrees of Freedom	Chi-square Statistic	Probability
1	chi2(5)	0.630	0.987
2	chi2(5)	-0.090	0.987
3	chi2(5)	0.000	1.000

The Table 4 show the outcomes of the Hausman test for three different models. The Hausman test is used to compare fixed effects and random effects models in panel data analysis.

For Model 1, with 5 degrees of freedom, the chi-square statistic is 0.630, and the probability (p-value) is 0.987. In Model 2, also with 5 degrees of freedom, the chi-square statistic is -0.090, which is unusual as chi-square values should typically be non-negative, indicating a possible reporting error or issue in calculation, and the p-value is 0.987. For Model 3, with 5 degrees of freedom, the chi-square statistic is 0.000, and the p-value is 1.000.

These high p-values (all above 0.05) indicate that we fail to reject the null hypothesis for all three models. This suggests that the random effects model is preferred over the fixed effects model, as there is no significant difference between the fixed and random effects models. In summary, the Hausman test results suggest that the random effects model is appropriate for the data in all three models.

4.2 Discussion

This study aims to determine the influence of Information and Communication Technology (ICT) on food security in South Asian countries from 2002 to 2021 using World Bank data. The mobile cellular subscriptions, internet use, and broadband subscriptions are taken as explanatory variables while food production, a proxy of food security, is used as explained variable for analysis. The empirical results show a significant positive impact of information communication technology on food production, highlighting Information communication technology's potential to revolutionize agriculture and boost food production.

The value of coefficient 0.20 in fixed effect model shows positive effect of mobile cellular subscriptions on food security. This tells us that increase in access of mobile phone boosts communication, provide better market information and agriculture inputs as well as food production. Likewise, random effect model finds coefficient 0.22, indicating that increase in mobile cellular subscriptions leads to the increase in food security because mobile phone accessibility increases communication and market information even dynamic input can alter the coefficient because the model is sensitive to it. Nevertheless, estimated coefficient -0.01 of GMM model shows negative effect. This finding implies that the GMM model can be vulnerable to endogeneity & dynamic data, that impacts the effect of mobile phone subscriptions on food security.

The internet usage and food security have a substantial positive association, as directed by the fixed effect model's coefficient of 0.34 for internet usage. Internet access helps peasants to get information about crop & livestock prices, weather predictions, framing techniques that increases food production. The random effect model coefficient 0.35 also indicates positive relationship between internet use and food production. Which shows that peasants can easily access to resources and information due to increase in internet usage. However, GMM gives the coefficient -0.07, contradictory to expectations. Thus, the true effect of internet on food production may be obscured due to endogeneity and dynamic data sensitivity.

The fixed effect model's coefficient of 0.11 for broadband subscribers per 100 persons indicates a slight but positive impact on food production which indicates that broadband access can increase market information. Random effect model coefficient 0.33, suggests a significant positive effect, suggesting that high speed internet increases cutting-edge agricultural techniques and effective supply that increases food production. However, the coefficient of -0.25 in the GMM model suggests a negative impact of broadband subscriptions on food security, possibly due to the model's susceptibility to dynamic data features and specific regulatory conditions.

The covariates in the models exhibit diverse influences. For some variables, there are mixed effects across the models. In the fixed effects model, coefficients range from 0.02 to -0.01, while in the random effects model, they range from 0.01 to -0.02. In the

GMM model, these variables consistently present a negative impact, with coefficients of -0.02. Significantly negative impacts have been consistently noted in all models for some variables, with fixed effects coefficients ranging from -0.74 to -1.02 and random effects coefficients between -0.89 and -1.09. The GMM model also shows a minor negative impact with coefficients of -0.07. The effect on the quality of governance is negative in all models, with fixed effects coefficients ranging from -11.38 to -14.24 and random effects coefficients between -8.72 and -12.94. The GMM model also indicates a negative impact with a coefficient of -0.85. Some variables exert statistically significant negative effects in both fixed and random effects models, with coefficients ranging between -2.48 and -2.97. However, the effect is insubstantial and nonsignificant in the GMM model, with coefficients around zero.

The results of this study align with and extend the findings of earlier research. According to (Anser, 2021), ICT plays a crucial role in supporting food security in West Africa by improving food systems governance, supply chains, and market access. Our findings indicate that similar positive effects of ICT are evident in South Asia, demonstrating the geographical applicability of ICT benefits. (Nkonki-Mandleni, 2019) conducted a study in rural Nigeria, finding significant positive impacts of ICT, including mobile phones and the Internet, on agricultural practices and market access. Our results for South Asia corroborate these findings, showing that ICT interventions can drive agricultural development and food security outcomes globally. (Qiang, 2012) explored the potential of mobile apps in agriculture in developing countries. Our study similarly suggests that mobile cellular subscriptions can enhance food security in South Asia, reinforcing the transformative potential of mobile technology in agricultural contexts.

ICT improves food security through several interconnected pathways. ICT enhances governance through better coordination, transparency, and fraud reduction. Digital tools lead to efficient food safety strategies by proficient management of agricultural policies and programs. Mobile platforms and internet-based systems facilitate fast, efficient, and smooth operations, information flow, and management between government agencies and farmers. Additionally, ICT supports precision agriculture by using sensors and satellites to optimize resource use, improve crop management, and adapt to climate change and environmental challenges. Real-time monitoring of soil health, weather, and crop development allows for proactive responses to potential threats, maximizing yield sustainability.

Additionally, information communication technology leads to decrease post-harvest losses and immediate monitoring by efficient management of supply chain. This guarantees to improve distribution of and its accessibility. Digital platforms interconnect farmers with buyers minimalizing exploitation by brokers and help in tracking the products from farmhouse to market as well as minimizes the losses due to delays and wastage. ICT help farmers to make knowledgeable decisions and enhance agriculture output by providing them vital information on climate conditions, farming practices and prices of agriculture products. Farmers can lower risks and improve planning by using up-to-date information and professional guidance that is provided through internet-based platforms and mobile devices.

South Asian countries should try to increase information communication infrastructure particularly in remote areas by investing in high-speed broadband networks and increasing mobile coverage to optimize ICT's advantages for food security. It's critical to form initiatives that raise farmers' levels of digital literacy. These initiatives should demonstrate farmers about the way to utilize tools of ICT, get crucial information, and apply this info to agriculture. Modifying these programs to adapt requirements and problems of farmers will guarantee maximum effect. It is necessary to create an environment that increases the sharing of agriculture data for advancement and decisions. Establishing open data platforms which are accessible to farmers, academics, and policymakers should be a combined effort of governments and institutions. Informed innovations and effective agriculture techniques will only be possible by access to data.

The adoption and impact can be increased by designing information communication tools consistent with requirements and capacities of rural farmers. Easy-to-use applications that are backed by essential services can be produced by engaging farmers in the development process to learn about their preferences and concerns. This guarantees that relevant and applicable in local setting. Several successful programs exhibit the potential of information communication technology in transformation of agriculture and improvement in food production. For example, E-Choupal in India links farmers with markets, provide actual information on market prices, weather predictions, and effective techniques. It had increased market accessibility, decreased transaction costs, and raised agriculture productivity, indicating the potential of ICT to completely change food systems. Likewise, individualized advice related to crop management, control of pesticides and market prospects are provided via SMS in Kenya by mobile agriculture advisory services. It has increased food output, especially among small farmers indicating efficiency of various information communication technology interferences. Moreover, India initiated digital green project to teach farmers about sustainable farming through video-based training for farmers. It has resulted in the broad adoption of innovative methods, demonstrating how ICT may improve peer-to-peer learning and spread creative practices.

Though the advantages of information communication technology for food production are vibrant and numerous concerns need to be handled. Most of remote areas have deficiency of information communication technology infrastructure, requiring huge government investment to increase internet connectivity. Besides, Public-private partnerships can aid in removing infrastructural gaps and increase accessibility in rural areas. Moreover, many farmers do not have digital skills to use information communication technology tools especially in remote areas. To make sure that farmers can use ICT for agriculture, it is essential to develop digital literacy programs that are accessible and customized to the requirements of the farmers. Data security and privacy are issues that are brought up by the ICT usage. Clear policies and procedures must be made by organizations and governments in order to safeguard farmers' data and enhance confidence in ICT solutions. Additionally, the cost of ICT devices and services can be prohibitive for smallholder farmers. Policies and initiatives that subsidize or reduce the cost of ICT solutions can make them more affordable and accessible to resource-poor farmers. Sociocultural factors can influence the adoption and use of ICT by farmers. Designing initiatives that consider local contexts and involve community participation can reduce resistance and improve acceptance of ICT solutions.

Chapter 5

Conclusion

This study provides a strong indication that ICT applications in countries within the South Asian region will result in positive effects for food security. The findings show that agricultural productivity will increase, and efficiency layers within the supply chain, together with improved access for farming products into the market, are ensured to sustain food security. The findings show tremendous transformative potential for ICT to drive food security, and with that, significant investment in ICT infrastructure, digital literacy, open data sharing, and user-centric solutions in ICT.

All this can only be achieved by concerted efforts of policymakers, governments, and international organizations working within an enabling environment that encourages innovation, removes barriers, and ensures the fruits of ICT reach into every nook and corner. It is in this way that South Asian countries shall go a long way toward realizing the United Nations Sustainable Development Goals related to the eradication of hunger and poverty, giving their people a complete, secure, and more prosperous future.

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