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ICT Adoption and Income Dynamics: Evidence from Rural Households in Pakistan

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ABSTRACT

Aim of study: This research focuses on the effects of the adoption of the Information and Communication Technology (ICT) on the agricultural productivity and farm, non-farm and total income among the rural population in Pakistan.

Methodology: The study uses Ordinary Least Squares (OLS) and Probit regression to assess both the effects of ICT tools in the economy and the socioeconomic determinants influencing their adoption using nationally representative data of the Household Integrated Economic Survey (HIES) 20182019.

Findings: The results also indicate that mobile phone usage, internet and digital agricultural applications have a significant impact on increasing household income and diversification of income of the farms. Adopting ICT devices helps farmers to have better access to market information, enhanced resource allocation, as well as reduced transactions costs. Findings further suggest that education, gender and household size are important determinants in the levels of ICT adoption.

Conclusion: This paper concludes that inclusive rural development can be fueled by ICT through enhancing efficiency and decision-making capabilities in the market. Thus, to reinforce agricultural performance and sustainable economic growth in Pakistan, it is necessary to implement policies that will enhance digital literacy and rural broad banding and gender-sensitive ICT policies.

Keywords: ICT Adoption, Farm Income, Non-farm Income, Agricultural Productivity, Rural Households.

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1. INTRODUCTION

Agriculture has traditionally been the backbone of human civilization, where the primary products (food, fiber, plant-based medicinal, raw materials) help to sustain the growth of the economy and survival of humans (Hemathilake and Gunathilake, 2022). The agricultural sector is significant in providing food insecurity and livelihood generation to countries- especially developing. Agriculture is a major part of the GDP and employment in developing countries (Pawlak & Kolodziejczak, 2020; UNICEF, 2021). When it

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is applied to the case of rural development, agriculture is a multidimensional industry. It helps in the production of income, management of natural resources, and social sustainability. It is also affecting a wide range of stakeholders, such as farmers, value chain players, consumers, and governmental institutions. This indicates its intricate and networked nature in the context of contemporary economies (Stringer et al., 2020).

Traditional agricultural systems were once the economic backbone of the rural communities particularly in the developed countries before the industrial revolution. As technologies were evolving, agricultural production was steadily changing; it brought the age of mechanization, crop control scientifically and, most recently, digital transformation. The farming sector has been transformed by digital technologies that can now be found in industry, including mobile communication systems, remote sensing, and precision farming systems. These technologies enable the exchange of information in real-time, resource optimization and decision-making in agriculture sector (Khan et al., 2022; Zhang and Wang, 2019). These innovations have not only enhanced agricultural productivity and resilience in the villages. The modern technologies has improved communication systems and sustainable land management and also increased farming activities (Basso and Antle, 2020).

Agriculture sector is among the leading sources of the national economy in Pakistan. It contributes up to almost 19 percent to the GDP. It also employs over 40 percent of the labor (GoP, 2019). The sector has certain structural constraints. These constraints include low productivity of crops, inadequate irrigation facilities, inadequate access to modern technology, and inadequate access to timely and accurate information on climate conditions, crop diseases, and market trends (World Bank, 2020). These challenges have resulted in income disparities amongst rural population and urban population that subjects rural communities to environmental shock, volatile markets and scarcity of resources.

Information and Communication Technology (ICT) emerge as one of the change agents that can enact solutions to most of these structural deficiencies. Since it can facilitate in strengthening of information flows, enhancing farm-level decisions, and sustainable farming practices (Dong *et al.*, 2023; Aker, 2011). ICT has come to be a modernizer to the world agricultural systems. Mobile phones, internet-based services and digital advisory services enable farmers to get real time information on market prices, weather information, pest control and better types of crops (Aker and Mbiti, 2010). The tools help in reducing the transaction costs, improving market transparency and supply chain efficiency. In addition, mobile banking and e-wallet are some electronic financial solutions that have expanded rural financial coverage because they can facilitate secure transactions and enable farmers to be better positioned to save, borrow, and invest in technology that can enhance their productivity (GSMA, 2022). It has been demonstrated that ICT use enhances farm productivity, leads to innovation, and links farmers with larger economic systems (Yang, 2024; Batool *et al.*, 2025).

The potential of the ICT is immense but ICT adoption in Pakistan is still uneven and limited by numerous socioeconomic and infrastructural factors. Even though mobile phone penetration is over 90, inaccessibility and inequality in rural internet connection, digital competencies, and affordability and awareness of technology (Khan et al., 2022; PTA, 2020). The age, gender, education level, and household size are socioeconomic factors that have a substantial influence on ICT adoption trends.

On the other hand, poor connectivity to broadband, unreliable electricity and scarce ICT infrastructure also limits rural access to digital services (Sahir *et al.*, 2021). These barriers impede the capacity of farmers to maximize the use of digital tools that may help farmers to boost their agricultural output and diversify their incomes. Moreover, despite the extensive recognition of the role of ICT in agriculture, there is limited evidence that empirically measures the effect of f ICT on rural household income in Pakistan. Many such studies are based on a case study or small-scale surveys without using nationally representative data or rigorous econometric designs (Khan *et. al*, 2020). Consequently, policy makers do

not have sturdy evidence-based information to guide them towards formulating effective digital inclusion policies in rural communities as a way of dealing with structural inequalities.

This research gap will be filled in this study by analyzing the effects of ICT adoption on farm, non-farm, and total household income through national representative data on the Household Integrated Economic Survey (HIES) 2018-2019. The study offers a holistic study on the role played by ICT in the generation of rural income, enhancement of productivity and diversification of livelihoods by incorporation of demographic and economic variables in strong econometric models. The results provide useful information to policy makers, agricultural extension agencies and development practitioners to develop specific interventions to boost digital literacy, improve rural connectivity and minimize structural inhibitions particularly among the marginalized populations such as women, landless laborers and smallholder farmers. Finally, the study can be used to add to the wider discussion of the topic of digital agriculture, specifically, the potential of ICT in spurring inclusive development, alleviating poverty, and promoting sustainable rural development in Pakistan.

1.1 Problems Statement

Pakistan has an agricultural economy that is one of the main sectors of the economy which provides a significant contribution to the employment sector, GDP and foreign exchange. Nevertheless, traditional farming and low level of knowledge lower production capacity and a high number of small and medium-sized farmers do not have access to ICT products that can enhance production and earnings. There is a paucity of existing research on the effect of adoption of ICT on farm income and the socio-economic aspects of factors influencing the use of ICT. This research attempts to fill these gaps by analyzing the role of ICT in increasing agricultural productivity, raising the income of farmers, and contributing to rural development and poverty alleviation to be used in effective policies.

1.2 Significance of Study

The primary significance of this study is to analyses the relationship between the usage of different ICT tools and socioeconomic parameters such as age, gender, education, farm income, and non-farm income. It also evaluates the influence of these factors on farm revenue in Pakistan.

1.3 Research Objectives

1. To determine the Impact of the usage of ICT tools on the farm income.
2. To examine the effect of ICT tools on non-farm Income and total income.
3. To investigate the association between Pakistani farmers' adoption of ICT tools and socioeconomic characteristics (age, gender, education, crop yield, use of ICT in house and family size).

2. REVIEW OF LITERATURE

An analysis of literature available worldwide on the relationship between Information and Communication Technology (ICT) and agriculture shows that there is a certain pattern; digital tools can transform agricultural systems in terms of increasing productivity, income, and inclusion. The last twenty years have seen the shift in the research on ICT and agriculture to include less descriptive studies on access and awareness, and more quantitative studies on the economic impact and social equity. Initial empirical studies within the developing nations centered on the conventional media of communication like radio and television and the aspect of their contribution in closing the gap of information in the rural areas. Dahri *et al.* (2023) and Khan *et al.* (2022) also established that in Pakistan, radio broadcasts and TV shows were the main sources of agricultural information among rural farmers because digital penetration is low. Nevertheless, with the overwhelming growth of mobile networks and the plunging down prices of smartphones, the situation in the countryside has been transformed dramatically in terms of communication.

ICT has helped farmers to reach real-time market information, weather and agronomic guidance. The recent studies highlight the direct impact of mobile-based interventions on productivity and income. The article by Khan *et al*. (2022), who studied farmers in Khyber Pakhtunkhwa, showed that using mobile and internet enhanced the efficiency of marketing significantly and boosted the revenues. Similar results were reported by Ahmed *et al*. (2021), who used mobile applications to deliver daily price and weather data, which increased the profitability of farms by 18 per cent at Sindh. These results can be supported by comparable evidence in other developing countries: Andika *et al.,* (2025) in Kenya and Kolapo *et al*. (2024) in Nigeria have found that digital platforms have a positive effect on access to inputs, credit, and market connections, which results in better yields and resilience.

In addition to productivity, ICT is a connector to financial inclusion and livelihood diversification. Through mobile banking, e-wallets and digital remittance, farmers can perform safe transactions, save and invest in input. Oyelami *et al.,* (2022) highlights that ICT provides smallholders with the potential to enter value chains, diversify their sources of income. It becomes less reliant on the traditional middlemen. Similar effects have been reported in Pakistan by Dong *et al.,* (2023). It is discovered that farmers who embraced mobile payment systems enjoyed better financial security and were likely to re-invest their earnings into mechanization and better inputs.

2.1. Theoretical perspective on ICT adoption

To comprehend the drivers of ICT adoption, the analytical lens should be able to capture behavioral, social and contextual aspects. There are two strong frameworks which have good explanations including Technology Acceptance Model (TAM) and Diffusion of Innovations (DOI) theory. TAM (Davis, 1989) describes two perceptions which influence adoption behavior: the perceived usefulness and the perceived ease of use. In an agricultural setting, these can be understood to mean that farmers believe that ICT can enhance their decision-making process, productivity, or profits and the tools are not extremely complicated. A test conducted by Shahzad *et al.,* (2024) on farmers in Punjab showed that the level of confidence in mobile advisory services through mobiles had a significant effect on their intentions to adopt these services.

The Diffusion of Innovations (DOI) theory of Rogers (2003) serves as a complement to TAM because it focuses on five characteristics of innovation diffusion as relative advantage, compatibility, complexity, trialability and observability. According to research, including that of Khan *et al.* (2022), rural farmers are encouraged to diffuse through social influence, community demonstrations, and visible reward among early adopters. All these theories imply that adoption will not only be dependent on the economic aspect but also on the trust, awareness and peer learning mechanisms in the farming communities.

2.2. Gender inclusion and ICT adoption

Gender has turned out to be an essential dimension in ICT oriented research in agriculture. The level of women involvement in the agricultural sector is also very high in Pakistan, however, access to information and technology is still limited due to cultural and structural barriers. Researchers emphasize that the household is frequently controlled by male members, who limit female access to access the information about agriculture directly (Khan *et al.*, 2022; Aslam *et al.*, 2024). Regardless of such limitations, women are increasingly adopting ICT, particularly in those areas where there are special digital literacy initiatives. The researchers found that the adoption of ICT can enable women to have more power in the market through the increase in their market knowledge and household decision capacity (Oyelami *et al.*, 2022).

On the same note, Shahbaz *et al.* (2022) found that mobile phone possession of female-headed families in Punjab was linked to better record keeping of farm and lower reliance on male family members of market information. However, the gender gaps in education and income remain, and they prevent equal access to digital agriculture. To fill this gap, gender-sensitive ICT policies, localization of content in local regional languages and outreach programs are needed so that women farmers can have safe and inclusive access.

2.3. Emergence of precision and smart agriculture

A literature that is developing revolves around precision agriculture, which is the next phase of ICT-based farming, which entails the application of drones, satellite images, sensors, and farm management software. Whereas these technologies are becoming popular in developed economies, in developing nations, they are still in the infancy of spreading. According to Basso and Antle (2020), precision agriculture has the capability of enhancing input use and environmental sustainability, yet barriers to its usage are high cost, technical expertise needed, and a lack of awareness to spread it widely. Precision tools are being used in the commercial farming sector, especially in cotton and sugarcane industries in Punjab, Pakistan, on a slow scale. Mobile-based crop monitoring systems and weather-advisory SMS services have been piloted by the Punjab Information Technology Board (PITB) and PARC (Pakistan Agricultural Research Council). Ubaid *et al*., (2023) recorded that farmers who used the assistance of drone monitoring in pest monitoring enjoyed a higher yield and minimized the input wastage. These advantages are, however, at the present limited to large-scale farmers. Access to precision technologies by smallholders will have to be subsidized, in the form of public-private collaboration, and capacity-building efforts to scale up precision technologies.

2.4. Regional Context: ICT Adoption across Pakistan's Provinces

The provincial disparity is a major factor in the ICT adoption rates in Pakistan. Punjab, being the most agricultural advanced province, exhibits the most rates of digital adoption because of the presence of better infrastructure and extension services. The connectivity in Sindh is poor, yet the high use of mobile-based market information systems can be observed because of the NGO programs (Chhachhar *et al*., 2014). Khyber Pakhtunkhwa (KP) is growing fast in the ICT adoption after rural telecommunication penetration, and ICT-focused entrepreneurship activities provide off-farm jobs (Khan et al., 2022). On the other hand, Balochistan is under-serviced by a large margin because of a lack of connectivity and the low density of population. The collective focus of regional studies has been that even though ICT infrastructure is a pre-requisite of adoption, social capital, education and institutional backing are the determinants of actual adoption. The digital inclusion policies should therefore consider the local realities, especially literacy differences, gender norms as well as infrastructural differences to ensure that they do not widen the inequality across rural areas.

2.5. Synthesis and Research Gap

The literature review confirms that ICT has the potential to improve agricultural productivity and household income significantly and enhance information flow, financial access, and decision support. The results of adoption, however, vary greatly based on the attributes of the users and the occasion surrounding the adoption. It is also revealed in the literature that despite the ubiquitous nature of mobile phones, the internet-based technologies are still not used well in rural Pakistan. Moreover, the available studies are based on small regional samples, or descriptive designs and few studies use nationally representative statistics. This paper is valuable to the current body of research by offering an econometric evaluation of the ICT adoption and its income impact based on the HIES 2018-2019 dataset, a nationally representative dataset. It combines the knowledge of TAM and DOI theories into an empirical model, and it is possible to analyze economic and behavioral factors that lead to the utilization of ICT in detail. This study can enhance the holistic knowledge of the contribution of ICT to inclusive and sustainable agricultural transformation in Pakistan through the examination of gender, geographical inequalities, and contemporary precision farming settings.

3. CONCEPTUAL FRAMEWORK

Figure 1: *Impact of ICT usage on Income*

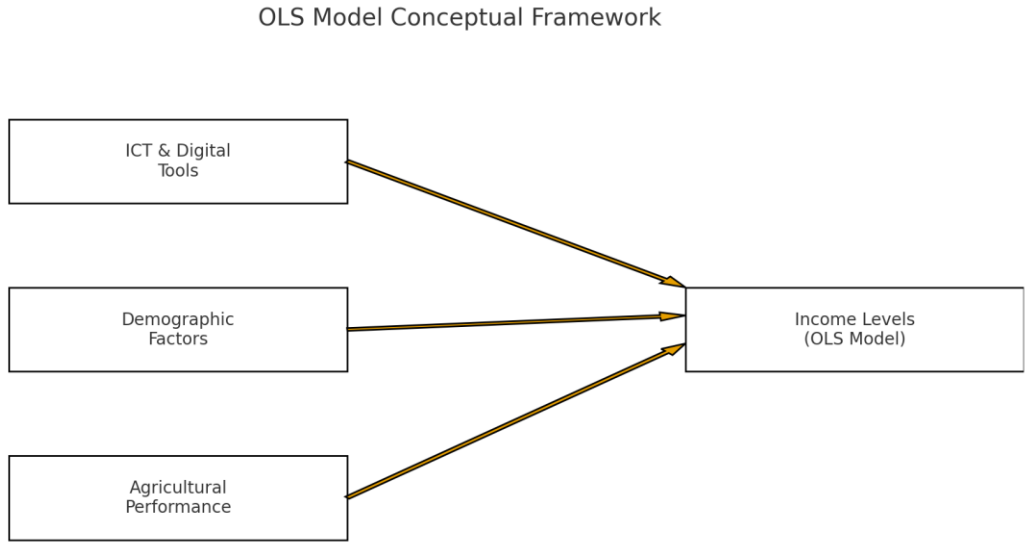
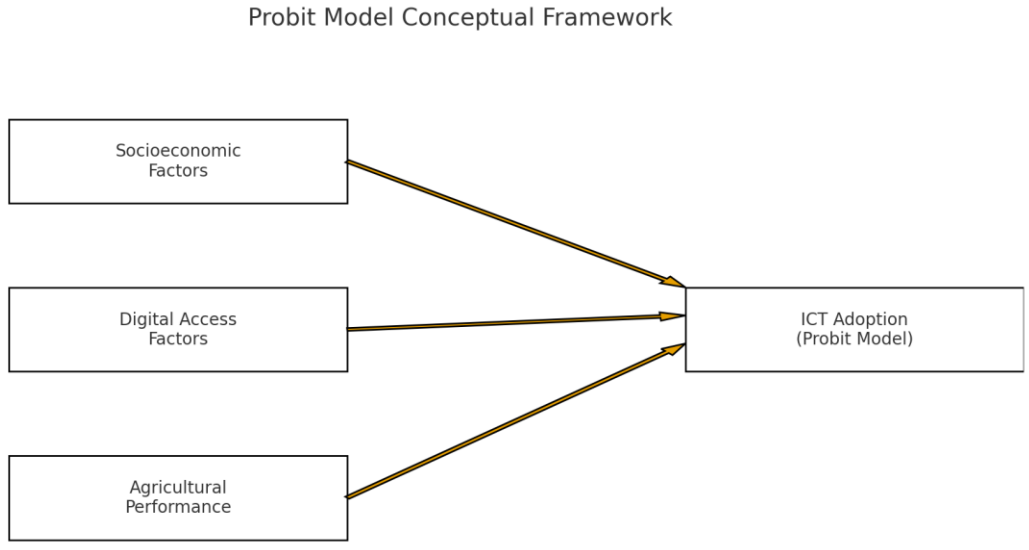


Figure 2: *Determinant of ICT usage in household*



4. MATERIAL AND METHODS

4.1. Data Source

The current paper utilizes secondary data of the Household Integrated Economic Survey (HIES) 2018-2019, which was carried out by the Pakistan Bureau of Statistics (PBS). The HIES is the component of the Pakistan Social and Living Standards Measurement (PSLM) framework and offers countrywide data on income, expenditure, demographics and farm activities in the country. The data includes rural and urban regions in all provinces, which will provide an opportunity to examine the regional variations in terms of ICT adoption and performance in the agriculture sector.

The data of HIES 2018-2019 is especially the most appropriate to utilize in this research due to additional information on the sources of household income, agricultural production, education, and gender and ICT equipment (mobile phones, computers and internet access). The attributes will allow a detailed analysis of the impact of the adoption of ICT on farm and non-farm income considering socioeconomic and demographic factors.

4.2. Variables and Measurement

4.2.1 Dependent Variables

1. Farm Income (lnFI): The natural logarithm of the agricultural income received in the agricultural activities, in livestock and crop production.
2. Non-Farm income (LNFI): Natural logarithm of the income derived by non-agricultural sources other than the wages of labor, services, or small businesses (non-agricultural income).
3. Total Income (lnTI): The sum of farm and non-farm income is also in logarithmic form.
4. ICT Adoption (ICT): Is a binary (1 = household uses at least one ICT tool such as mobile phone, computer, or internet; 0 = otherwise)

4.2.2 Independent Variables

1. Age: Age of head of the household (in years).
2. Gender: 1 = Male, 0 = Female.
3. Education: Years of formal schooling of the head of the household.
4. Household Size: This is the total number of members in a household.
5. Crop Yield: The total yield (kg) of agricultural activities.
6. Internet Use: 1 = Internet at least one of the household members; 0 = otherwise.
7. Region: Dummy variables of provinces (Punjab, Sindh, KP, Balochistan) to reflect the heterogeneity in the regions. All financial values were put in the natural form of logarithms to minimize the skew and equalize the scale. The most important variables ICT use and access to the internet are the technological involvement at the domestic level.

4.3. Econometric Model Specification

The analysis proceeds in two stages. First, the effect of ICT adoption on income (farm, non-farm, and total) is examined using an Ordinary Least Squares (OLS) model:

$$\ln(Income)_i = \beta_0 + \beta_1 ICT_i + \beta_2 internet_i + \beta_3 Age_i + \beta_4 Gender_i + \beta_5 Education_i + \beta_6 Household\ size_i + \beta_7 crop\ yield_i + \beta_8 Region_i + \epsilon_i \quad (1)$$

Where

$\ln(\text{Income})_i$ is the natural logarithm of farm, non-farm, or total income of the *i-th* household,

ICT_i and Internet_i represent ICT adoption and internet use respectively, and

ϵ_i denotes the random error term.

The model assumes a linear relationship between ICT adoption and income while controlling socioeconomic and demographic characteristics. OLS is used for estimating the income models due to its efficiency and interpretability when the dependent variable is continuous and log transformed. To ensure robustness, heteroskedasticity-consistent (robust) standard errors are applied.

Probit Model for ICT Adoption

To identify the determinants of ICT adoption, a Probit model is used, suitable for binary dependent variables:

$$P(\text{ICT}_i = 1) = \Phi(\alpha_0 + \alpha_1 \text{Age}_i + \alpha_2 \text{Gender}_i + \alpha_3 \text{Education}_i + \alpha_4 \text{Income}_i + \alpha_5 \text{Household Size}_i + \alpha_6 \text{Region}_i + u_i) \quad (2)$$

Where Φ represents the cumulative normal distribution.

The coefficients indicate the marginal effects of demographic and economic variables on the probability of adopting ICT. The Probit model is preferred over the Linear Probability Model (LPM) because it bounds predicted probabilities between 0 and 1 and accounts for nonlinear relationships. Both models together provide complementary insights: the OLS reveals the magnitude of ICT's income effects, while the Probit identifies who adopts ICT and why.

5. RESULTS AND DISCUSSION

This section shows and discusses empirical results of Ordinary Least Squares (OLS) and Probit regressions. Discussion of results is presented concerning available literature and theoretical models of Technology Acceptance (TAM) and Diffusion of Innovations (DOI).

5.1. Descriptive Statistics

Table 1: *Descriptive Statistics*

Variable	Mean	SD	Min	Max
Age of household head (years)	49.0	13.9	16	99
Gender (1 = Male)	1.06	0.23	1	2
Education (years)	2.46	4.49	0	28
Household size (persons)	7.26	3.54	1	55
Crop yield (kg)	1199.3	1591.2	4	9840
Total income (log)	12.75	0.65	10.60	16.07
Farm income (log)	12.04	1.07	8.01	15.61
Non-farm income (log)	0.71	0.42	2.03	5.35
ICT adoption (1 = Yes)	0.94	0.23	0	1
Internet use (1 = Yes)	0.25	0.43	0	1
No. of observation = 4692 rural households				

Descriptive statistics show a high level of mobile-phone use (94%), and a low level of internet use (25%), showing that there is still a digital divide between the presence of access and use. The lack of high human-capital potential to use ICT at an advanced level is indicated by the low average education level (≈ 2.5 years).

5.2. OLS Regression results: ICT adoption and income

Regression analysis with OLS technique addresses the determinants total income, farm income and non-farm income. Results on this point are valuable for understanding sources of rural income and their determinants, including not only individual characteristics but also broader structural variables.

Table 2: *Regression analysis for impact of ICT tools on income of farmers*

Variables	Total Income (lnTI)	Farm Income (lnFI)	Non-Farm Income (lnNFI)
ICT Usage	0.266 ***	0.145 ***	0.122 **
Internet Use	0.465 ***	0.142 ***	0.323 ***
Age	0.006 ***	−0.000	0.006 ***
Gender (1 = Male)	−0.220 ***	0.320 ***	−0.540 ***
Education (years)	−0.001	0.004	−0.005 *
Household Size	0.065 ***	0.015 ***	0.049 ***
Crop Yield	0.042 ***	0.527 ***	0.485 ***
Constant	11.31 ***	8.45 ***	2.86 ***
R^2	0.335	0.489	0.453

According to the regression findings in Table 2, the use of ICT will help improve household income in all categories significantly. The ICT use coefficient (0.266) supports the claim that ICT enhances market information and transaction costs as well as bargaining power of farmers by about 26.6 percent, as ICT adoption in households implies higher total income (Aker and Mbiti, 2010; Leng *et al.*, 2020). Similarly, the influence of Internet use is even more significant (0.465), which means that total income will increase by 46.5 percent. This correlates with Ahmad *et al.* (2024) and Kang *et al.*, (2023) who discovered that the presence of internet increases technical efficiency and productivity due to the timely access to markets, extension services, and weather information. There is also a gender disparity due to the results of which the male-headed households earn more non-farm income whereas the female-headed households reflect a comparatively better farm-income performance. The same trends are mentioned by Rahman and Huq (2023), who mention that women are more than homestead farming and livestock are operated, which could be enhanced with ICT tools.

Nevertheless, there are still structural constraints that limit the digital engagement of women due to accessibility of the devices (Acilar and Sæbø, 2023). Regarding the control variables, age has a small yet positive impact on total and non-farm income and may indicate more people live by diversifying their livelihoods with experience (Ayim *et al*., 2022). The impact of education is still weak, which means that digital literacy instead of formal education is a more decisive factor in the gains linked to ICT (Dayanand, 2024). There are positive impacts of household size on income, and it is perhaps because of increased labor supply to various activities. The impact of crop yield on farm income is the most significant, which is in line with the fact that productivity is a fundamental determinant of rural welfare in the literature (Acilar and Sæbø, 2023). In general, the results indicate that ICT and access to internet are the sources of income growth, which improves agricultural and non-farm livelihoods. Developing digital infrastructure and the digital literacy of women and low-literacy farmers are also critical to ensuring high benefits of ICT.

5.3. Probit Model Results: Determinants of ICT Adoption

Table 3: *Determinants of ICT tools (Marginal effects)*

Variables	Internet Use (1 = Yes)	ICT Adoption (1 = Yes)
Age	0.004 **	−0.001
Gender (Female = 1)	0.180 **	0.225 *
Education (years)	−0.012 **	−0.004
Income (log)	0.063 ***	0.026 ***

Household Size	0.003	0.041 ***
Region controls	Yes	Yes

ICT and internet adoption is positively correlated with age and income, which is also in accordance with the Diffusion of Innovation (DOI) theory, as proposed by Rogers (2003), especially the relative advantage concept, according to which people adopt technologies when they see them as having an economic payoff. The growing adoption of mobile technologies by female-headed families by families is an indicator of new trends in digital inclusion, which is aligned with the results of Rahman and Huq (2023), yet structural obstacles to digital inclusion among women still exist (Alam et al., 2023).

The small impact of education on adopting evidence is the preceding evidence that formal education has a minor impact, and that specific digital training has a stronger effect on encouraging the ICT usage among rural population (Dayanand *et al.*, 2024). Regional disparities, namely increased adoption in Punjab and Khyber Pakhtunkhwa, reflect the recorded disparities in digital infrastructures and literacy in Pakistan (Qureshi, 2020). The findings also indicate that ICT use increases farm and non-farm income through market access, information flow strength as well as livelihood diversification, which is in line with findings in other agricultural settings (Aker and Mbiti, 2010; Leng *et al.*, 2020). The findings support the Technology Acceptance Model (TAM) and DOI theory that have placed underground perceived usefulness and social diffusion as the primary determinants of technology adoption (Davis, 1989; Venkatesh et al., 2003). The noticed gender and regional heterogeneity lend credence to the necessity of the context-related policy responses to the increased diffusion of digital agriculture and to the provision of ICT benefits equally throughout Pakistan.

6. CONCLUSION AND POLICY IMPLICATIONS

This research is robust empirical evidence that the Information and Communication Technology (ICT) adoption is a gamechanger in improving the economic status of rural households in Pakistan. The findings obtained by examining nationally representative data on HIEs, 2018-2019, indicate that the ICT use, in general, and internet access, in particular, contribute largely to farm, non-farm, and total household income. The improvement in access to markets, the minimization of information gaps, communications and the diversification of livelihood strategies make these gains of income a result of ICT. These results emphasize the strategic role of digital tools in empowering rural productivity and resilience. The research also shows that provision of ICT is not similar among all the population, but it is demographic and regional in nature. Although age, gender, household size, and income all influence digital activity, additional, more specific awareness and skills-building initiatives are necessary since education alone is insufficient to guarantee ICT use.

Positively, the involvement of female headed households is an indicator that technology is a source of empowerment of women, if the issue of access, affordability and cultural obstacles are dealt with appropriately. The regional differences (Punjab and Khyber Pakhtunkhaw excelling over Sindh and Baluchistan) also highlight the necessity of region-specific measures to enable the elimination of digital gaps and enhance connectivity. In general, the research confirms that ICT can play a formidable role as catalyst to rural development, modernization of agriculture and eradication of poverty in Pakistan. To achieve these advantages in their fullest potential, policymakers need to ensure that they focus on the development of robust and affordable digital infrastructure, contribute to localized and inclusive digital literacy, and pursue gender-sensitive policy-making that ensures fair access to ICT assets.

The inculcation of digital tools in the agricultural extension services, market information systems and rural development programs will be critical towards promoting inclusive economic growth. With Pakistan on the road to a more digitally connected future, ICT must be placed at the heart of rural transformation strategies and allow households to join economic activity more actively and enhance their general livelihoods. The results of the study have indicated the transformational nature of ICT in enhancing the livelihood of rural people, and thus, the importance of policy specific initiatives to ensure that these gains are maximized. Digital access can be greatly increased in rural communities by strengthening broadband

and mobile connectivity because of public-private partnerships. Digital literacy, particularly among the women and the youth, should be an important promotion activity to ensure meaningful inclusion in the digital economy.

ICT application in agricultural extension services using mobile applications and SMS notification can give farmers real time information about weather, market and pest control. Providing micro-credit and subsidies on smart phones and internet connectivity will also aid small-holder farmers. Also, localization of digital content in local languages, with easy-to-use interfaces, can be used to make ICT tools more accessible to low-literacy populations. Policies that promote women participation in digital programs are essential to ensure a fair development process, and innovation can be promoted by using the resources of the private sector to invest in precision agriculture and mobile-based agri-services to develop the technology on a long-term basis in rural regions.

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REFERENCES

Acilar A, Sæbø Ø (2023), "Towards understanding the gender digital divide: a systematic literature review". *Global Knowledge, Memory and Communication*, *72*(3), 233–249. https://doi.org/10.1108/GKMC-09-2021-0147

Ahmad B, Zhao Z, Jile X, Gultaj H, Khan N and Yunxian Y (2024) Exploring the influence of internet technology adoption on the technical efficiency of food production: insight from wheat farmers. *Front. Sustain. Food Syst. 8*, 1385935. https://doi.org/10.3389/fsufs.2024.1385935

Aker, J.C. (2011), Dial "A" for agriculture: a review of information and communication technologies for agricultural extension in developing countries. *Agricultural Economics, 42*, 631-647. https://doi.org/10.1111/j.1574-0862.2011.00545.x

Aker, Jenny C., and Isaac M. Mbiti. 2010. "Mobile Phones and Economic Development in Africa." *Journal of Economic Perspectives, 24*(3), 207–32**.** https://doi.org/10.1257/jep.24.3.207

Alam, G. M. M., Khatun, N. N., Sarker, M. N. I., Joshi, N. P., & Bhandari, H. (2023). Promoting agri-food systems resilience through information and communication technology (ICT) in developing countries amid COVID-19. *Frontiers in Sustainable Food Systems, 6,* Article 972667. https://doi.org/10.3389/fsufs.2022.972667

Aldosari, F., Al Shunaifi, M., Ullah, M. A., & Khan, M. A. (2019). Farmers' perceptions regarding the use of information and communication technology in agriculture. *Journal of the Saudi Society of Agricultural Sciences, 18*(2), 211–217. https://doi.org/10.1016/j.jssas.2017.05.004

Andika, Gilbert Weboko, and Godfry K. Makau. "Technology Performance and Adoption of Miwa Bora Mobile Application Among Small-Scale Sugarcane Farmers in Kakamega County, Kenya." *International Journal of Social Sciences Management and Entrepreneurship (IJSSME)* 9.1 (2025).

Aslam, M., et al. (2024). Dynamics of ICT adoption in Pakistan's agriculture: Implications for rural development. *Cuadernos de Desarrollo Rural*, 21. https://doi.org/10.11144/Javeriana.cdr21.dict

Ayim, C., Kassahun, A., Addison, C., Tekinerdogan, B. (2022). Adoption of ICT innovations in the agriculture sector in Africa: a review of the literature. *Agric & Food Secur, 11*, 22. https://doi.org/10.1186/s40066-022-00364-7

Basso, B., & Antle, J. (2020). Digital agriculture to design sustainable agricultural systems. *Nature Sustainability, 3*(4), 254–256. https://doi.org/10.1038/s41893-020-0510-0

Batool, M., et al. (2025). Digital exclusion in agricultural communication: Exploring socioeconomic and infrastructural barriers to ICT use in rural Pakistan. *Social Sciences & Humanities Open, 12,* 102264. https://doi.org/10.1016/j.ssaho.2025.102264

Chhachhar, A. R., Qureshi, B., Khushk, G. M., & Ahmed, S. (2014). *Impact of information and communication technologies in agriculture development*. *Journal of Basic and Applied Scientific Research, 4*(1), 281–288.

Dahri, G. N., Wang, J., Khanzadab, B., Soomro, A. S., Hingorjo, W. B., Mari, M. A., & Tabassum, S. (2023). Impact of training approaches to reduce knowledge and skills gap in cotton crop: a case study Taluka Sinjhoro District Sanghar, Sindh. *Journal of Applied Research in Plant Sciences*, *4*(1), 502-511. https://doi.org/10.38211/joarps.2023.04.01.60

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13(3*), 319–340. https://doi.org/10.2307/249008

Dayanand, R., Khan, Z., Kalwar, M., & Kumar, A. (2024). Digital literacy for rural women's empowerment and socioeconomic participation: A comprehensive study. *Available at SSRN 5093591*. http://dx.doi.org/10.2139/ssrn.5093591

Dong, Y., Ahmad, S. F., Irshad, M., et al. (2023). The digitalization paradigm: Impacts on agri-food supply chain profitability and sustainability. *Sustainability, 15*(21), 15627. https://doi.org/10.3390/su152115627

Go, P. (2019). Economic survey of Pakistan. *Islamabad: Economic Advisor's Wing Ministry of Finance*, *20*.

GSMA. (2022). *The mobile economy: Asia Pacific 2022*. GSMA Intelligence.

Hemathilake, D. M. K. S., & Gunathilake, D. M. C. C. (2022). Agricultural productivity and food supply to meet increased demands. In *Future foods: Global trends, opportunities, and sustainability challenges* (pp. 539–553). Academic Press. https://doi.org/10.1016/B978-0-323-91001-9.00016-5

Kang, S., Ait Sidhoum, A., Frick, F., Sauer, J., & Zheng, S. (2023). The impact of information and communication technology on the technical efficiency of smallholder vegetable farms in Shandong of China. *Q Open*, *3*(1), qoad017.https://doi.org/10.1093/qopen/qoad017

Khan, H. N., Zhang, D., & Rasheed, M. I. (2020). The role of ICT in agricultural productivity and rural development: Evidence from developing countries. *Journal of Cleaner Production*, *260*, 121–130. https://doi.org/10.1016/j.jclepro.2020.121030

Khan, N. A., Gao, Q., Ali, S., Shahbaz, B., Khan, P., & Abid, M. (2022). Analyzing ICT-enabled agricultural advisory services in Pakistan: evidence from a marginalized region of Punjab province: NA Khan et al. *Electronic Commerce Research*, *22*(4), 1107-1129. https://doi.org/10.1007/s10660-020-09442-z

Khan, N. A., Shah, A. A., Tariq, M. A. U. R., Chowdhury, A., & Khanal, U. (2022). Impact of farmers' climate risk perception and socio-economic attributes on their choice of ICT-based agricultural information services: Evidence from Pakistan. *Sustainability, 14*(16), 10196. https://doi.org/10.3390/su141610196

Khan, N., Ray, R. L., Kassem, H. S., Khan, F. U., Ihtisham, M., & Zhang, S. (2022). Does the adoption of mobile internet technology promote wheat productivity? Evidence from rural farmers. *Sustainability*, *14*(13), 7614. https://doi.org/10.3390/su14137614

Khan, N., Ray, R. L., Zhang, S., Osabuohien, E., & Ihtisham, M. (2022). Influence of mobile phone and internet technology on income of rural farmers: Evidence from Khyber Pakhtunkhwa Province, Pakistan. *Technology in Society*, *68*, 101866. https://doi.org/10.1016/j.techsoc.2022.101866

Kolapo, A., & Didunyemi, A. J. (2024). Effects of exposure on adoption of agricultural smartphone apps among smallholder farmers in Southwest Nigeria: Implications on farm-level efficiency. *Agriculture & Food Security*, *13*, 31. https://doi.org/10.1186/s40066-024-00485-1

Leng, C., Ma, W., Tang, J., & Zhu, Z. (2020). ICT adoption and income diversification among rural households in China. *Applied Economics, 52*(33), 3614–3628. https://doi.org/10.1080/00036846.2020.1715338

Oyelami, L. O., Sofoluwe, N. A., & Ajeigbe, O. M. (2022). *ICT and agricultural sector performance: Empirical evidence from Sub-Saharan Africa. Future Business Journal, 8*(1), 18. https://doi.org/10.1186/s43093-022-00130-y

Pawlak, K., & Kołodziejczak, M. (2020). The role of agriculture in ensuring food security in developing countries: Considerations in the context of the problem of sustainable food production. *Sustainability*, *12*(13), 5488. https://doi.org/10.3390/su12135488

PTA. (2020). *Annual Report 2020.* Pakistan Telecommunication Authority.

Qureshi, S. (2020). Digital ecosystems for rural development in Pakistan. *Information Technology for Development, 26*(4), 757–776. https://doi.org/10.1080/02681102.2020.1840324

Rahman, M. M., & Huq, H. (2023). *Implications of ICT for the livelihoods of women farmers: A study in the Teesta River Basin, Bangladesh*. *Sustainability, 15*(19), 14432. https://doi.org/10.3390/su151914432

Rogers, E. M. (2003). *Diffusion of innovations (5th ed.).* Free Press.

Shahbaz, P., Haq, S. ul, Abbas, A., Batool, Z., Alotaibi, B. A., & Nayak, R. K. (2022). Adoption of climate-smart agricultural practices through women involvement in decision making: Role of empowerment and innovativeness. *Agriculture*, *12*(8), 1161. https://doi.org/10.3390/agriculture12081161

Shahzad, A. R., Fatima, N., & Saleem, M. (2024). Mobile phones in agriculture: Understanding the role of perceived awareness in shaping farmers' adoption decisions in Punjab, Pakistan. *Pakistan Social Sciences Review, 8*(3). https://doi.org/10.35484/pssr.2024(8-III)59

Shair, W., Tayyab, M., Nawaz, S., & Amjad, K. (2023). *Digital divide in Pakistan: Barriers to ICT adoption. Bulletin of Business and Economics, 12*(2), 243–252. https://doi.org/10.5281/zenodo.8375238

Spielman, D. J., Lecoutere, E., & Van Campenhout, B. (2021). ICT and agricultural extension in developing countries. *Annual Review of Resource Economics, 13,* 177–201. https://doi.org/10.1146/annurev-resource-101520-080657

Stringer, L. C., Fraser, E. D. G., Harris, D., Lyon, C., Pereira, L., Ward, C. F. M., & Simelton, E. (2020). *Adaptation and development pathways for different types of farmers. Environmental Science & Policy, 104*, 174–189. https://doi.org/10.1016/j.envsci.2019.10.007

Ubaid ur Rehman, U., Iqbal, T., Hussain, S., Cheema, M. J. M., Iqbal, F., & Basit, A. (2023). Drone and robotics roadmap for agriculture crops in Pakistan: A review. *Environmental Sciences Proceedings, 23*(1), 39. https://doi.org/10.3390/environsciproc2022023039

UNICEF. (2021). *The state of food security and nutrition in the world 2021*. FAO

Venkatesh, V., Morris, M. G., Davis, G. B., & Davis, F. D. (2003). User acceptance of information technology: Toward a unified view1. *MIS quarterly*, *27*(3), 425-478. https://doi.org/10.2307/30036540

World Bank. (2020). Pakistan: Country agriculture sector assessment. Available at https://www.adb.org/sites/default/files/linked-documents/46528-002-ssa.pdf

World Bank. (2021). World development report 2021: Data for better lives. Available at https://www.worldbank.org/en/publication/wdr2021

Yang, C., Ji, X., Cheng, C., Liao, S., Obuobi, B., & Zhang, Y. (2024). Digital economy empowers sustainable agriculture: Implications for farmers' adoption of ecological agricultural technologies. *Ecological Indicators*, *159*, 111723. https://doi.org/10.1016/j.ecolind.2024.111723