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Influence of mobile phone and internet technology on income of rural farmers: Evidence from Khyber Pakhtunkhwa Province, Pakistan

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ABSTRACT

Mobile phone and Internet technology usage (MPITU) in organizational systems are rapidly escalating. MPITU has advanced agricultural structures and has considerably revolutionized agricultural activities to enhance smart agriculture. The main objective of this research was to effectively evaluate the impact of MPITU on the selection of sales productivity and marketing channels and examine if MPITU helps increase the incomes of growers. It is crucial to understand whether MPITU can ultimately increase the incomes of rural farmers. This study used data set of 580 wheat growers from four districts in the Khyber Pakhtunkhwa Province (KPK) of Pakistan. We used propensity score matching (PSM), ordinary least squares (OLS), and Heckman's two-step regression (HTSR) techniques to achieve the research goals. The larger the MPITU, the more substantial and positive the impact on agricultural income. After applying the PSM and Heckman regression methods, it was found that MPITU significantly improved the efficiency of selecting sales channels. Its impact on agricultural profits was also leading (about 41%), with support and non-agricultural profits exceeding 31%. Finally, the results showed a significant impact of the choice of favorable auction and marketing channels on the rural farmer's income. It is recommended that government and non-governmental organizations improve the rural and agricultural development policies. In addition, the authorities should expand MPITU training services for farmers, including wheat growers, which may help improve growers' ability to increase agricultural productivity and household income.

1. Introduction

Agricultural society whose economy depended on agricultural products continued to rely on traditional farming for an extended period until the industrial revolution, even in the developed countries. On the other hand, conventional farming is still common in rural areas of many developing countries. Traditional methods, lacking technology, eventually decrease agriculture production [1]. Technology has completely changed society, including agricultural society [2]. Modern technology and advanced agricultural tools have enhanced communications and improved rural economies with modern agricultural methods. For example, the study showed that modern technologies positively impacted farmers and the overall national economy of an agricultural country like India [2]. Information and communication technologies (ICT), including mobile phones and the internet, are already revolutionizing the agricultural sectors of developed countries. Mobile phones and internet technology have significantly affected practically all sectors of the economy, including agriculture [3,4].

Compared to the past agricultural practices, farmers of developed countries have better access to information, including available services, farming techniques, processing options, prices, and markets [5]. In addition, using advanced technologies, farmers of developed countries are moving forward in adopting precision agriculture and climate-smart farming to minimize the impact of climate change on agriculture. However, rural farmers of developing countries still use the traditional approaches to get needed information from their experiences, word of mouth, and local leaders [6].

Traditional methods and lack of technologies impact agriculture significantly [1]. Since agriculture has a significant impact on the economies of developing countries, effective technology transfer can

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improve the incomes of rural farmers [1,7–11]. In addition, in developing countries, where agricultural production is exposed to adverse impacts of climate change [12], technology could help extensively increase agricultural production under changing climates [13]. A revolution in ICT is required in rural areas of these developing countries, as these areas still have limited access to ICT. This includes internet and mobile phones, as compared to rural areas of developed countries [14].

Several researchers found that the ICT, which includes mobile phones, the internet, and other technologies, has a significant impact on increasing agricultural production, conserving the environment, and improving the rural economy that affects developing countries' national economies [15–18]. For example, Siaw et al. [15] investigated the effects of internet use on farm income and household income using data from 478 rural farmers in Ghana. They found an increase in household income by 15.47%.

Bizikova et al. [19] listed several benefits of using mobile phones and/or the internet, which benefit farmers and growers to increase their incomes. Mobile phone and internet technology usage (MPITU) helps them to get information or service of commodity prices, market information, sales, and electronic financial tools, which ultimately provides direct access to prices in regional markets for informed decision making, direct money transfers, and developing borrower profiles, based on yield and sales data from app-based systems.

The MPITU is an essential tool, particularly in trade and commerce, because it rapidly facilitates the collection, storage, and dissemination of information [20–22]. At present, with the rapid development of worldwide and fierce contest, the financial influence of Internet technology in remote areas is growing [23,24]. This is because Internet technology provides several different forms of innovation for rural society, especially in production and distribution [25–27]. Concurrently, it gives advanced marketplace distribution networks, fostering industrial results, increasing growers' income, and promoting rural economic development [28–31].

In developing countries, the application and promotion of internet technology through computers and smartphones have greatly reduced the cost of information search for growers and conquered information obstacles [32,33]. Interestingly, this may be crucial in the context of the government's launch of supply-side structural reforms and rural revitalization policies [34–37]. Consequently, the widespread of MPITU significantly influences the contravention of growers' information dilemma, reshaping remote social and economic conditions and advancing market access facilities [38,39]. Therefore, MPITU helps promote advanced agriculture and rural development, enabling growers to participate in the overall distribution of economic resources and further discuss the market reforms.

Although the promotion of MPITU in the agricultural sector is an important indicator of agricultural development [40,41], the rapid progress of MPITU in agricultural production may potentially upgrade traditional farming, particularly in developing countries [42,43]. The outlook of an effective agricultural plan is essential to safeguard smooth changes in information and competitiveness of business farms [44]. If sufficient information is lagging and there is no effort to improve it, farmers will be disappointed. In this case, communication becomes cohesive for farmland management [45–48].

In practice, MPITU interaction in choosing sales and marketing would be vital because the price of agriculture products is dynamic, relying not only on product quality but also on various external factors such as storage services, knowledge, time, and environmental conditions. This is even more obvious as every grower needs to boost incomes [21,50]. Though the MPITU conversion charge is simpler to contemplate, it is also difficult to appraise or assess possibilities to increase profits. Researchers usually consider if MPITU would help promote upgrading the agricultural industry [51–53] and ultimately promote income growth.

Many developing countries, such as China, are at a critical stage of the rapid transformation of socioeconomic expansion and technical progress [54,55]. The transformation includes the paramount significance of market dynamics and the appropriate use of appreciated assets advocated by the government [56–58]. Technological innovation driven by advanced technology is an essential requirement for promoting rural economy and society [59,60].

In addition, from the perception of increasing growers' incomes, various researchers assumed that achievement of information could change the distribution of production factors and construction structure, enhance the agricultural yield, reduce needless transitional associations, and endorse a significant upsurge in growers' financial benefits [61,62]. Muto and Yamno [63] presented that the MPITU could help growers enter and improve the market, promote resource efficiency and remote trading markets, especially the price convergence of agricultural products among developing countries. Zhang et al. [64] investigated the possible methods of farming advancement to boost growers' revenue, counting the improvement of farming production, employment transformation structure, and distribution and agricultural assets utilization.

It is generally believed that strengthening the dissemination of knowledge will positively influence agribusiness development and interpersonal communication. In addition, obtaining real-time benefits is problematic and costly, particularly in dynamic industries such as agro-industry, where the leading players usually live in remote parts [21,65,66]. The continuous usage and advancement of web technology in remote areas have created space for additional hypothetical study in those areas. Most extant studies focused on whether growers have the latest technology, such as mobile phone and internet technology but rarely investigated the influence of growers' MPITU to varying degrees on transaction channels and sales income. However, research mainly focused on food and agriculture development. There is limited research that could focus on the impact of MPITU on the incomes of rural farmers.

While several researchers have investigated the impact of mobile phones and/or internet technology on agricultural production and rural income using mixed data for several crops in rural areas of developing countries [67], limited studies focused on particular crops or fruits. For example, Mariyono et al. [68] studied the impact of mobile phone use on sales and profit of vegetable growers in Indonesia and found that growers had higher sales and profits.

Kaila and Tarp [69] investigated the impact of the internet on the livelihood of rural Vietnam and found a 6.8% higher volume of agricultural output. Chhachhar and Hassan [70] investigated the impact of mobile phone use on agricultural development in Malaysia and concluded that mobile phones had saved the energy and time of farmers and ultimately improved their income. While these findings are promising and relevant, it is unclear whether the grower community had higher or lower benefits because the different crop has different growing seasons, processing, and marketing requirements associated with the technologies. Therefore, it is important to investigate the impact of MPITU on household income or incomes of rural farmers using data from specific crop farmers. This helps policymakers make effective plans or support farmers and growers better to enhance their production and income.

Thus, this study contributes by empirically investigating the impact of MPITU on effective wheat selection, and other high-value agro-products sales and marketing would have high investigated value. To the best of our knowledge, no such study appears to exist, particularly in rural regions of developing countries, focusing on wheat growers. The main objectives of this research were to (i) effectively evaluate the impact of MPITU on the selection of productive sales and marketing channels and (ii) examine if MPITU helps increase the income of growers.

In developing countries, sales and marketing include senior mediators, and growers should select suitable trade channels [48,49]. According to Internet technology usage (ITU) [6], Pakistani growers have made progress exploring resolutions to achieve sustainable agriculture production, which is of great significance for changing the livelihood of growers.

This article is organized as follows: Section 1 presents the general introduction. Section 2 includes the theoretical outlook of the study. Section 3 presents materials and methods: wheat production, study area, and data collection, and model specification, and selection of variables. Section 4 details the empirical results and discussion, and section 5 gives the conclusion of the study.

2. Theoretical outlook

First, Pakistan has mostly small to medium-sized growers. In 2020, Pakistan had 80% of small and medium-sized growers [86]. In terms of the labor force, agriculture is the largest economic sector of Pakistan, and most of the population's livelihood directly or indirectly depends on agriculture. In addition, in the past few decades, its contribution to gross domestic products (GDP) has gradually declined to 19.3% [71]. However, by increasing the utilization of modern agricultural technology, national productivity would be increased. In Pakistan, the agriculture sector has a great potential to contribute to GDP [71]. MPITU can help grow the channel access of small and medium growers, thus potentially affecting sales channels selections. Compared with cooperatives, intermediary and self-service channels with wider information networks and more robust administrative facilities. They have a greater trading capability, assisting growth in agricultural product sales [72–74]. With the fluctuation of sales prices, decreasing the charge of information search may support small and medium growers to boost sales revenue [75,76].

Second, MPITU can assist small and medium growers in reaching market subtleties on time, increasing the market scope [77,78], providing a better domestic and foreign sales market, and promoting a significant growth in sales. These tools (mobile phone and internet technology) benefit agricultural product prices and help increase sales volume to substantially boost profits [21,79]. Third, based on transaction cost theory, the MPITU through growers can reduce the sales procedure of farming commodities, reduce the bargaining time, diminish the bargaining cost, and promote decision-making, thus decreasing agricultural commodities values and boosting sales income [80–83]. Fourth, MPITU influences growers' access to information, enhances their employment abilities and off-farm employability, and makes up for the deficiency of the education system. Fifth, MPITU is beneficial to increasing the growers' social links and employment networks, thus boosting the likelihood of off-farm employment and income level.

3. Materials and methods

The conceptual framework of the effect of mobile phones and internet technology usage (MITU) to increase the income of rural farmers is presented in Fig. 1.

3.1. Wheat production in the research area

Wheat is produced in various parts of Pakistan, including Punjab, Sindh, Balochistan, and Khyber Pakhtunkhwa (KPK) provinces. For this research, KPK province was selected because the area has favorable climatic conditions for wheat and can produce high-quality wheat. The annual rainfall is 1532 mm, while the temperatures during plantation and harvest are ideal for wheat production [84].

The soil texture and type in most areas of the province also favor wheat production. Due to high rainfall in the study area, wheat production mainly depends on rainwater for nourishment, and only small numbers of growers (about 40% in our study) use irrigation. Small numbers of growers plant cash crops that dominate wheat production. This sector needs modern technologies (such as mobile phones, internet, TV, computer, and internet of things) to support wheat production. However, in this area, the mechanization rate is still relatively low, challenging wheat production. However, this study region has limited studies focusing on wheat growers. For example, rather than focusing on wheat growers, Latif et al. [4] investigated factors affecting the diffusion and adoption of ICT among all rural users of KPK.

Wheat production is influenced by insects and viruses on a global scale. Pakistani wheat growers typically replace wheat seeds with new and improved varieties with higher tolerance after 3–4 years of high yield [84]. Pakistan is the eighth leading producer of global wheat production, after China, India, Russia, the United States, France, Australia, and Canada (Fig. 2). As shown in Fig. 2, the difference in wheat production between the countries has an exponential relationship; annual wheat production exponentially decreases from the largest country (China) to the 10th largest country (Ukraine) [85,86] (see Fig. 2).

3.2. Study area and data collection

This study was conducted in KPK Province, Pakistan, from January to March 2021. A total of 580 questionnaires were distributed to the wheat-growers to collect data. A multistage random sampling technique was used to collect essential information from face-to-face wheat growers. To understand the mobile phone and internet technology usage by wheat farmers in KPK province, data were collected in four districts, namely, Dera Ismail Khan (DIK), Charsadda, Mansehra, and Swat, depending on the share of agriculture production in these areas (Fig. 3). Furthermore, according to the provincial map, four districts from e four different zones were selected. These districts were Swat located in the North, Charsadda in the West, Mansehra in the East, and DIK in the south (Table 1 and Fig. 3).

In the second step, one tehsil was selected from each district to fill out questionnaires, and in the third step, one union council was targeted from each tehsil. In the fourth step, four villages were focused randomly on each selected union council, and finally, the essential data were collected from wheat growers in the study villages. The questionnaires used in this study were divided into different sections. The first portion of the organized questionnaire contained the demographic and socioeconomic characteristics of the respondents. The rest of the questionnaire aimed to obtain information about MPITU by wheat growers. The questionnaire was initially written in English and later translated to Urdu for the ease of the interviewees.

Data from wheat growers in KPK, Pakistan, was collected using interviews and questionnaires. An in-depth interview was conducted due to the complex nature of the questionnaire. To clear the uncertainty, there was a pre-test of the questionnaire. The survey data questionnaires covered information on the socioeconomic characteristics, MPITU, and other various variables that contributed to the aim of the study. The data was edited and coded to ensure accuracy, validity, uniformity, consistency, and completeness using Stata 14.

3.3. Empirical model specification and selection of variables

In terms of variable choice, three various sales channels; cooperatives, intermediaries, and self-service recommended by Refs. [21,87,88] were utilized. We also checked the household agricultural support and total income, whether mobile phone and internet technology are actively used as a dependent variable to achieve market data, as pointed out by Xu et al. [89]. The usage level is a necessary descriptive variable, and the fundamental attributes of the growers, producers, and managing attributes were chosen as control variables[1] [21,90]. The descriptive analysis and detailed variables are presented in Table 1. The ordinary least squares (OLS) were first used for examining the impact of wheat growers MPITU on sales and marketing channels choice and income. The formula is as follows.

[1] See Table 2 in Section 4 for the particular variables and explanatory surveys.

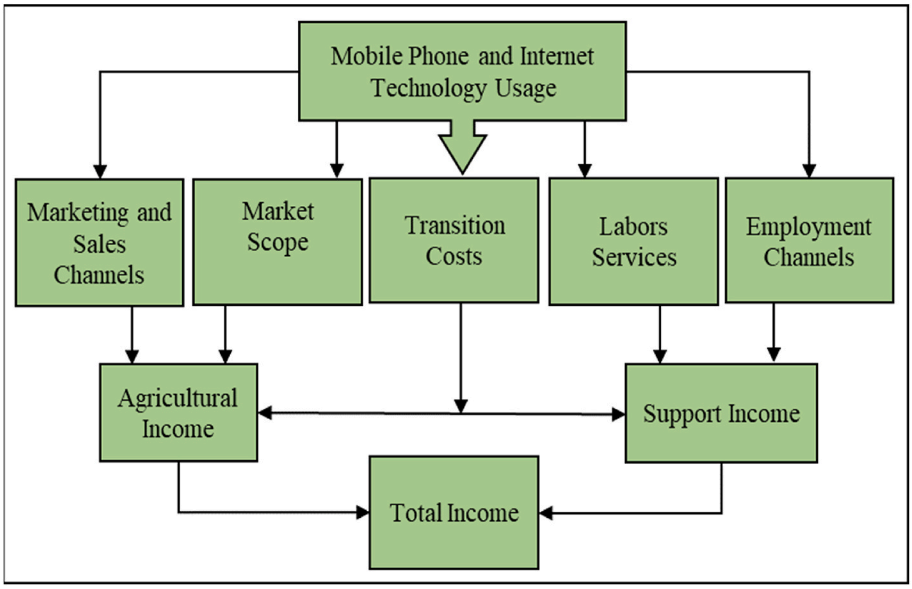

Fig. 1. The conceptual framework of the effect of mobile phones and internet technology usage to increase the income of rural farmers.

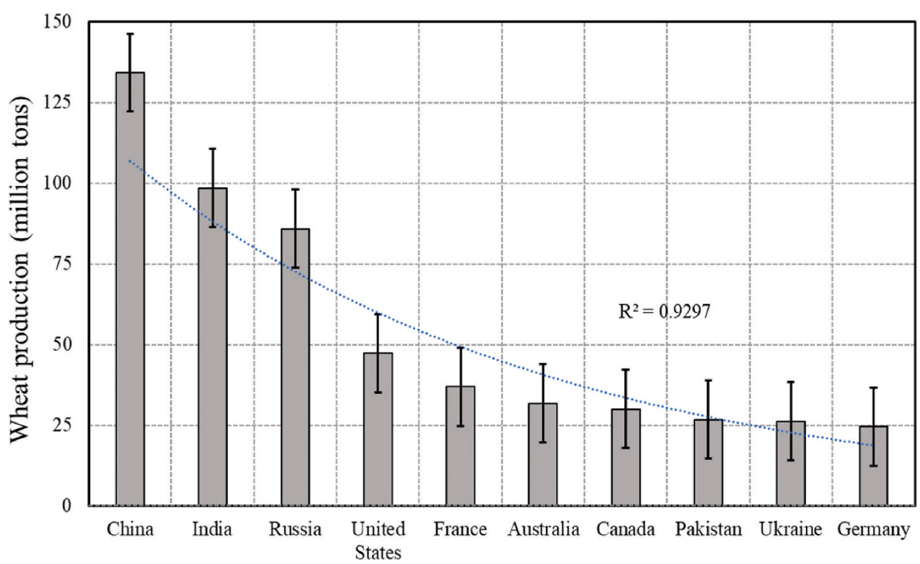

Fig. 2. Total wheat production in the top ten countries in 2021. Source: FAOSTAT.

$$Y_i^* \,/\, InY_i \,/ W_i = \beta_0 + a_1X_i + \mu_i \tag{1}$$

wherever Y_i^* shows the surveyed growers have various selections of the three sales channels. Moreover, in Y_i is the agricultural, supporting, and total incomes of the i^{th} growers' household under study. W_i shows whether wheat growers are actively using advanced mobile phones and internet technology to achieve assisting information. X_i is an observable characteristic variable influencing wheat grower revenue for the i^{th} the grower households. As the sample wheat growers were quite older, had a lesser education level, and more conventional living and expenditure, the MPITU was primarily for inquiries about production and sales information presented on the internet via mobile phones and telephone discussions. Hence, in this article, the whole annual communication expenses X_0 of growers to replace the MPITU as the intervention variable, and the rest X_i is control variable, and μ_i denotes the error term.

This study examined the impact of wheat growers' MPITU on sales choice, household incomes, and marketing channels. An important problem that could not be ignored was that various behavioral selections and distinguished second-time activities led to the growers' likelihood to attain supporting and agricultural incomes. The process of choosing the income behavior of growers could be separated into two methods. These include whether to choose to help with the development of wheat planting labor, participate in agricultural labor to obtain agricultural labor income, or choose to help labor based on outdoor work and procurement supporting incomes.

Consequently, simply examining whether the grower contributed to the agricultural workforce selection can investigate the stable income that can be obtained in the future. Hence, there are predictable problems of sample bias. To resolve this type of bias produced by selection errors as soon as conceivable, Heckman's step regression method could be utilized to perform regression management to confirm the influence of crop growers' MPITU on their support and agricultural incomes, recommended via Puhani [91] and Winship and Mare [92]. Heckman's step regression method primarily includes two equations, choice, and outcome [93,94]. First, we used the selection equation to assess how growers choose supporting and agricultural labor. Subsequently, the

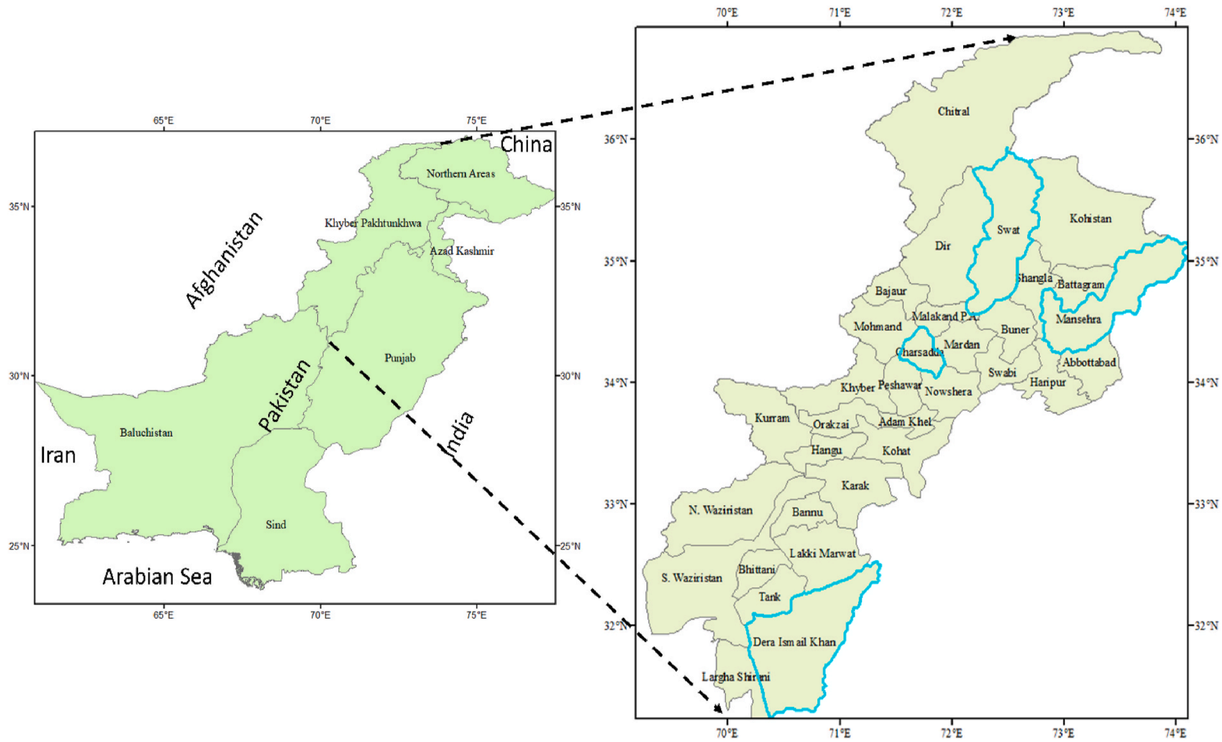

Fig. 3. Map of the study area. The boundaries of the selected four districts are shown with the cyan color. (For interpretation of the references to color in this figure legend, the reader is referred to the Web version of this article.)

Table 1
Sample distribution.

Name of province	Name of zones	Name of districts	No. of tehsils	No. of union council	No. of village	No. of samples
Khyber Pakhtunkhwa	South	DIK	One	One	Four	145
	West	Charsadda	One	One	Four	145
	East	Mansehra	One	One	Four	145
	North	Swat	One	One	Four	145
Total	Four	Four	Four	Four	Sixteen	580

selection equation is used to evaluate the various choice of inverse factories/mills and labor partaking and control variables as an independent. Later we utilized the outcome calculation to assess the MPITU. The influence on the support and agricultural income of the crop growers is estimated as:

Choice Formula:

$$Y^{*} = Z_i\eta + \mu_i \; if \; Y^{*} > 0, w_i = 1,$$

Else:

$$w_i = 0, \quad \text{Prob} \quad (w_i = 1|Z_i) = \varphi(Z_i\lambda) \tag{2}$$

Outcome Formula:

$$\ln \left(Y_i^{*}\middle| w_i = 1\right) = \gamma X_i + \omega_i \tag{3}$$

where, second is the selection formula, and third is the outcome, w_i stands for choice-making selection, $w_i = 1$ stand for agricultural labor selection, $w_i = 0$ stands for support labor selection; Y^{*} is the latent variable, In $(Y_i^{*} | w_i)$ is the log of supporting income and agricultural revenue gained through crop growers; X_i is the independent variable that influences the agricultural and non-agricultural total incomes examined by the crop growers household; Z_i is considered as the latent factors vector that constitutes the choice equation outcome; η and γ are two aspects sets to be evaluated, μ_i & ω_i are the two equations residual spans, φ is the normal common distribution function, which observes the bivariate normal distribution of N_2 $(0, 0; \; \sigma, \varepsilon, \; 1; \varrho)$.

Table 1 reveals that the MPITU via crop growers is a selection made by growers based on their source capabilities. This is not random behavior; it can be an estimate of self-choice. The extent to which crop growers MPITU is frequently decided by their own and household attributes as well as production and operation attributes. These attributes will unavoidably influence their related income, which leads to an endogenous issue in model estimation associated income. An effort would be forced to apply the PSM model to solve the bias issues affected via self-choice. We also presented the PSM method to test the robustness of mobile phone and internet technology and their impact on farmers' incomes. In the absence of experiments, PSM compares the treatment effects between participants and matched non-participant units and matches a series of observed characteristics. Therefore, PSM assumes that selection bias is based only on observed characteristics; they cannot explain the unobserved factors that influence participation. PSM can control potential selection bias [95]. Rosenbaum and Rubin [96], reported that PSM technique, the average treatment effect on a treated group (ATT) could be denoted as:

$$ATT = \frac{1}{N_1} \sum_{iDi=1} (Y_{1i} - Y_{0i}) \tag{4}$$

The main stages are as follows: First, utilize the relevant revenue Y_{1i} gained through the active choice of MPIT via the crop growers "processing group" and the matching revenue Y_{0i} of these growers, if they cannot utilize the relevant information of the mobile phone and internet technology "control group" and associated variables X_i for instance, D_i to evaluate the usage of crop growers likelihood score, and then match the propensity score according to the likelihood to control the consistent deviation of every constituent of the related variable X_i.

$$X_{treat} - X_{control} \Big/ \left(S^2_{x,\mathrm{treat}} - S^2_{x,\mathrm{control}}\right) \Big/ 2 \quad (5)$$

Among them, X_{treat} and $X_{control}$ denote the treating and control group mean; $S^2_{x,treat}$, and $S^2_{x,treat}$ respectively denote the sample differences of the treating and control clustering variable X, and support the standardized devotion of matching variable to be fewer than 10%. Baser [97], reported that kernel matching (KM), radius matching (RM), k-nearest neighbor matching in calipers (K-NNMC), and nearest-neighbor matching (NNM), are mostly utilized to evaluate the average treatment effect of matching outcomes. If the matching outcomes gained through various matching techniques are relevant, the matching consequences are fairly rebutted/reliable [98]. The regression model was tested for multicollinearity using a variance inflation factor (VIF). The generated result of the VIF was 1.13, and this is below the threshold of 10. The result means that no serious multicollinearity problem between the explanatory variables used in the model [99].

4. Results and discussion

4.1. Variable description and summary statistics

Table 2 shows the basic characteristics of research contributors. Fundamental evaluation indicates that more than 70% of the interviewees were men, with an average of more than 50%, and most had junior high school educations. The average farm size was less than 5 acres, but farmers were experts in farming. More than 60% of crop growers accounted for more than 80% of total household income, and more than 70% of growers had joined agricultural cooperatives (Table 2). Wheat growers are properly represented in this region. This indicates that young growers were more likely to use mobile phones and internet technology and understand its impact on farmers' income. Young farmers tend to have higher cognitive abilities and creativity, while older growers tend to be more conservative about new technologies [100].

4.2. Impact of MPITU on the selection of wheat growers' sales networks

The model assessment results in Table 3, show that MPITU by wheat growers had a significant impact on both broker and cooperative, but self-operated sales had no significant influence. The impact on the broker and cooperative sales were substantially associated at the 1% level. This revealed that frequent MPITU boosts the wheat farmers' possibilities of choosing efficient transactions networks. The probable aim is that as a high-level cost and storage capacity stable crop, wheat is further expected to persuade brokers and cooperatives for a marketing system, and additional market-related information is needed. In contrast to self-service sales, the other two are more vital for mobile phones and internet technology and have a stronger dependence on MPITU. However, the regression outcomes also indicate whether joining a cooperative and the space between field and market has a particular degree of encouraging influence on selecting the above two outlets. Furthermore, it shows that high-charge farming products strongly influence business associations and information tools. The use of OLS to evaluate the results of wheat growers' transactions networks is shown in Table 3.

4.3. Estimated findings of Heckman model

To approve the reasonableness of the estimated impact of MPITU on the revenue of wheat farmers, this article utilized OLS and Heckman's step regression techniques to assess the predicted outcomes, as shown in

Table 2
Variable description and summary statistics.

Category	Variables	Code	Description	Mean (S.D)
Dependent Variables	Cooperative	(Y1)	1 if the farmers sells through cooperative; 0 otherwise	0.494 (0.505)
	Intermediary	(Y2)	1 if the farmers sells through a middleman; 0 otherwise	0.703 (0.556)
	Self-Service	(Y3)	1 if the farmer sells directly; 0 otherwise	0.631 (0.497)
	Agricultural income (in log)	(Y4)	Estimated by the incomes of the gross transaction of wheat in 2021 (PKR)	10.123 (0.839)
	Supporting/Other income (in log)	(Y5)	Supporting incomes in 2021 (PKR)	10.135 (0.829)
	Total income (in log)	(Y6)	Total household income in 2021 (PKR)	10.45 (0.840)
	Internet btechnology usage (ITU)	(T_i)	1 if the respondent actively utilized Internet technology; 0 otherwise	0.593 (0.497)
	Wheat growers less than 50 years old	(T_{i1})	1 If the respondent actively utilized Internet technology; 0 otherwise	0.545 (0.540)
	Wheat growers 50 years old and above	(T_{i2})	1 If the respondent actively utilized Internet technology; 0 otherwise	0.601 (0.491)
Intervention Variables	MPITU	(x1)	The log of the total yearly MP transmission cost of growers, showing the ITU (PKR) (log)	25.923 (6.902)
Control Variable				
Fundamental attributes of wheat growers	Gender	(x2)	1 if the respondent is male; 0 otherwise	0.370 (0.494)
	Age	(x3)	Age of respondent (years)	52.096 (9.643
	Household size	(x4)	Number of family members	6.94 (2.96)
	Education	(x5)	Education of respondent (years)	7.741 (5.525)
Production and operation attributes	Years of wheat growing	(x6)	Wheat is grown (years)	27.424 (6.087
	Wheat growing	(x7)	Average wheat planting area (2021)	4.317 (0.582)
	Cooperative membership	(x8)	1 if cooperative membership; 0 otherwise	0.708 (0.760)
	Degree of specialization	(x9)	The share of wheat production income to total in 2021 (%)	78.361 (6.835)
	Outside work	(x10)	1 if worked outside; 0 otherwise	0.608 (0.499)
	Communication Technology	(x11)	Does the ICT usage is easy? (a) = very simple; (b) = simple; (c) = normal; (d) = not simple	2.275 (1.260)
	Distance	(x12)	Distance between farm to market (km)	1.485 (0.853)
	Soil fertility	(x13)	How fertile is farmland? a = poor; b = fair; c = good = d very good	2.481 (1.089)
		(x14)	Have you participated in	2.541 (0.713)

(continued on next page)

Table 2 (*continued*)

Category	Variables	Code	Description	Mean (S.D)
	Growing Technology Training		plating technology training recently? a = participate; b = Rare participate; c = Frequent participate	

Table 3
The influence of MPITU to choose improved sales networks.

Variables	Self-Service sales		Broker Sales		Cooperative Sales	
	C	SE	C	SE	C	SE
X1	0.019	0.016	0.061***	0.019	0.089***	0.019
X2	−0.029	0.060	−0.072	0.061	−0.007	0.053
X3	−0.001	0.003	−0.005	0.002	−0.000	0.003
X4	0.268	0.225	0.146	0.351	0.379	0.296
X5	0.012*	0.007	−0.006	0.007	0.006	0.007
X6	0.002	0.004	−0.001	0.005	0.001	0.005
X7	0.006	0.013	0.001	0.014	−0.000	0.014
X8	0.249***	0.037	0.103***	0.039	0.158***	0.040
X9	−0.001	0.647	1.045	0.678	0.530	0.687
X10	0.039	0.067	−0.020	0.070	0.005	0.071
X11	−0.052**	0.024	−0.022	0.026	−0.043	0.026
X12	0.045	0.034	0.085**	0.036	0.076**	0.037
X13	−0.025	0.028	0.027	0.029	−0.023	0.029
X14	−0.010	0.039	0.047	0.041	0.047	0.041
Constant	0.418	0.584	−0.266	0.644	−0.285	0.636
Observations	580		580		580	
Adjusted R^2	0.146		0.078		0.156	

Notes: ***, **, and * indicate statistically significant at 1%, 5%, and 10% levels, respectively.

Table 4. The results showed that main explanatory variables were used in the regression outcomes of MPITU and OLS. The values of *p* confirmed the one and five percent substantial evaluation, and inverse Mills ratio (IMR) in the Heckman method approved the one percent substantial test, showing that the assessment method choice is suitable.

According to the outcomes assessed by the OLS method, the active MPITU by wheat growers had a significant influence of 1% on their agricultural and total revenue. Simultaneously, it also had an optimistic influence on their support revenue, which was a substantially 5% level. Moreover, the usage of Heckman's step regression model eliminates the bias of wheat growers in participating in farming and supporting labor. The findings indicate that whether growers aggressively MPITU also significantly impacts their farming and supporting revenue. Additionally, compared with the assessment of supporting revenue by the HTSR technique, the outcome of OLS usage to assess agricultural revenue was lowered by 0.023. Simultaneously, the outcomes gained via using the OLS are expected to be 0.017, smaller than Heckman's step regression technique.

Furthermore, the OLS and Hackman's two-step evaluation outcomes indicate that sowing level positively impacts agriculture, support, total revenue, and evaluation of Heckman's regression method, which is more durable with OLS evaluation results. It indicates that the improvement of farming yield, mild development of the farm growing scale is conducive to the further expansion of growers' revenue intensity and has a substantial influence on the expansion of support revenue. The potential purpose is that the better farming income of wheat growers creates opportunities for determining whether to participate in endorsing industries to achieve profits. The group variances outcomes indicated that OLS outcome and the HTSR for wheat farmers under 50 years were stable with the outcomes of the total regression method, but the OLS technique for wheat farmers over 50 years old was not substantial, and HTSR could not gain the outcomes. The possible reason is that most growers over 50 stay at home, and challenging for them to find steady off-farm revenue from working outdoors. Overall, an efficient MPITU significantly impacts wheat growers' overall, agricultural and auxiliary profits by over 30%.

4.4. Matching calculation of wheat growers' MPITU

Reflecting that the choice of matching factors would gratify both the MPITU rate and income of the wheat-growers, this paper selected attributes of the respondents and the growers' business attributes as matching variables and usages the OLS method to accomplish logit method assessment of the PSM. Table 5 shows that MPITU's decision to join a cooperative, showing specialization degree and the distance between farmhouse and marketplace, has a substantial and optimistic impact on whether MPITU is suitable for matching variables. According to the estimated logit, older age would reduce the likelihood of using mobile phones in business, while an extra year of education would increase the possibility of MPITU. This satisfies the expectation that educated people have the knowledge needed to operate mobile phones and internet technology, while the elderly tend to be conservative about new things. These findings align with Jensen [100], who pointed out that adopters of new technologies tend to be younger and more educated. Furthermore, households with large non-agricultural enterprises tend to prefer MPITU regarding the number of workers and households engaged in the service industry.

4.5. The ATT of wheat growers' profits

The assessed outcomes of MPITU impact on wheat growers' profits are shown in Table 6. The ATT of wheat growers' agricultural revenue achieved by the propensity matching technique is substantial at the 1% level. The ATT outcomes were attained utilizing the PSM (4) techniques such as 0.355 (KM), 0.367 (RM), 0.414 (K-NNMC). The consequences achieved by the four matching approaches have little differences, showing that the matching outcomes have particular stability. Additionally, it showed that after reducing the obvious bias caused through observable heterogeneity, on average, households that actively used mobile phones and internet technology had 39.2% greater agricultural income than households that did not actively use it (control group). Consequences from the usage of PSM (4) approaches to acquire supporting profits ATT (wheat growers under 50 years), the ATT is substantial at the 10% level, and its outcomes are 0.312 (KM), 0.325 (RM), 0.271 (K-NNMC), and 0.329 (1:3 NNM).

The PSM (4) techniques outcomes are still relatively close, showing that the corresponding findings are comparatively consistent. Simultaneously, after excluding the obvious bias caused via measurable heterogeneity, the average support revenue of actively MPITU is greater than the average support profits of unused families, which is 30.9% greater. From the outcome of utilizing the PSM (4) technique to achieve auxiliary revenue ATT (wheat growers aged 50 and above), the ATT is non-substantial at the 10% level. This indicates that it is hard for them to get balanced off-farm profits when they go out to work, and forming a domestic could be the greatest option. Lastly, judging as of the estimated outcomes that influence the total profits of wheat growers, ATT of the total wheat income, the growers utilizing the PSM (4) techniques are substantial at the 1% level. The ATT findings are: 0.336 (KM), 0.354 (RM), 0.395 (K-NNMC), and 0.344 (1:3 NNM). The four matching approaches findings are comparatively close to each other, which further shows the stability of the matching outcomes. After reducing the obvious bias caused via measurable heterogeneity, the consequences revealed that the overall revenue of wheat growers who used mobile phones and internet technology was 35.7% greater than those who did not use it.

Table 4
The impact of MPITU on household profits measurement of wheat growers.

Models	OLS	OLS	OLS	Heckman Agricultural Revenue		Heckman Supporting Revenue	
Variables	Agricultural Profits	Supporting Profits	Total Profits	Profits Equation	Choice Equation	Profits Equation	Choice Equation
X1	0.134***	0.085**	0.156***	0.123***	−0.103	0.083**	−0.035
	(0.034)	(0.033)	(0.033)	(0.037)	(0.055)	(0.032)	(0.052)
X2	0.099	0.039	0.073	0.110	0.148	0.041	0.037
	(0.126)	(0.120)	(0.119)	(0.123)	(0.198)	(0.116)	(0.186)
X3	0.001	−0.001	0.001	−0.003	0.021** (0.011)	−0.001	0.005
	(0.006)	(0.007)	(0.006)	(0.007)		(0.006)	(0.010)
X4	0.193	0.296	0.351	0.156	0.225	0.223	0.271
	(0.256)	(0.146)	(0.156)	(0.351)	(0.198)	(1.248)	(0.209)
X5	0.012	−0.003	0.015	0.014	0.025	−0.001	0.021
	(0.014)	(0.013)	(0.013)	(0.013)	(0.027)	(0.017)	(0.022)
X6	−0.003	−0.004	−0.005	−0.004	−0.013	−0.003	0.013
	(0.009)	(0.009)	(0.009)	(0.009)	(0.015)	(0.009)	(0.014)
X7	0.101 ***	0.063 **	0.075 **	0.101 ***	−0.012	0.064 **	0.003
	(0.028)	(0.034)	(0.027)	(0.027)	(0.045)	(0.038)	(0.043)
X8	0.165	−0.096	−0.044	−0.147 **	0.350	−0.079	0.596 ***
	(0.072)	(0.069)	(0.070)	(0.075)	(0.219)	(0.070)	(0.209)
X9	0.743	0.180	0.464	1.190	4.417 ***	0.223	0.510
	(1.368)	(1.290)	(1.284)	(1.475)	(2.197)	(1.248)	(2.042)
X10	0.065	0.143	0.093	−0.092	0.225	0.073	0.271
	(0.141)	(0.137)	(0.135)	(0.142)	(0.198)	(0.137)	(0.209)
X11	−0.062	−0.086	−0.087	−0.036	0.247 ***	−0.079	0.080
	(0.054)	(0.051)	(0.051)	(0.064)	(0.220)	(0.050)	(0.076)
X12	−0.087	0.022	−0.028	−0.124	0.317	−0.001	0.249 **
	(0.079)	(0.080)	(0.074)	(0.093)	(0.110)	(0.077)	(0.106)
X13	0.018	0.072	0.027	0.026	0.080	−0.057	0.202
	(0.057)	(0.055)	(0.054)	(0.056)	(0.089)	(0.056)	(0.089)
X14	−0.008	0.037	0.038	−0.002	0.069	0.038	0.029
	(0.083)	(0.079)	(0.079)	(0.081)	(0.125)	(0.076)	(0.121)
T_i	0.407 ***	0.322 **	0.370 ***	0.430 ***	0.199	0.339 *	0.172
	(0.126)	(0.123)	(0.108)	(0.126)	(0.205)	(0.121)	(0.187)
T_{i1}	0.431 ***	0.355 **	0.377 ***	0.356 **	0.025	0.340 *	0.092
	(0.141)	(0.139)	(0.134)	(0.158)	(0.192)	(0.141)	(0.220)
T_{i2}	0.235	0.267	0.354	–	–	–	–
	(0.418)	(0.378)	(0.345)				
Constant	8.366 **	9.960 ***	9.698 ***	8.399 ***	−4.308 **	9.739 ***	−1.302
	(1.238)	(1.182)	(1.168)	(1.482)	(2.073)	(1.175)	(1.872)
IMR	–	–	–	−0.243 ***	–	−0.314 ***	–
				(0.082)		(0.066)	
Prob > chi^2	–	–	–	0.000	–	0.064	–
Prob > F	0.005	0.000	0.185	–	–	–	–

Notes: ***, **, and * indicate statistically significant at 1%, 5%, and 10% levels, respectively.

4.6. *Stability assessment of corresponding variables and relative estimation of various variables evaluation approaches*

In the study reported by Rosenbaum and Rubin [96], the PSM outcome was more reliable and convincing only when there was no significant difference in the matching variable, the clearer the matching impact and more consistent the PSM assessment. Table 7 depicts the divergence of treatment and control clusters centered on the average of the corresponding factor before and after the coordinated factor match. Overall, the PSM (4) variables, MPITU rate, whether to enter cooperative, the specialization level in sowing, the space between the farmhouse and the marketplace before matching, and every variable p-value substantially enhanced after matching. But the residual outcomes are non-substantial, indicating whether mobile phones and internet technology are actively used after matching is not influenced via its fundamental attributes' characteristic variables. The matching impact is better, and the assessment outcomes are further consistent. Moreover, it can be observed from the comparison that MPITU has an impact on the wheat growers' income gained by various approaches, as shown in Table 8. Though the outcomes are slightly distinct, the total variation is not significant. In particular, compared with the outcome of PSM, the regression findings estimated through OLS overestimated the growers' total income boosted by 1.3%.

Perception of the agricultural revenue comparison, the regression outcome of OLS estimation overestimated agricultural profit expansion about 1.6%. The valuation consequence of the Heckman regression method overestimated the impact of agricultural profits growth by 3.9%. From the contrast supporting revenue, equated with the PSM assessment outcome, the income growth influence of the OLS assessment regression outcome was underestimated by 4.4%. The effect of supporting profits growth is underestimated by 2.7%. A difference between groups revealed that the OLS estimate of wheat growers under 50 underestimated the impact of revenue growth by 6.8%. The Heckman regression method underestimated the effect of off-farm profits growth by 3.1%.

Furthermore, three regression methods outcomes for wheat growers over 50 years old are non-substantial. This also shows that it is difficult for most growers over 50 to attain stable non-agricultural income through migrant works. In this assumption, various techniques are not comparable, but the utilization of HTSR and PSM eliminates the recognition bias created by OLS assessment to a certain extent and tests the robustness of each other [101]. This indicates that MPITU substantially influences growers' income, which aligns with the findings of Jenson [102].

5. Conclusion, policy implications and limitations

Agribusinesses in emerging economies face many challenges, from alleviating growing production demands through sustainable extension to employment opportunities for fragile rural communities. In addition,

Table 5
Logit regression assessment of growers' propensity scores based on MPITU.

Variables	Coeff. (S.D)	*P*-Value
X1	−0.025 (0.016)	0.121
X2	−0.273 (0.309)	0.371
X3	0.247*** (0.089)	0.005
X4	0.078 (0.361)	0.439
X5	−0.032 (0.035)	0.364
X6	0.002 (0.023)	0.928
X7	−0.012 (0.070)	0.862
X8	1.159*** (0.332)	0.000
X9	5.495* (3.291)	0.095
X10	−0.078 (0.361)	0.836
X11	−0.117 (0.128)	0.363
X13	0.346* (0.189)	0.067
X14	0.118 (0.143)	0.409
X12	0.216 (0.199)	0.278
Likelihood = −153.414	Pseudo R^2 = 0.123 (Prob > chi^2 = 0.0001)	

Notes: ***, **, and * indicate statistically significant at 1%, 5%, and 10% levels, respectively.

Table 6
The ATT of wheat growers' income MPITU.

Dependent Variables	Matching Approaches	Control Group	ATT (S. D)	t-Value
Agricultural Profits	RM (caliper 0.03)	240/340	0.367 *** (0.162)	2.27
	K-NNMC (caliper 0.01)	240/340	0.414 *** (0.165)	2.50
	1:3 NNM	240/340	0.431 *** (0.159)	2.72
	NM(1)	240/340	0.315 *** (0.152)	2.34
	ATT mean	–	0.392 (–)	–
Support profits (Growers <50 years old)	RM (caliper 0.03)	240/340	0.325 ** (0.165)	2.26
	K-NNMC (caliper 0.01)	240/340	0.271 ** (0.146)	2.36
	1:3 NNM	240/340	0.329 ** (0.163)	2.32
	NM	240/340	0.312 ** (0.158)	2.39
	ATT mean	–	0.309 (–)	–
Support profits (Growers aged 50 and above)	RM (caliper 0.03)	240/340	0.265 (0.456)	0.58
	K-NNMC (caliper 0.01)	240/340	0.157 (0.769)	0.20
	1:3 NNM	240/340	0.172 (0.332)	0.52
	NM	240/340	0.129 (0.415)	0.30
	ATT mean	240/340	0.181 (–)	–
Total incomes	RM (caliper 0.03)	240/340	0.354 *** (0.161)	2.20
	K-NNMC (caliper 0.01)	240/340	0.395 *** (0.174)	2.27
	1:3 NNM	240/340	0.344 ** (0.175)	1.96
	NM	240/340	0.342 *** (0.151)	2.24
	ATT-Mean		0.358 (–)	–

Notes: ***, **, and * indicate statistically significant at 1%, 5%, and 10% levels, respectively (1)NM, nuclear matching.

Table 7
Similar assumption testing before matching and after matching (BM/AM).

Variables	BM & AM	Treatment	Control	Difference Level (%)	Variation Level (%)	P-Value
X1	BM/ AM	2.262/ 2.137	1.250/ 2.036	48.48/4.9	/90.0	0.001/ 0.913
X8	BM/ AM	0.917/ 0.851	0.608/ 0.804	43.9/6.9	/84.6	0.004/ 0.672
X9	BM/ AM	0.776/ 0.776	0.771/ 0.778	16.4/-4.4	/73.1	0.198/ 0.686
X12	BM/ AM	1.535/ 1.464	21.95/ 1.294	31.7/-25.2	/20.8	0.009/ 0.143

the rapid expansion of global commercial development trends and structural modifications have had a great impact on this sector. These characteristics have created a particular need because mobile phone and internet technology dynamics can be used to deal with possible issues and respond to worldwide economic development while sustaining a good transition of production and dissemination. Therefore, it has shown strong interest in mobile phone and internet technology farm-level interaction among industry experts, policymakers, academia, and the worldwide communities.

This research investigated whether MPITU interaction can improve the appropriate sales selection and dissemination systems and ultimately help growers increase agricultural, non-agricultural, and total income. Stimulatingly, the current study has mainly summarized the MPITU impact to a single dimension and conducted a comprehensive exploration of MPITU. Likewise, contrasted with past investigations, this study selected one of the important crops, such as wheat, which may have greater research significance. The empirical setting of the study included 580 wheat growers from Pakistan's KPK province. More precisely, PSM, HTSR, and OLS were used to formulate the assessment.

The empirical assessment showed the greater the MPITU interaction that growers have, the greater the possibility of obtaining effective sales channels, while the self-operating sales were comparatively low. The utilized model estimate also showed that the active MPITU increased the wheat growers' agricultural total supporting revenue by more than 35.7%. MPITU has the most noticeable impact on agricultural revenue growth, with an average revenue growth influence is (approximately 41%) pursued by off-farm revenue (approximately 31%). While a high-level value-added farming product, wheat is easier to obtain higher agricultural revenue than other farming commodities, it would also benefit the non-agriculture labor force. The estimation as well as observed parallel outcomes showed low enthusiasm for non-agricultural or supporting income.

The regression findings of several age groups indicate that wheat growers over 50 years were more likely to obtain additional agricultural revenue by wheat cultivation, while the income of off-farm was not substantial for growers. Off-farm revenue mostly comes from young and middle-aged wheat growers, less than 50 years. Based on the above assumptions and arguments, this research is summarized as follows. First, the government would apply expanded guidance skills to expand the feasibility of transaction channels to ensure the efficient distribution

Table 8
Relative evaluation of regression outcomes of MPITU on the revenue difference of wheat growers.

Regression Consequences	OLS	Heckman	PSM mean	PSM choice deviation
Agricultural profits	0.417	0.430	0.393	0.016/0.039
Supporting profits (M_i)	0.322	0.338	0.355	−0.045/-0.028
Supporting profits (M_{i1})	0.377	0.341	0.310	−0.069/-0.032
Supporting profits (M_{i2})	0.352	–	0.182	Not significant
Total profits	0.371	–	0.356	0.014

of fundamental sales and marketplace information. Both private and public investments would be promoted, through farming experiment areas must be utilized to obtain useful knowledge in remote regions. Awareness-structure activities would also be carried out to eliminate the adaptability problems of fundamental MPITU, particularly for older grower groups. In addition, support between private and public sectors will stimulate agricultural information dissemination policies, expand publicity coverage and marketing services, and provide important agricultural advancements for most growers in an appropriate manner.

Although this study observed the significance of MPITU for efficiently managing the distribution system available to wheat growers, there are still some limitations requiring further investigations in future studies. Firstly, because KPK has plain areas, middlemen and other workers may often go to the farm to buy wheat, which may also impact increasing the income of the growers. Therefore, more studies are needed to include this impact while developing the model. Probable research has to examine how and to what degree the MPITU promotes growers' market participation to promote transition expenses in the perspective of supply chain assets and financial efficacy. Secondly, due to ongoing Covid-19 pandemic issues, this study only focused on four districts in Pakistan's KPK province. Thirdly, due to unobserved heterogeneity issues, the data limit the expansion of our results within one year and restricts the control of selection bias. Therefore, future research can use panel data to extend this analysis to determine the impact of MPITU over an extended period. Moreover, future research must pay special consideration to MPITU impact on further key outcome variables, for instance, marketing and sales channels, food security, poverty, consumer spending, and agricultural productivity income.

Credit author statement

Nawab Khan: Conceptualization, Data management, Formal analysis, Methodology, Software, Investigation, Writing – original draft. **Ram L. Ray:** Investigation, Validation, Writing – review & editing. **Shemei Zhang:** Software, Formal analysis, Investigation, Writing – review & editing. Supervision. **Evans Osabuohien:** Investigation, Writing – review & editing, **Muhammad Ihtisham:** Draft, Data management.

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Abbreviations

Abbreviations of the study

MPIT	Mobile Phone and Internet Technology
MP	Mobile Phone
PSM	Propensity Score Matching
HTSR	Heckman's Two-Step Regression
MPU	Mobile Phone Usage
ICTs	Information Communication Technologies
IT	Internet Technology
AM	Agricultural Modernization
GDP	Gross Domestic Products
IMR	Inverse Mills Ratio
ATT	Average Treatment Effect on Treated
RH	Research Hypothesis
NM	Nuclear Matching
OLS	Ordinary Least Squares
SC	Sales Channels
MDs	Mobile Devices
OS	Outcome Stage
KPK	Khyber Pakhtunkhwa
MITA	Mobile Internet Technology Adoption
IoT	Internet of Things
ATE	Average Treatment Effect
GOP	Government of Pakistan

References

[1] S. Daud, S.M.M. Gilani, I. Hamid, A. Kabir, Q. Nawaz, DSDV and AODV Protocols Performance in Internet of Things Based Agriculture System for the Wheat Crop of Pakistan, Pak. J. Agric. Sci. vol. 57 (2020).
[2] A.A. Naikoo, S.S. Thakur, T.A. Guroo, A.A. Lone, Development of Society under the Modern Technology-A Review, Scholedge Int. J. Bus. Pol. Govern. vol. 5 (2018) 1–8.
[3] U. Deichmann, A. Goyal, D.J.A.E. Mishra, Will Digital Technologies Transform Agriculture in Developing Countries?, vol. 47, 2016, pp. 21–33.
[4] Z. Latif, W. Lei, Z.H. Pathan, S. Hussain, K. Khan, Factors affecting diffusion and adoption of information and communication technology among rural users in Khyber Pakhtunkhwa Province, Pakistan, Int. J. Inf. Technol. Manag. 17 (2018) 349–370.
[5] L. Bizikova, S. Brewin, R. Bridle, T. Laan, S. Murphy, L. Sanchez, C. Smaller, The Sustainable Agriculture Transition, 2020.
[6] W.I.C.T. Bank, In Agriculture (Updated Edition): Connecting Smallholders to Knowledge, Networks, and Institutions, The World Bank, 2017.
[7] G.A. Khan, S. Muhammad, K.M. Chaudhry, M.A. Khan, Present Status and Future Preferences of Electronic Media as Agricultural Information Sources by the Farmers, Pak. J. Agri. Sci. vol. 47 (2010) 166–172.
[8] P. Mehta, P. Monteiro, Concrete: Microstructure, Properties, and Materials, McGraw-Hill Education, 2014.
[9] C. Mehta, N. Chandel, T. Senthilkumar, Status, Challenges and Strategies for Farm Mechanization in India, Agric. Mech. Asia, Afr. Lat. Am. vol. 45 (2014) 43–50.
[10] W. Li, M. Awais, W. Ru, W. Shi, M. Ajmal, S. Uddin, C.J.A.i.M. Liu, Review of Sensor Network-Based Irrigation Systems Using IoT and Remote Sensing, 2020, p. 2020.
[11] Z. Latif, S. Latif, L. Ximei, Z.H. Pathan, S. Salam, Z.J.T. Jianqiu, Informatics. The Dynamics of ICT, Foreign Direct Investment, Globalization and Economic Growth: Panel Estimation Robust to Heterogeneity and Cross-Sectional Dependence, vol. 35, 2018, pp. 318–328.
[12] T.A. Tran, Land use change driven out-migration: evidence from three flood-prone communities in the Vietnamese Mekong Delta, Land Use Pol. 88 (2019) 104157.
[13] P. Pingali, A. Aiyar, M. Abraham, A. Rahman, Transforming Food Systems for a Rising India, Springer Nature, 2019.
[14] S.J.N.M. Gaiani, Information and Communication Technologies (ICTs) for Rural Development in Developing Countries, vol. 7, 2008, p. 50.
[15] A. Siaw, Y. Jiang, M.A. Twumasi, W.J.S. Agbenyo, The impact of internet use on income, Case Rural Ghana 12 (2020) 3255.
[16] X. Zhu, R. Hu, C. Zhang, G.J.T.F. Shi, S. Change, Does Internet Use Improve Technical Efficiency? Evidence from Apple Production in China, vol. 166, 2021, p. 120662.
[17] J. Sheng, Q.J.E.S. Lu, P. Research, The Influence of Information Communication Technology on Farmers' Sales Channels in Environmentally Affected Areas of China, vol. 27, 2020, pp. 42513–42529.
[18] C. Parker, K. Ramdas, N.J.M.S. Savva, Is IT Enough? Evidence from a Natural Experiment in India's Agriculture Markets, vol. 62, 2016, pp. 2481–2503.
[19] L. Bizikova, E. Nkonya, M. Minah, M. Hanisch, R.M.R. Turaga, C.I. Speranza, M. Karthikeyan, L. Tang, K. Ghezzi-Kopel, J.J.N.F. Kelly, A Scoping Review of the Contributions of Farmers' Organizations to Smallholder Agriculture, vol. 1, 2020, pp. 620–630.
[20] A. Molla, K. Peszynski, S. Pittayachawan, The use of e-business in agribusiness: investigating the influence of e-readiness and OTE factors, J. Global Inf. Technol. Manag. 13 (2010) 56–78.
[21] F. Zhang, A. Sarkar, H. Wang, Does internet and information technology help farmers to maximize profit: a cross-sectional study of apple farmers in Shandong, China, Land 10 (2021) 390.
[22] T. Sugiharto, Impacts of information technology on business performance of small-sized agribusiness firms, Jurnal Ilmiah Ekonomi Bisnis 14 (2011).
[23] A.A.-W. Karakara, E. Osabuohien, ICT adoption, competition and innovation of informal firms in West Africa: a comparative study of Ghana and Nigeria, J. Enterprising Communities People Places Glob. Econ. (2020).
[24] J.O. Ejemeyovwi, E.S. Osabuohien, E.I. Bowale, ICT adoption, innovation and financial development in a digital world: empirical analysis from Africa, Trans. Corp. Rev. 13 (2021) 16–31.

[25] J.R. Henderson, J.T. Akridge, F.J. Dooley, Internet and e-commerce use by agribusiness firms: 2004, J. Agribus. 24 (2006) 17–39.
[26] C.W. Weick, Agribusiness technology in 2010: directions and challenges, Technol. Soc. 23 (2001) 59–72.
[27] Latif, Z.; Tunio, M.Z.; Pathan, Z.H.; Jianqiu, Z.; Ximei, L.; Sadozai, S.K. A review of policies concerning development of big data industry in Pakistan: subtitle: Development of big data industry in Pakistan. In Proceedings of 2018 International Conference on Computing, Mathematics and Engineering Technologies (iCoMET); pp. 1-5.
[28] H. Kaila, F. Tarp, Can the Internet improve agricultural production? Evidence from Viet Nam, Agric. Econ. 50 (2019) 675–691.
[29] J.F. Heang, H.U. Khan, The role of internet marketing in the development of agricultural industry: a case study of China, J. Internet Commer. 14 (2015) 65–113.
[30] W. Ma, X. Wang, Internet use, sustainable agricultural practices and rural incomes: evidence from China, Aust. J. Agric. Resour. Econ. 64 (2020) 1087–1112.
[31] Z. Latif, Z. Jianqiu, R. Ullah, Z.H. Pathan, S. Latif, Application of Optical Frequency Comb in High-Capacity Long Distance Optical Communication for China-Pakistan Economic Corridor, J. Opt. Commun. vol. 38 (2017) 331–340.
[32] M.B. Naika, M. Kudari, M.S. Devi, D.S. Sadhu, S. Sunagar, Digital extension service: quick way to deliver agricultural information to the farmers, in: Food Technology Disruptions, Elsevier, 2021, pp. 285–323.
[33] R. Jensen, The digital provide: information (technology), market performance, and welfare in the South Indian fisheries sector, Q. J. Econ. 122 (2007) 879–924.
[34] A. Kaloxylos, J. Wolfert, T. Verwaart, C.M. Terol, C. Brewster, R. Robbemond, H. Sundmaker, The use of future internet technologies in the agriculture and food sectors: integrating the supply chain, Procedia Technol. 8 (2013) 51–60.
[35] F. Zhang, Research on applications of internet of things in agriculture, in: Informatics and Management Science VI, Springer, 2013, pp. 69–75.
[36] Zhou, Z.; Zhou, Z. Application of internet of things in agriculture products supply chain management. In Proceedings of 2012 International Conference on Control Engineering and Communication Technology; pp. 259-261.
[37] N. Khan, R.L. Ray, G.R. Sargani, M. Ihtisham, M. Khayyam, S. Ismail, Current progress and future prospects of agriculture technology: gateway to sustainable agriculture, Sustainability 13 (2021) 4883.
[38] C. Stork, E. Calandro, A. Gillwald, Internet going mobile: internet access and use in 11 African countries, Info (2013).
[39] Abishek, A.; Bharathwaj, M.; Bhagyalakshmi, L. Agriculture marketing using web and mobile based technologies. In Proceedings of 2016 IEEE Technological Innovations in ICT for Agriculture and Rural Development (TIAR); pp. 41-44.
[40] F.H. Bunte, Y. Dijkxhoorn, R. Groeneveld, G.J. Hofstede, J. Top, J. Van der Vorst, J. Wolfert, Thought for Food; the Impact of ICT on Agribusiness, LEI Wageningen UR, 2009.
[41] B.Ž. Ljutić, D. Đurđević, Z. Đorđević, A. Damnjanovic, Serbian large agribusiness corporations knocking at the door of E-agribusiness revolution, AGRIS on-line Paper. Econ. Inf. 8 (2016) 57–65.
[42] He, P.; Liu, S.; Zheng, H.; Cui, Y. Empirical study on the relationship between ICT application and China agriculture economic growth. In Proceedings of International Conference on Computer and Computing Technologies in Agriculture; pp. 648-655.
[43] N.A. Khan, G. Qijie, S. Ali, B. Shahbaz, A.A. Shah, Farmers' use of mobile phone for accessing agricultural information in Pakistan, Ciência Rural. 49 (2019).
[44] L. Klerkx, E. Jakku, P. Labarthe, A review of social science on digital agriculture, smart farming and agriculture 4.0: new contributions and a future research agenda, NJAS - Wageningen J. Life Sci. 90 (2019) 100315.
[45] B. Yan, C. Yan, C. Ke, X. Tan, Information Sharing in Supply Chain of Agricultural Products Based on the Internet of Things, Industrial Management & Data Systems, 2016.
[46] Feng, C.; Wu, H.R.; Zhu, H.J.; Sun, X. The design and realization of apple orchard intelligent monitoring system based on internet of things technology. In Proceedings of Advanced Materials Research; pp. 898-902.
[47] K.C. Chung, P. Fleming, E. Fleming, The impact of information and communication technology on international trade in fruit and vegetables in APEC, Asian Pac. Econ. Lit. 27 (2013) 117–130.
[48] X. Zhu, R. Hu, C. Zhang, G. Shi, Does Internet use improve technical efficiency? Evidence from apple production in China, Technol. Forecast. Soc. Change 166 (2021) 120662.
[49] S. Rathore, Econ. Surv. ume 2 (2019-20).
[50] D. Kahan, Entrepreneurship in Farming. *Farm Management Extension Guide*, 2013.
[51] X. Hu, L. Sun, Y. Zhou, J. Ruan, Review of operational management in intelligent agriculture based on the Internet of Things, Front. Eng. Manag. 7 (2020) 309–322.
[52] F. Wu, J. Ma, Evolution dynamics of agricultural internet of things technology promotion and adoption in China, Discrete Dynam Nat. Soc. (2020) 2020.
[53] Y. Zeng, H. Guo, Y. Yao, L. Huang, The formation of agricultural e-commerce clusters: a case from China, Growth Change 50 (2019) 1356–1374.
[54] S. Min, M. Liu, J. Huang, Does the application of ICTs facilitate rural economic transformation in China? Empirical evidence from the use of smartphones among farmers, J. Asian Econ. 70 (2020) 101219.
[55] H. Jun, H. Xiang, Development of circular economy is a fundamental way to achieve agriculture sustainable development in China, Energy Proc. 5 (2011) 1530–1534.
[56] T. Berger, Agent-based spatial models applied to agriculture: a simulation tool for technology diffusion, resource use changes and policy analysis, Agric. Econ. 25 (2001) 245–260.
[57] J. Yu, J. Wu, The sustainability of agricultural development in China: the agriculture–environment nexus, Sustainability 10 (2018) 1776.
[58] Z. Latif, W. Xin, D. Khan, K. Iqbal, Z.H. Pathan, S. Salam, N.J.H.S.M. Jan, ICT and Sustainable Development in South Asian Countries, vol. 36, 2017, pp. 353–362.
[59] M. Ummesalma, R. Subbaiah, S. Narasegouda, A decade survey on internet of things in agriculture, in: Internet of Things (IoT), Springer, 2020, pp. 351–370.
[60] Lianguang, M. Study on supply-chain of agricultural products based on IOT. In Proceedings of 2014 Sixth International Conference on Measuring Technology and Mechatronics Automation; pp. 627-631.
[61] N. Rao, A framework for implementing information and communication technologies in agricultural development in India, Technol. Forecast. Soc. Change 74 (2007) 491–518.
[62] V.N. Ozowa, The nature of agricultural information needs of small scale farmers in Africa: the Nigerian example, Q. Bull. IAALD (IAALD) (1995).
[63] M. Muto, T. Yamano, The impact of mobile phone coverage expansion on market participation: panel data evidence from Uganda, World Dev. 37 (2009) 1887–1896.
[64] Y. Zhang, L. Wang, Y. Duan, Agricultural information dissemination using ICTs: a review and analysis of information dissemination models in China, Inf. Proc. Agric. 3 (2016) 17–29.
[65] G. Lewis, S. Crispin, L. Bonney, M. Woods, J. Fei, S. Ayala, M. Miles, Branding as innovation within agribusiness value chains, J. Res. Market. Entrepr. (2014).
[66] C.D. Carroll, J. Overland, D.N. Weil, Saving and growth with habit formation, Am. Econ. Rev. 90 (2000) 341–355.
[67] C.-V. Radulescuu, M.-L. Popescu, M.D.O. Negescu, D.A. Bodislav, Digital Technologies Applied in Agriculture for Sustainable Development, Eur. J. Sustain. Dev. 8 (2019), 75-75.
[68] J. Mariyono, S.I. Santoso, J. Waskito, A.A.S. Utomo, Usage of Mobile Phones to Support Management of Agribusiness Activities in Indonesia, Aslib J. Inf. Manag. (2021).
[69] H. Kaila, F.J.A.E. Tarp, Can the Internet improve agricultural production? Evid. Viet Nam 50 (2019) 675–691.
[70] A.R. Chhachhar, M.S. Hassan, Information Communication Technology for Agriculture Development, J. Am. Sci. vol. 9 (2013) 85–91.
[71] G.o. Pakistan, Eonomic Survey Report, finance division., 2021, p. 556.
[72] S. Mittal, Modern ICT for Agricultural Development and Risk Management in Smallholder Agriculture in India, CIMMYT, 2012.
[73] K. Irungu, D. Mbugua, J. Muia, Information and Communication Technologies (ICTs) attract youth into profitable agriculture in Kenya, East Afr. Agric. For. J. 81 (2015) 24–33.
[74] E.K. Nyaga, Is ICT in agricultural extension feasible in enhancing marketing of agricultural produce in Kenya: a Case of Kiambu District, Q. J. Int. Agric. 51 (2012) 245–256.
[75] J. van der Lee, S. Oosting, L. Klerkx, F. Opinya, B.O. Bebe, Effects of proximity to markets on dairy farming intensity and market participation in Kenya and Ethiopia, Agric. Syst. 184 (2020) 102891.
[76] N. Poole, Smallholder Agriculture and Market Participation, Food and Agriculture Organization of the United Nations (FAO), 2017.
[77] E. Fischer, M. Qaim, Linking smallholders to markets: determinants and impacts of farmer collective action in Kenya, World Dev. 40 (2012) 1255–1268.
[78] J. Minkoua Nzie, J.-C. Bidogeza, N. Azinwi Ngum, Mobile phone use, transaction costs, and price: evidence from rural vegetable farmers in Cameroon, J. Afr. Bus. 19 (2018) 323–342.
[79] S.O. Mwombe, F.I. Mugivane, I.S. Adolwa, J.H. Nderitu, Evaluation of information and communication technology utilization by small holder banana farmers in Gatanga District, Kenya, J. Agric. Educ. Ext. 20 (2014) 247–261.
[80] M. Hernández-Espallardo, N. Arcas-Lario, G. Marcos-Matás, Farmers' satisfaction and intention to continue membership in agricultural marketing co-operatives: neoclassical versus transaction cost considerations, Eur. Rev. Agric. Econ. 40 (2013) 239–260.
[81] N. Singh, Information Technology and its Role in India's Economic Development: A Review, Development in India, 2016, pp. 283–312.
[82] A. Abdulai, W.E. Huffman, The diffusion of new agricultural technologies: the case of crossbred-cow technology in Tanzania, Am. J. Agric. Econ. 87 (2005) 645–659.
[83] A. de Janvry, E. Sadoulet, Using agriculture for development: supply-and demand-side approaches, World Dev. 133 (2020) 105003.
[84] G.o. Pakistan, Economic Survey Report. Finance Division, 2021, p. 556.
[85] F.A.O. Crop, Prospects and food situation, in: Quarterly Global Report No. 3 2021, September 2021 (Rome).
[86] FAO. FAO, Statistical Yearbook – World Food and Agriculture, 2021, p. 368.
[87] Jiang, L.; Sun, W. Analysis of agricultural product marketing channels based on diversity under the background of big data. In Proceedings of Journal of Physics: Conference Series; p. 012119.
[88] J. Sheng, Q. Lu, The influence of information communication technology on farmers' sales channels in environmentally affected areas of China, Environ. Sci. Pollut. Control Ser. 27 (2020) 42513–42529.
[89] G. Xu, A. Sarkar, L. Qian, Does organizational participation affect farmers' behavior in adopting the joint mechanism of pest and disease control? A study of Meixian County, Shaanxi Province, Pest Manag. Sci. 77 (2021) 1428–1443.
[90] V. Valencia, H. Wittman, J. Blesh, Structuring markets for resilient farming systems, Agron. Sustain. Dev. 39 (2019) 1–14.
[91] P. Puhani, The Heckman correction for sample selection and its critique, J. Econ. Surv. 14 (2000) 53–68.
[92] C. Winship, R.D. Mare, Models for sample selection bias, Annu. Rev. Sociol. 18 (1992) 327–350.

[93] S.T. Certo, J.R. Busenbark, H.s. Woo, M. Semadeni, Sample selection bias and Heckman models in strategic management research, Strat. Manag. J. 37 (2016) 2639–2657.

[94] Busenbark, J.R.; Certo, T.; Woo, H.-S. Sample selection bias and Heckman models in strategic management research. In Proceedings of Academy of Management Proceedings; p. 13314.

[95] S.O. Ogutu, J.J. Okello, D.J.J.W.D. Otieno, Impact of information and communication technology-based market information services on smallholder farm input use and productivity, Case Kenya 64 (2014) 311–321.

[96] P.R. Rosenbaum, D.B. Rubin, The central role of the propensity score in observational studies for causal effects, Biometrika 70 (1983) 41–55.

[97] O. Baser, Too much ado about propensity score models? Comparing methods of propensity score matching, Value Health 9 (2006) 377–385.

[98] E.A. Stuart, Matching methods for causal inference: a review and a look forward, Stat. Sci.: Rev. J. Inst. Math. Stat. 25 (2010) 1.

[99] S. Chatterjee, A.S. Hadi, Regression Analysis by Example, John Wiley & Sons, 2015.

[100] B.I. Rahayu, R. Riyanto, The role of mobile phone and internet use in the performance of rural non-farm enterprises: an analysis of Indonesian Rural Households, Bul. Pos dan Telekomun. 18 (2020) 29–46.

[101] J. Michalek, Counterfactual Impact Evaluation of EU Rural Development Programmes-Propensity Score Matching Methodology Applied to Selected EU Member States. Volume 2: A regional approach, Joint Research Centre, 2012 (Seville site).

[102] R.T.J.A.E. Information Jensen, efficiency, and welfare in, agricultural markets 41 (2010) 203–216.