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Agriculture Technology Adoption Determinants: Panel Data Analysis

ABSTRACT

The agriculture sector of Pakistan has a key role in the economy because it has a major share in the country's GDP. Faisalabad district has also an important role in the agriculture sector and most traditional methods are used in the district. The new and improved methods are being introduced in the province. The current study investigates the sources and determinants of improved agriculture technologies in the district by using primary panel (2006-07 & 2018-19). The logistic approach is used to determine influencing factors in both periods separately with marginal effects. The major factors responsible for agriculture technology adoption are the age of the farmer's head, family size, farmer education, higher education of family members, household member employment, livestock ownership, number of visits to agriculture extension officers, and media access.

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Author's contribution in the article: 1- Conceived and designed the analysis, 2- Reviewed and compiled the literature, 3- Collected the data, 4- Contributed data or analysis tools, 5- Performed the analysis, 6- Wrote the paper, 7- Financial support for the conduct of the study, 8-Other

1. INTRODUCTION

Food demand is increasing over time in developed as well as in developing countries due to continuous increase in population growth. It also puts pressure on agriculture production. In Pakistan, the food demand is increasing over time with an increase in population growth. The agricultural culturable land is also reducing over time due to urbanization and other factors which makes it challenging for policymakers to increase its yield over time. It is in dire need of the current era that the country should focus on new agriculture technology adoption to increase its production to meet the demand. The agriculture sector mostly depends upon technological change. It also shapes and improves the agriculture sector by reducing poverty and improving living standards through increased productivity (Bandiera & Rasul, 2006; Barrett et al., 2010).

The agriculture sector is an important sector that leads toward economic development and growth. It has the potential to contribute even more if there would be tech-based agriculture practices. The country must adopt a fourth-generation technology approach to the traditional and old techniques. Although research institutes in the country introduce new varieties and techniques for better and high productivity adoption is very limited. It is a dire need to adopt new techniques throughout the country to increase the productivity of ordinary farms.

The conservative agriculture system is less productive with low yield and high cost of production. The system relates with no-tillage or minimum tillage and direct planning is important. The modern and improved methods are more environmentally friendly as compared to other conservation methods. Under this system, to prevent water and wind erosion, this system is a kind of cultivation system in which at least 30 percent of the arable land surface is covered by crop residue. This system has various economic and other benefits. This system saves labor, energy time, cost of machinery, prevention of soil erosion, conserves soil, and increases organic matter. Due to crop residue on soil surface reduces water and wind erosion, energy, and cost leads toward the problem in establishment of seed and its germination. The pioneering work on agriculture technology adoption has been investigated in the USA where the effects of improved hybrid cord have been explored (Griliches, 1957). The previous studies related to adoption have been concerned with answering different questions of producer's technology adoption, determination pattern of technology diffusion among potential adopters.

It is fact that new improved agriculture technology plays an important role in accelerating and deepening agriculture growth. There is a need to streamline inadequate organized research systems for innovative solutions to sort out issues related to agriculture. The farmers further receive a low return due to usage of uncertified or local seed varieties, substantial pesticides, and traditional techniques. The current study explains the existing technology and innovation system in this sector and compares it with new technology and innovation.

The current study has investigated the factors responsible for agriculture technology adoption in the area based upon panel data. These agriculture technologies include improved seed adoption to social/internet access for agriculture technology adoption determinants. the earlier studies conducted consists of one or two agriculture technologies, but the current study deals with seven various agriculture technologies and their determinants. Further, the study not only used single time analysis but panel data for two time (base line & end-line) to show variations in adoption determinants in the area. The Faisalabad city has important role in economic activity of Pakistan economy and well-known agriculture research institutes working in the city. The other contribution is that is there any role of these research institutes in agriculture technology adoption determinants.

The main objective of the study is the investigation of agriculture technology adoption determinants in both periods and change over time (2006-07 & 2018-19) respectively.

2. REVIEW OF LITERATURE

Technological advancement has an immense impact on the agriculture sector through various channels. The current revolution in technology has placed agriculture at the top and leads toward another revolution that not only affects the variety and yield but also climatological and social outcomes. The technologies of the internet, artificial intelligence, and robotics have enabled data-driven and automated agriculture. The study cover review of current and emerging agriculture technologies (Charania & Li, 2020).

The green revolution in Asia as well as new agriculture technologies leads toward significant productivity and low productivity to high productivity (Bank, 2008). Household well-fare is positively related to high yield varieties adoption (Menodola, 2007). Further, the study investigates that new agriculture technology increase farm household income and increase employment and wage rates of landless laborer and lower the price of food staples.

There is a new debate on technology definition. Some has considered technology as a way of producing goods and services through organized methods as well as physical technique. Others have defined technology as the knowledge or information that permits some tasks to be completed more easily, some service to be rendered, or the manufacture of a product (Loevinsohn & Sumberg, 2012). They have also explored that farmers' decision to adopt new technology is conditioned by a dynamic interaction between characteristics of the technology itself and the array of conditions and circumstances. Technology itself is aimed at improving a given situation or changing the status quo to a more desirable level. It assists the applicant to do work easier and saves time and labor (Bonabana-Wabbi, 2002).

For developing countries' economic progress, technology is an essential prerequisite factor. The integration of innovation into farmers' normal farming activities over an extended period is called adoption (Feder et al., 1985). Adoption is a mental process an individual passes from first hearing about an innovation to final utilization of it. Adoption has two categories, rate of adoption and intensity of adoption. The rate of adoption is the relative speed of farmers' adoption of a specific technology with time element while the intensity of adoption refers to the level of use of a given technology at any time. Some studies classify these factors into different categories. The determinant of agricultural technology adoption has been grouped in three categories; these are economic, social, and institutional factors. The influencing technology adoption categories are economic, social, and physical (Kofi-Lavison, 2013). The study by (Huffman & Mercier, 1991) categorized influencing factors as farmer characteristics, farm structure, institutional characteristics, and managerial structure.

Technology characteristics are a precondition of adopting it. The study finds out trialability or a degree to which a potential adopter can try something out on a small scale first before adopting it (Doss, 2007). The other study related to rice varieties adoption in the region depends upon farmers' perception of characteristics of modern rice variety. They have a significant role in adoption decisions (Adesina & Zinnah, 1993). The improved agricultural technologies have been investigated as a driving force for technology adoption because it reduces poverty level by increasing productivity, income, and asset accumulation. The findings show a positive and significant impact on household per capita income and asset ownership respectively (Manda et al., 2019).

Farm size has a positive impact on new technology adoption. Various studies confirm its role in determining technology adoption. Some studies are scale-dependent because it has an important role in

technology adoption. Various studies confirm its relationship with agriculture technology adoption (Haggblade, 2003; Mignouna et al., 2011; Maruod et al., 2013).

The off-farm income has a positive and significant impact on technology adoption. It has an important strategy for overcoming credit constraints that are faced by rural households in many developing countries. It plays as a substitute for borrowed capital in rural economies where credit facility is either missing or dysfunctional. On the other hand, it also works as liquid capital for purchasing productivity-enhancing inputs such as improved seed and fertilizers (Ellis & Freeman, 2004; Diiro, 2013). The quest for off-farm income by farmers may demoralize their adoption of modern technology by reducing the amount of household labor allocated to farming activities (Goodwin & Mishra, 2004).

The credit facility is also an important and positive factor in technology adoption. It encourages technology adoption (Mohamed & Temu, 2008). The access to credit facilities promotes the adoption of risky technologies by relaxation of the liquid constraint as well as boosting of household's risk-bearing ability. Access both formal and informal sources of credit facility increase new technology adoption significantly (Simtowe & Zeller, 2006).

Farmers' human capital plays an important role in farmer's decisions of new technology adoption. The farmer's human capital is mostly measured by its education. Farmer's education is positively linked with farmers' decisions regarding new technology adoption (Conor et al., 2010). Farmer education increases the ability to obtain, process, and uses information related to the adoption of new technology (Namara et al., 2003). Many studies confirm that higher education influences respondents' attitudes and thoughts making them open, rational, and able to analyze the benefits of the new technologies (Okunlola & Akinwalere, 2011; Adebiyi & Okunlola, 2013).

The age factor of the household head also plays an important role in farmer technology adoption behavior. It influences farmers' information access and shapes their ability to change the available information into action. The farmer's experience and own resources allow them more possibilities for trying new technology. The younger farmers are more likely to adopt new technology due to higher education. The technology adoption varies accordingly. Some studies investigated that the older farmers have more knowledge and experience over time and are better able to evaluate technical information than younger ones (Kariyasa & Dewi, 2011). While other studies negated the results because as farmers grow older, there is a risk aversion factor that decreases interest in long-term investment in the farm while the younger farmers are less risk-averse and adopt to try new technologies (Mauceri et al., 2006).

The other study investigated the impact of improved varieties on household food security and income effect, respectively. By applying the propensity score matching method, the treatment effect model, and the Tobit selection model, the study shows that the adoption of improved varieties has a positive and significant impact on food security and income. Females are more adopters than males in the region (Sinyolo, 2020).

3. RESULTS AND INTERPRETATION

The consistent model to investigate the technology adoption determinants is the logistic model, frequently used in literature. The logistic model has been used to determine the technology adoption determinants (Griliches, 1957). The logistic approach is used in this study to assess and determine the influencing factors in agriculture technology adoption. The variable used in the model is binary form, representing 1 as adopters and 0 otherwise. The model is more efficient as compared to other ones in the sampled data set that consists of the dichotomous outcome variable. It is an extremely flexible and easily used model from a mathematical point of view (Huffman & Mercier, 1991). Further, the results obtained from this

model have a meaningful interpretation. It does not require normally distributed variables. The cumulative logistic probability model is econometrically specified as follows in equation 1:

$$P_i = F(Z_i) = F(\gamma + \sum \lambda_i \times_i) = \frac{1}{1+e^{-Z_i}} \quad (1)$$

Where P_i is the probability that a farmer will adopt improved agriculture technology or not given X_i; e represents the base of natural logarithms, X_i is the i^{th} explanatory variables and γ and λ are parameters to be estimated.

For interpretation of the coefficients, the logit model can be written in terms of the odds and log of odds. The odds ratio shows the ratio of the probability (P_i) that a farmer adopts to the probability $(1 - P_i)$ that the farmer is non-adopter. The following regression model in equation 2 is used:

$$Y_i^n = \beta_o + \beta_i X_i + U_i \quad (2)$$

Where Y_i is for the dependent variable in binary form 1 for adopters while 0 for non-adopters while n represents many agriculture technologies used for the study. Here n is equal to seven as we have used seven agriculture technologies. X_i relates to independent or explanatory variables.

U_i indicates error term which is an independently distributed random variable with a mean of zero.
Based upon equation (1), the general logistic model has been estimated for each type of agriculture to estimate adoption determinants for 2006-07 and 2018-19. In this paper, we have adopted the following agriculture technology to find out its determinants at the farm level. Farmer adoption of agriculture technology depends upon various factors e.g., demographic, financial, institutional, socioeconomic, etc. The technologies used for the current study consists of:

1) Improved Seed Varieties
2) Farm Mechanization
3) Water Irrigation Technologies
4) Fertilizer Usage
5) Access to Improved Electricity
6) Internet/social media Access
7) Mobile Phone Access

In this paper, we have estimated the determinants of these technologies for both years (2006-07 and 2018-19) respectively. For this paper, we have used the main crops for their technology usage by considering wheat, rice, sugarcane, cotton, and maize. The data collected from field interviews consists of 2006-07 as a baseline while 2018-19 as end-line to assess the changeover the time in the region covering 360 farmers in each period. The micro-panel data was collected in the wheat harvesting season.

Faisalabad is the most populated city of Pakistan, and its land is fertile. For our analysis, we have selected this city as the main study area because of its third-largest district of the country as well as its important role in the agriculture sector of the economy. Further, the agricultural land is fertile and various research institutes exist in the district related to new agriculture technologies. Different crops are cultivated in this area. The main crops are wheat, rice, sugarcane, and fodders. The area under different crops depends upon future market prices of the selected prices and profit margin. In this section, we will discuss the descriptive analysis of data collected from the field during 2006-07 and 2018-19. A comparison/change over the period from 2006-07 and 2018-19 would be drawn of their demographic, social, perception, education, net margin from crops, adoption of new agriculture technologies, their views, and perception upon new agriculture technology introduced by the government.

In these union councils, the farmers mostly grow sugarcane, wheat, cotton, and rice in some areas. The source of income of these villages is the agriculture sector and a large portion of the population is attached to this profession. From these four unions' councils, we further analyzed 12 villages by selecting three villages from each union council, respectively. From each village, we have randomly selected sixty (60) farmers for agriculture technology adoption-related information in different crops and possible constraints to adopting these agriculture technologies. The randomly selected villages' details are presented in Table 1.

Table 1: Randomly Selected Villages Demographic Change

Sr. No.	Village No.	Village Name	1998		2017	
			Population	No. of Houses	Population	No. of Houses
1	103 JB	Barnala	5829	931	7212	1152
2	106 JB	Khachiean	3654	572	5670	887
3	109 JB	Nanilian Wala	1965	267	3089	420
4	20 JB	Khankay	2987	455	3062	466
5	23 JB	Bhattian	6152	731	6318	943
6	467 JB	Jahllaran	968	136	1150	198
7	468 GB	468/GB Raghbirpura	4362	646	5419	803
8	470 GB	470 GB/Kishanpura	5501	735	8762	1309
9	472 GB	472 GB/Hargobind	2631	348	3649	482
10	168 GB	Siraj/ Babrian	2756	372	3268	441
11	438 GB	Bhart	2048	274	2396	377
12	463 GB	Haryal	4472	704	9007	1418
Chak Jhumra selected villages total			21555	3091	26050	3966
Samundri selected villages total			21770	3079	32501	4830
Overall Change (%age)-1998-2017					20.9%	28.3%

Source: Population census 1998 & 2017 by Bureau of Statistics (BSP), Pakistan

4. RESULTS AND DISCUSSION

The study investigates the agriculture technology adoption influencing factors in the region. For each technology, a separate analysis has been carried out. The estimation of agriculture technology adoption has been performed using logistic methods to explore the main determinants of each technology in the area for both years (2006-07 base-year, 2018-19 end-line). The marginal effects also have been estimated to observe the change to each factor for each agriculture technology. The seven agriculture technologies have been estimated with various influencing factors of each technology, respectively.

The result shows that household member employment, livestock ownership, knowledge of agriculture extension officer, agriculture extension officer contact during the season, participation in local agriculture discussion, radio ownership, Television ownership, farmers newspaper reading habit, and internet access has significant on these technology adoptions in the area. The detailed results are shown in Table 2.

The improved seed varieties adoption rate has increased Pakistan significantly over the period for better yield and productivity. The current study reveals the influencing factors of its adoption in district Faisalabad, Pakistan in panel data 2006-07 and 2018-19 respectively. In improved seed technology adoption, family member specialization, household member employment, and many visits to agriculture extension officers for consultancy have a positive and significant role in determining its adoption during 2018-19. While tenancy status has a negatively significant impact on improved seed technology adoption during base period 2006-07 while soil type has negatively impacted its adoption. Soil fertility has a positive significantly role in determining improved seed technology adoption in the district.

The farm mechanization technology adoption has also been estimated to determine influencing factors responsible for its adoption for 2006-07 and 2018-19 respectively. In farm mechanization technology adoption, various factors are responsible for its adoption that varies in our analysis. Tenancy status, Knowledge of agriculture officers, and radio ownership have a positive significant role in determining farm mechanization technology adoption. The radio is the main source of information in the local area to assess information regarding farm mechanization and subsidy on these technologies. The main negatively impacting factor of its adoption is television ownership in the area.

Water irrigation technology adoption is the need of the current period as there exists a water crisis both for drinking and agriculture purposes. The current study also investigated the influencing factors of its adoption in the district of Faisalabad, Pakistan. The positive significant factors responsible for its adoption are farmer education and farm size. The farmer education factor is positive and significant at 5 percent in 2006-07 while significant at 1 percent during 2018-19 respectively. The other positive and significant factor of its adoption is farm size that is significant at 1 percent in both years (2006-07, 2018-19). The other positive significant factors during 2018-19 are household member employment (10% level of significance), livestock ownership (1% level of significance), soil type (10% level of significance), and agriculture extension officer contact (1% level of significance).

The significant negatively impacting its adoption in the area is farmer specialization (5% level of significance, 2018-19) and television ownership (10% level of significance) respectively. The recommended fertilizer usage adoption in crops has also an important role in agriculture yield and productivity. The positive and significant factors influencing its adoption are farmer education level (1% level of significance), farmer specialization (10% level of significance), and farm size (5% level of significance) during 2018-19 while there is not any positive significant factor during 2006-07.

The negatively impacting factors are soil fertility (5% level of significance) during 2006-07 while tenancy status (5% level of significance) and radio ownership (1% level of significance) respectively. Electricity in the local area and specific to Pakistan is the main other source after canal irrigation for the agriculture sector. The positive and significant factors of this technology adoption are the age of farmer's head (10% level of significance), family size (10% level of significance), household member employment (5% level of significance), tenancy status (5% level of significance), soil type (1% level of significance), soil fertility (1% level of significance), number of visits to agriculture extension officer (5% level of significance) and participation of local discussion (10% level of significance) during 2018-19 while there is no any positive significant factor during 2006-07.

The negative significance factors are far size (1% level of significance) during 2018-19 while soil fertility (1% level of significance) significantly negatively affecting its adoption during 2006-07, respectively. Internet and social media access adoption has also an important role in the agriculture sector. The main influencing positive significant factors are farmer education level (1% level of significance), family member specialization (1% level of significance), farm size (1% level of significance), and soil fertility (1% level of significance) during 2018-19 while there is not any positive significant factor found during 2006-07 period due to less or limited availability.

On the other side, no negative significant factor was responsible for its adoption reduction in the study. In Pakistan, mobile phone access is considered a major source of information and agriculture information (improved seed information, weather package (information), etc.). The current study also investigated the factors responsible for its adoption. The positive significant determinants of its adoption are farmer education (1% level of significance), family member specialization (10% level of significance), soil type (5% level of significance), and television ownership (5% level of significance) during 2018-19 while no positive significant factor found during 2006-07. On the other hand, no negative significant factor is responsible for its adoption reduction.

Table 2: Determinants of Agriculture Technology Adoption (2006-07 & 2018-19)

Variables	Improved Seed Adoption		Farm Mechanization Adoption		Water Irrigation Adoption		Fertilizer Usage Adoption		Access to Improved Electricity Adoption		Internet/Social Media Access Adoption		Mobile Phone Access Adoption	
	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19
Age of farmer head	-0.004	-0.001	-0.01	-0.001	0.006	-0.006	-0.01	0.01	-0.033***	0.015*	-0.020	0.005	0.01	-0.029
	0.021	0.007	0.018	0.012	0.011	0.007	0.008	0.01	0.012	0.009	0.020	0.008	0.043	0.017
	0.864	0.889	0.562	0.923	0.603	0.434	0.186	0.315	0.006	0.093	0.322	0.507	0.815	0.091
Family Size	0.22	0.101	-0.088	-0.012***	0.067	0.105	-0.018	0.001	-0.167*	0.52***	0.175	-0.053	0.192	0.016
	0.201	0.074	0.11	0.069	0.122	0.073	0.09	0.098	0.087	0.154	0.223	0.071	0.362	0.099
	0.275	0.172	0.425	0.866	0.583	0.148	0.839	0.991	0.055	0.001	0.431	0.456	0.595	0.875
Farmer Education	0.11	0.013	-0.06	-0.118**	0.075**	0.104***	0.017	0.156***	0.059	-0.041	0.048	0.148***	0.019	0.772***
	0.068	0.03	0.042	0.033	0.030	0.040	0.044	0.030	0.044	0.036	0.031	0.074	0.045	0.176
	0.106	0.656	0.153	0.000	0.012	0.009	0.695	0.000	0.182	0.246	0.126	0.045	0.672	0.000
Famer Specialization	0.036	0.139	-0.532	-0.414***	-0.367	-0.449**	0.096	0.645*	0.195	0.076	-0.149	-0.018	-0.860	-0.018
	0.418	0.223	0.395	0.209	0.256	0.22	0.22	0.384	0.286	0.247	0.382	0.215	0.533	0.338
	0.932	0.533	0.178	0.048	0.153	0.042	0.662	0.093	0.496	0.757	0.697	0.935	0.107	0.957
Higher Education of Family Member	-	-	0.167	0.362***	-	-	-	-	-	-	-	-	-0.060	-0.100**
	-	-	0.026	0.033	-	-	-	-	-	-	-	-	0.174	0.044
	-	-	0.000	0.000	-	-	-	-	-	-	-	-	0.730	0.025
Family member Specialization	0.102	1.055***	-	-	-0.056	0.054	-0.047	-0.096	0.336	-0.460***	-0.177	0.877***	-20.302	0.486*
	0.139	0.383	-	-	0.206	0.14	0.166	0.187	0.233	0.165	0.146	0.290	2555.34	0.280
	0.463	0.006	-	-	0.784	0.702	0.779	0.608	0.148	0.005	0.224	0.003	0.994	0.082
Experience of Farming	-	-	0.011	0.000	-	-	-	-	-	-	-	-	0.009	0.019
	-	-	0.018	0.012	-	-	-	-	-	-	-	-	0.044	0.018
	-	-	0.548	0.982	-	-	-	-	-	-	-	-	0.844	0.283
Household Member Employment	0.318	4.246***	0.03	-1.228***	0.523	0.394*	0.181	1.324***	-0.763*	0.762**	0.154	2.103***	1.072	0.11
	0.217	0.694	0.244	0.288	0.329	0.22	0.312	0.262	0.432	0.306	0.232	0.537	2.435	0.329
	0.142	0.000	0.903	0.000	0.112	0.073	0.563	0.000	0.077	0.013	0.507	0.000	0.66	0.738
Livestock Ownership	-0.139	0.268	-0.282	0.284	0.191	2.127***	-0.484	-0.06	0.003	0.348	1.358	-0.006	1.391	-0.366
	0.756	0.238	0.344	0.203	0.247	0.634	0.336	0.332	0.502	0.292	0.93	0.255	1.424	0.349
	0.854	0.26	0.414	0.163	0.438	0.001	0.15	0.857	0.995	0.233	0.144	0.982	0.328	0.295
Farm Size	0.035	0.007	-0.022	-0.001	0.072***	0.060***	-0.016	0.074**	0.01	-0.053***	0.008	0.069***	0.014	0.01
	0.027	0.016	0.014	0.013	0.016	0.018	0.013	0.029	0.02	0.018	0.016	0.025	0.032	0.024
	0.191	0.636	0.122	0.908	0.000	0.001	0.227	0.010	0.612	0.003	0.618	0.006	0.67	0.692
Tenancy Status	-1.059*	-0.258	0.083	0.373*	-0.34	-0.048	0.147	-0.499**	-0.199	0.551**	-0.676	0.21	-0.505	-0.055
	0.562	0.183	0.177	0.205	0.272	0.183	0.187	0.223	0.308	0.257	0.546	0.186	0.965	0.254
	0.059	0.159	0.638	0.069	0.211	0.795	0.433	0.025	0.519	0.032	0.216	0.259	0.601	0.827
Soil Type	-0.395	-1.146**	0.043	-0.278	-0.122	0.466*	0.005	-0.297	-0.396	1.249***	-1.187	-0.454	-0.827**	2.278*
	0.723	0.325	0.379	0.292	0.436	0.278	0.289	0.355	0.479	0.474	1.085	0.340	0.334	1.262
	0.585	0.000	0.909	0.341	0.78	0.093	0.986	0.403	0.408	0.008	0.274	0.182	0.013	0.071
Soil Fertility	1.113*	0.827***	-0.104	0.152	0.503	0.358	-0.533**	0.07	-1.401***	1.781***	-0.339	0.932***	1.165	0.747*
	0.574	0.241	0.329	0.255	0.306	0.24	0.257	0.319	0.493	0.445	0.601	0.235	0.84	0.403
	0.053	0.001	0.751	0.55	0.101	0.136	0.038	0.826	0.004	0.000	0.572	0.000	0.165	0.064
Knowledge of Agriculture Officer	-	-	0.072	1.116*	-	-	-	-	-	-	-	-	-	-
	-	-	0.349	0.651	-	-	-	-	-	-	-	-	-	-
	-	-	0.837	0.086	-	-	-	-	-	-	-	-	-	-

Continue Table 2:

Agriculture Extension Officer Contact	0.435	0.359	-	-	-0.11	2.227***	-0.09	0.509	-0.836	0.069	0.27	-0.053	0.218	-0.192
	0.868	0.366	-	-	0.477	0.489	0.391	0.545	0.567	0.438	0.679	0.365	0.741	0.653
	0.616	0.327	-	-	0.817	0.000	0.819	0.35	0.141	0.875	0.691	0.884	0.768	0.769
Visits to agriculture extension Officer	-	2.159***	-0.401	-0.526	-	-	-2.611	0.292	-0.716	1.233**	-	-	-	-
	-	0.670	0.587	0.499	-	-	1.837	0.817	0.584	0.604	-	-	-	-
	-	0.001	0.494	0.291	-	-	0.155	0.72	0.22	0.041	-	-	-	-
Participation of Local Discussion	-1.851	-1.521	-	-	1.73	0.294	1.702	-0.76	-1.918	2.211*	-	-	-	-
	6.313	1.178	-	-	1.425	1.401	1.336	1.26	1.279	1.306	-	-	-	-
	0.769	0.197	-	-	0.225	0.834	0.203	0.547	0.134	0.09	-	-	-	-
Radio Ownership	0.482	0.282	-0.383	0.469*	0.248	-0.198	0.014	-1.217***	-0.188	0.461	0.78	0.149	0.701	0.647
	0.679	0.287	0.514	0.283	0.376	0.297	0.304	0.412	0.406	0.355	0.596	0.298	0.936	0.499
	0.477	0.326	0.456	0.097	0.509	0.504	0.962	0.003	0.643	0.194	0.191	0.616	0.454	0.195
TV Ownership	-0.614	-0.274	-0.307	-1.059***	-0.616*	-0.057	-0.097	0.195	0.126	0.014	-0.42	-0.068	0.504	0.984**
	0.639	0.248	0.241	0.393	0.363	0.251	0.254	0.343	0.362	0.308	0.583	0.259	0.647	0.465
	0.336	0.268	0.203	0.007	0.090	0.819	0.703	0.57	0.728	0.964	0.471	0.792	0.436	0.034
Newspaper Reading	0.41	-0.551	-0.907	-0.291	-0.669	-0.263	0.095	0.068	-0.152	0.604	0.017	-0.363	0.778	-0.183
	0.718	0.34	0.593	0.328	0.508	0.354	0.348	0.499	0.518	0.483	0.71	0.363	0.677	0.498
	0.568	0.105	0.126	0.376	0.187	0.458	0.786	0.892	0.769	0.212	0.981	0.318	0.251	0.712
Constant	-1.262	-8.763***	-0.574	-1.913*	-5.451***	-2.57***	0.996	1.512	0.518	-3.962***	-4.219***	-2.845***	-14.376***	3.754*
	0.775	2.065	0.775	1.019	1.205	0.768	0.838	1.005	1.45	1.232	2.090	0.801	3.323	2.262
	0.103	0.000	0.459	0.061	0.000	0.001	0.235	0.132	0.721	0.001	0.044	0.000	0.00	0.097

Source: Own Estimation Result, 2006-07 & 2018-19, The values in each variable represents coefficients, standard error (SE) and p-value while asterisks describe significance level (*, 10%), (**, 5%), (***, 1%)

The overall logistic results of determining factors of technology adoption are age of the farmer's head, family size, farmer education level, farmer specialization, higher education of family member, family member specialization, household member employment, farm size, tenancy status, soil type, soil fertility, knowledge of agriculture officer, agriculture extension officer contact, number of visits to agriculture extension officer, participation in local discussion, radio ownership, and television ownership. The study has also investigated the marginal effects from the logistic model which are presented in Table 3.

Results indicate that marginal effects significantly vary across technology adoption. The household member employment, livestock ownership, knowledge of agriculture extension officer contact, radio ownership, television ownership, and newspaper reading has positive significant effects on the probability of agriculture technologies adoption.

The positive significant factors on the probability of improved seed technology adoption during the base period 2006-07 are household member employment, agriculture extension officer contact, radio ownership, and newspaper reading while during 2018-19, household member employment, livestock ownership, agriculture extension officer contact, radio ownership increases the probability of its adoption in the district Faisalabad, Pakistan. On the other hand, during 2006-07, livestock ownership reduces the probability of its adoption while farmer participation in the local discussion also reduces its adoption probability during 2018-19.

The farm mechanization technology adoption factors that increase its probability of adoption are household member employment, livestock ownership, knowledge of agriculture extension officer contact, and radio ownership. The base period (2006-07) indicates that only knowledge of agriculture extension officers increases its adoption probability while household member employment, livestock ownership, radio ownership, television ownership, and newspaper reading reduce the probability of its adoption in the area. The end line period (2018-19) measures the changes in probability adoption factors. The positive significant adoption probability factors are household member employment, livestock ownership, knowledge of agriculture officers, and radio ownership. While the negative significant probability adoption factors are television ownership and newspaper readings during 2018-19.

The factors that increase the adoption probability of irrigation technologies in the area are household member employment, livestock ownership, agriculture extension officer contact, participation in local discussion, and radio ownership. The factors that increase irrigation technologies adoption vary across technologies and periods (2006-07 & 2018-19). Household member employment, livestock ownership, and participation in local discussions have positive effects on the probability of adoption of irrigation technologies in both years (2006-07 & 2018-19). While agriculture extension officer contact has positive effects on this technology adoption during 2018-19 and radio ownership during 2006-07. Radio ownership has negative effects on the probability of technology adoption during 2018-19 while television ownership and newspaper reading in both years, respectively.

Under access to improved electricity adoption, various factors affect the probability of its adoption. Livestock ownership and radio ownership have positive significant effects on the probability of this technology adoption in both years respectively (2006-07 & 2018-19). During 2006-07, participation in local discussion has significant positive effects on its adoption probability while household member employment, agriculture extension officer contact, radio ownership, and newspaper reading have positive significant effects on its adoption probability in 2018-19, respectively.

Table 3: Marginal Effects of Agriculture Technology Adoption (2006-07 & 2018-19)

Variables	Improved Seed Adoption		Farm Mechanization Adoption		Water Irrigation Adoption		Fertilizer Usage Adoption		Access to Improved Electricity Adoption		Internet/Social Media Access Adoption		Mobile Phone Access Adoption	
	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19	2006-07	2018-19
Age of farmer head	0.000	0.000	-0.001	0.000	0.001	-0.001	-0.003	0.001	-0.003	0.002	0.000	0.001	0.000	-0.003
Family Size	0.002	0.025	-0.011	-0.003	0.007	0.026	-0.005	0.000	0.039	-0.021	0.002	-0.010	0.000	0.001
No. Of Adult Members	-	-	-	-	-	-	-	-	-	-	-	-	0.000	-0.031
Farmer Education	0.001	0.003	-0.008	-0.029	0.011	0.019	0.039	0.002	0.004	-0.005	0.002	0.009	0.000	0.002
Famer Specialization	0.000	0.035	-0.068	-0.100	-0.038	-0.112	0.024	0.073	0.015	0.010	-0.002	-0.003	0.000	-0.002
Highest Edu. of family member	-	-	0.046	0.041	-	-	-	-	-	-	-	-	0.000	-0.009
Family member Specialization	0.008	0.025	-	-	-0.006	0.013	-0.012	-0.011	0.025	-0.057	0.012	-0.035	0.000	0.046
Experience of Farming	-	-	0.001	0.000	-	-	-	-	-	-	-	-	0.000	0.002
HH-Member Employment	0.175*	0.079*	-0.125*	0.007*	0.061*	0.098*	0.316*	0.020*	-0.049*	0.082*	0.059*	0.031*	0.000*	0.010*
Livestock Ownership	-0.001*	0.066*	-0.039*	0.070*	0.122*	0.048*	-0.120*	-0.007*	0.000*	0.046*	-0.001*	0.012*	0.000	-0.032*
Farm Size	0.000	0.002	-0.003	0.000	0.007	0.015	-0.004	0.008	0.001	-0.007	0.001	0.002	0.000	0.001
Tenancy Status	-0.008	-0.064	0.048	0.020	-0.035	-0.012	0.036	-0.057	-0.015	0.069	-0.009	0.041	0.000	-0.005
Soil Type	-0.003	-0.286	0.006	-0.067	-0.013	0.116	0.001	-0.034	-0.030	0.156	-0.016	-0.089	0.000	-0.078
Soil Fertility	0.009	0.206	-0.013	0.037	0.052	0.089	-0.133	0.008	-0.106	0.222	-0.005	0.184	0.000	0.070
Knowledge of Agri. officer	-	-	0.192*	0.017*	-	-	-	-	-	-	-	-	-	-
Agri. extension officer contact	0.004*	0.089*	-	-	-0.011*	0.440*	-0.022*	0.049*	-0.048*	0.008*	-0.010*	0.004*	0.000	-0.019*
Visits to Agri. extension Officer	0.017	-	-0.051	-0.127	-	-	-0.649	0.033	0.094	-0.089	-	-	-	-
Participation of Local Discussion	-0.007*	-0.311*	-	-	0.310*	0.073*	0.363*	-0.112*	0.367*	-0.390*	-	-	-	-
Radio Ownership	0.004*	0.070*	-0.045*	0.110*	0.027*	-0.049*	0.004*	-0.182*	-0.014*	0.052*	0.016*	0.030*	0.000*	0.052*
TV Ownership	-0.004*	-0.068*	-0.106*	-0.075*	-0.055*	-0.014*	-0.024*	0.021*	0.010*	0.002*	-0.005*	-0.013*	0.000*	0.072*
Newspaper Reading	0.004*	-0.133*	-0.088*	-0.072*	-0.056*	-0.065*	0.024*	0.008*	-0.011*	0.062*	0.000	-0.066*	0.000*	-0.018*

Source: Own Estimation Result, 2006-07 & 2018-19 Marginal Effects dy/dx

The negative significant effects of its adoption probability are household member employment, agriculture extension officer contact, radio ownership, and newspaper reading during 2006-07. While there are no negative significant factors found during 2018-19. Household member employment and radio ownership have positive effects on the probability of adoption of internet/social media access in both years (2006-07 & 2018-19). Livestock ownership and agriculture extension officer contact have positive effects on this technology adoption probability during 2018-19.

Television has a significant negative factor of technology adoption probability in both periods (2006-07 & 2018-19). The other negative effects of technology adoption probability are livestock ownership and agriculture extension officer contact during the base period (2006-07) in the district. Mobile phone access adoption is also an important technology tool for the agriculture sector including timely information as well as weather and other crops-related information with minimum or no cost. Household member employment, radio ownership, and television ownership have positive effects on the probability of technology adoption in the area for both periods (2006-07 & 2018-19). The negative significant technology adoption probability factors are livestock ownership, agriculture extension officer contact, and newspaper reading that reduces technology adoption.

5. CONCLUSION AND POLICY IMPLICATIONS

This study uses primary data collected from two time periods 2006-07 and 2018-19 respectively to assess the potential factors determining agriculture technology adoption in the district of Faisalabad, Pakistan. The seven agriculture technologies were considered for analysis for both periods. In this study, the logistic regression analysis used to determine the factors responsible for technology adoption and marginal effects also estimated accordingly. There are various socio-economic, financial, and other factors responsible for its adoption over time.

The micro panel data was collected from a field survey conducted in tehsil Chak Jhumra and Sammundari district Faisalabad, Pakistan for two years (2006-07 and 20018-19). From these two tehsils, twelve villages were randomly selected with six villages from each tehsil and sixty respondents from each village. There are an estimated seven technology adoption factors responsible for its change over time.

Results show that significant factors determining technology adoption during 2006-07 are farmer education, farm size, soil type, and television ownership. On the other hand, the factors responsible for technology adoption probability are household member employment, livestock ownership, and knowledge of agriculture officer, agriculture officer contact, and participation in local discussion, radio ownership, television ownership, and newspaper reading. These factors affect technology adoption probability accordingly.

The positive and significant factors responsible for technology adoption in the district during end line period 2018-19 are the age of farmer's head, family size, farmer education, farmer specialization, higher education of family member, family member specialization, household member employment, livestock ownership, farm size, tenancy status, soil type, soil fertility, knowledge of agriculture officer, agriculture officer contact, number of visits to agriculture extension officer, participation of local discussion, radio ownership, and television ownership. These are potential and positive influencing factors in determining agriculture technology adoption in the area. The factors vary across technologies adoption.

Our findings have important policy implications in the district of Faisalabad, Pakistan. The results suggest that farmer pieces of training regarding new and improved technologies are necessary to increase its adoption rate in the area because the adapters don’t have any opportunity of training in the area that needs to be developed and promoted to increase the adoption rate in the area. The study is based on short (only

two rounds) of panel datasets that need to be extended to capture fully dynamics and long-run effects of multiple agriculture technologies adoption in the area. The study also suggests that government facilitate the farmers to avail credit facility at the doorstep as no one has any credit facility availing. Therefore, future research should focus on adoption dynamics by taking multiple agricultural technologies using nationally representative longitudinal panel datasets.

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