SOWING THE SEEDS OF CHANGE: ASSESSING THE DETERMINANTS OF AGRICULTURAL TECHNOLOGY ADOPTION IN BANGLADESH

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Abstract

Incorporating technology in the agricultural sector can bring about positive change. In this paper, we would like to examine the determinants that are key to adopting agricultural technology in Bangladesh. The study used a probit regression model to investigate the impact of different variables on the adoption of technology. A typical farmer goes through a decision-making process when he has the option of adopting technology. If he surpasses a certain net-expected utility, which is regarded as a threshold, we can conclude that he adopts technology. The study found that factors such as electricity, connection between farmers and agricultural extension services, annual harvest, distance to the closest town and seed dealers, and loan access have significant relationships with adopting technology in the agricultural sector. Also, we observed that individuals who opted to embrace technology had a greater harvest size compared to those who didn't. This could be helpful in identifying policy focus areas for initiatives aiming to introduce new technologies.

JEL Classification: Q16
Keywords: Agriculture; Improved Seeds; Machines; Technology Adoption.

1. INTRODUCTION

Agriculture remains a key driver of economic development in Bangladesh, consistently maintaining a prominent position over the years. As Bangladesh has a high potential for producing crops and vegetables, it stands to benefit significantly from the integration of technology in its agricultural sector, leading to substantial improvements and a peak contribution of agriculture to the GDP. To achieve this objective, policymakers should actively promote the adoption of technology in agriculture so that they can ensure broad inclusion. Observing the productivity enhancements in agriculture achieved through technology adoption in wealthy and developed nations, it is imperative for Bangladesh, as a developing country, to adopt significant advancements in agricultural technology without delay.According to a study conducted by Woittiez et al. (2015), in terms of well-defined and quantitative indicators, adoption is the integration of a technology in the long term, or a fraction of technology, into the range of activities that make up a household's livelihood. The choice of businesses, farmers, or consumers to employ a new technology, approach, practice, etc. is referred to as adoption. On the other hand, Rogers (1962) defines the adoption process as "the mental process an individual passes from first hearing about an innovation to final adoption" (p. 17).

In recent times, Bangladesh has witnessed significant advancements in the adoption of agricultural technology, which have revolutionised traditional farming practices. Collaborations between the government and technology providers have been instrumental in promoting the uptake of modern agricultural technologies, making them more accessible to farmers across the country and in various regions. Leading economists have increasingly emphasised the adoption of modern machinery. Additionally, the agricultural technology startup scene in Bangladesh is flourishing, with companies developing solutions ranging from smart farming equipment to data analytics, fostering innovation within the agricultural sector. The widespread adoption of sustainable technology in agriculture could lead to an inevitable agricultural revolution in Bangladesh. As the country embraces

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technology in agriculture, there is growing optimism that these advancements will play a vital role in achieving sustainable development goals and enhancing the overall agricultural landscape. The expansion or outward shift of the Production Possibility Frontier (PPF) underscores the crucial role of agricultural technology adoption in the process of economic progress. In the context of Bangladeshi agriculture, the uptake of technology is influenced by various factors. Notably, receiving training significantly enhances adoption rates, as evidenced by a 28% increase among farmers who have undergone vermicomposting training. To further promote adoption, it is advised to focus on enhancing extension services and providing incentives to stimulate entrepreneurial activities. (Rahman & Majumder, 2021).

Farmers face numerous barriers to adopting agricultural technologies, including high costs, lack of information, poor market access, inadequate infrastructure, and limited access to complementary inputs. Other challenges include limited internet access, unfavourable policies, low awareness, insufficient training and finance, and inadequate extension and market systems. These obstacles hinder technology adoption and improved productivity. Addressing these issues requires a contextual approach focused on providing farmers with the necessary information, support, and resources to facilitate adoption. The availability and affordability of digital services are also some of the major concerns, with mobile phone ownership and connectivity being more expensive for the poor and a lack of awareness and ability to use the internet being prevalent. (Department for International Development, 2019)

In this study, we aim to investigate what forces drive the adoption of agricultural technology in Bangladesh. Our study aims to inquire into the determining factors that impact the adoption of sustainable technological practices and examine the impact of various factors on determining whether these factors have an impact on the overall yield of crops. In many instances, agricultural technologies are presented as comprehensive packages comprising various elements, such as high-yielding varieties (HYV), fertilisers, improved seeds, irrigation pumps (LLP, shallow, and deep), pesticide and fertiliser sprayers, rice transplanters, drum threshers, and corresponding cultivation practices. While these package components may work together, some can be implemented separately. Consequently, farmers are confronted with diverse technological choices, including the adoption of the entire innovation package introduced in their region or opting for subsets of the package. This situation gives rise to multiple concurrent processes of adoption and diffusion.

The existing body of knowledge has illuminated the process of adopting agricultural technologies, including machinery and enhanced crop varieties. To further enrich this understanding, our aim is to contribute by utilising household-level data (BIHS-18/19). We also aim to investigate the key factors influencing farmers' decisions to adopt technology.

This study provides valuable insights for policymakers to formulate effective strategies for adopting technology in the agricultural sector. To achieve our objectives, we have posed the following research question: "What factors drive farmers to adopt agricultural technology (machinery and improved crop varieties)?" In addressing this question, we aim to explore various dimensions, such as infrastructure, socio-economic factors, geographic accessibility, and demographics. Subsequently, we have examined how these aspects influence technology adoption.

The threshold considered in our model is net expected utility. Net expected utility indicates the overall benefit that farmers expect to gain from adopting a new technology, considering both the potential gains and the costs involved in its adoption. This concept plays a key role in farmers' decision-making processes as they assess the risks and benefits associated with adopting new technologies to maximise their expected utility. By comparing the expected benefits with the costs and risks involved, farmers can make precise decisions about technology adoption so that they can enhance their overall well-being and agricultural productivity. The consideration of net expected utility is essential in understanding the factors influencing farmers' adoption decisions and can guide policymakers and researchers in designing effective strategies to promote the adoption of sustainable agricultural innovations.

2. LITERATURE REVIEW

Various factors, such as shifting climates and floods, impact agriculture significantly. Therefore, the adoption of advanced seed varieties and mechanisation becomes imperative. According to Abdi Mohammed et al. (2023), some of the important factors, for example, household head's education, size of the farm, availability of extension services, size of the land, and livestock, have a positive impact on the adoption of sustainable agricultural intensification methods. On the other hand, the age of the household head and the media have a negative effect on adoption. He also highlighted the significance of enhancing education coverage and designing participatory approaches to involve farmers in education. However, this paper does not provide information on the specific criteria that has been adopted for selecting the sample households, which could be a source of bias in the analysis. Moreover, it does not explore the potential barriers or challenges faced by farmers in adopting advanced technological practices. Magruder (2018) analysed that input credit, where inputs can be borrowed and repaid at a specific rate, plays a very significant role in promoting technology adoption compared to solely credit constraints. He also concluded that strong informational frictions are very prevalent and widespread in the adoption of agricultural technology in developing countries.

In another study conducted by Juanwen and Niehof (2011), it was found that female farmers face more challenges in accessing information compared to male farmers, which helped them analyse the disparities between male and female in accessing extension services related to agriculture. They also found out that different groups of people, especially farmers, get information about technology through various sources, such as self-searching, reading related materials, and interacting with other farmers who are familiar with agricultural technology. Also, credit access, education, and extension services contribute to promoting technology adoption and agro-innovation. The intervention and support of the government in this regard are necessary for successfully implementing agricultural productivity-enhancing measures (Smale, 2005). Technologies in agriculture, for example, genetic engineering and IT have the potential to revolutionise the agricultural industry and significantly impact the structure of agriculture. However, these technologies can have an adverse impact on the environment and natural resources, which is a significant concern (Lu, 1985). A study conducted by Xiang and Guo (2023) suggests that local governments can provide ecological compensation and subsidies of certification so that farmers are encouraged to adopt GCT (Green Control Techniques). As suggested by Juma et al. (2013), sustainable intensification, or SI, implies the use of agricultural inputs and techniques that maximise the effective use of resources while enhancing production. This strategy seeks to boost environmental services, build resilience, and reduce environmental harm all at the same time, side by side with increasing productivity.

Furthermore, farmers who adopt sustainable intensification practices—such as improved crop varieties, improved infrastructure in irrigation, and advances in cultivation techniques—are better able to maintain productivity, reduce environmental stress, and shift from growing subsistence crops to ones that are commercially viable. (Mariyono & Sumarno, 2015). According to Dybvig and Spatt (1983), the costs and advantages of adopting technology may depend on the number of users due to economies of scale. Feder (1980), mentioned that aversion to risk is one of the major factors that hinders the adoption of new technologies by farmers in their survey of technology adoption. As the economic condition of farmers is not that stable in Bangladesh, any negative shock can have a significant impact on their lives. Thus, to avoid uncertainty, they sometimes tend not to adopt technology and follow conventional methods of cultivation. Clay (1975) and Mann (1977) found that all of the current individual technology adoption models that have been examined so far are based on the idea that a farmer chooses one contemporary technology, and then they have to decide whether and how much to use that technology.

However, in reality, contemporary agricultural technologies are frequently presented as all-inclusive bundles consisting of several components. Even though these elements could be complementary to one another, adopting them all at once is not required. For this reason, the farmer must make a choice between multiple unique configurations of contemporary parts contained in a technical package.

Farmers make technological decisions based on their subjective and individual probability assessments, and consequently, they make decisions based on the information they are exposed to about new and innovative technologies. Farmers in Tunisia are more likely to accept newly developed native varieties than unfamiliar imported varieties of crops, as demonstrated by Gafsi and Roe's (1979) research. A related theory mentions that subjective uncertainty is decreased by increasing exposure to relevant information across a variety of communication channels. The main and crucial challenge is to identify how much information farmers tend to have. Though technology adoption has contributed to an increase in productivity, a decrease in poverty, and an improvement in living standards, farmers in developing nations have been sluggish in adopting advanced technology, and they are incompletely adopting new and improved technologies (Barrett and Carter (2010); Bandiera and Rasul (2006); Dadi et al. (2004)). This has left policymakers perplexed and confused (Fuglie and Kascak (2001); Suri (2011)). In another context, Hu et al. (2022) has shown some evidence in China that larger farms are susceptible to adopting new technology and willing to spend more on generating agricultural knowledge than small farms. On the contrary, there is no ubiquitous relationship between farm size and the adoption of technology. Moreover, the varying adoption rates by farm size might be influenced by economies of scale and the specific requirements of different technologies.

According to Lindner et al. (1980), the interval between awareness and adoption of technology is favourably correlated with the variance of the actual profit and inversely correlated with the mean profitability of the new technology. A shorter and smaller lag in adoption is also linked to a higher initially targeted average profit and low initial variability. There is a positive association between increasing production and income, which in turn affects GDP growth. A similar kind of study has been conducted by Muluneh et al. (2022) and Abafita et al. (2016), Societies in developing countries that heavily rely on the agricultural sector must transition from subsistence farming to a commercial orientation in order to promote economic growth and development. Participation by farmers in vegetable farming training sessions shortens the adoption time, indicating that educating and training farmers is a useful strategy for boosting IPM (Integrated Pest Management) adoption. The timing of IPM (Integrated Pest Management) adoption is significantly influenced by factors linked to information distribution, farmers' perceptions of the use of IPM, and non-economic traits like age and education. Conversely, adoption decisions are not influenced directly by economic concerns (Ahsanuzzaman, 2014). Although previous studies explored this theme in different contexts across different countries, we are going to explore the same theme in the context of Bangladesh. We have taken more variables and found some similar and dissimilar significant relationships between explanatory variables and technology adoption. Furthermore, while studies have identified challenges such as inadequate extension services, poor market systems, and high costs as barriers to adoption, there is a need for more research on the specific constraints faced by farmers in adopting agricultural technologies. Therefore, there is a need for a more comprehensive understanding of the factors influencing the adoption of agricultural technologies in Bangladesh.

3. METHODOLOGY

3.1 DATA

The Bangladesh Integrated Household Survey (BIHS) dataset, which is comprehensive and covers the entire nation, has been utilised in this study to examine various factors. The dataset includes three rounds of surveys conducted in 2011/12, 2015, and 2018/19, with the same samples used in each round, making it a panel dataset. This dataset provides insights into various aspects of poverty, food security, and agricultural development in Bangladesh, with a focus on rural areas. The data was collected from all divisions of Bangladesh, including Dhaka, Barishal, Sylhet, Khulna, Rangpur, Rajshahi, and Chattogram, and covers 5604 households in 325 primary sampling units (PSU). The latest BIHS dataset from 2018/19 has been used in this study, leading to a cross-sectional analysis.

3.2 METHOD

We applied quantitative methods to examine the significant determinants influencing the adoption of technology, seeking empirical evidence for these factors. Policymakers heavily rely on empirical data for understanding current circumstances, predicting outcomes, assessing policy impacts, and conducting cost-benefit analyses. Quantitative methods play a crucial role in analysing how farmers embrace emerging agricultural technologies because they enable researchers to measure specific factors, extrapolate conclusions for larger farmer populations, and delve into significant relationships. These methods help to narrow down characteristics and uncover underlying relationships crucial for modernising agricultural production. Although modernization involves intricate interactions between socioeconomic and behavioural factors, empirical measures concerning production and demographics capture the core of farmers' decision-making processes. Recognising broader structural contexts reveals commonalities in individual farmers' production decisions, providing valuable insights for policy interventions aimed at accelerating the modernization process.

Our objective is to empirically assess the importance of infrastructure, socioeconomic status, geographic accessibility, and demographic factors in shaping farmers' choices regarding the adoption of agricultural technology. We consider various facets of agriculture in our analysis. We conducted a probit regression using data from the BIHS 2018/19 survey to investigate agricultural technology adoption and its influencing factors.

The probit model is a model where the dependent variable has two categories [1, 0]. Probit analysis is based on the cumulative normal probability distribution. The dependent variable (y) is dichotomous variable. This analysis provides statistically significant findings about which factors influence (increase or decrease) the probability of agricultural technology adoption among farmers.

It's assumed that if the ith farmer obtains maximum net-expected utility, they prefer to adopt technology rather than using conventional cultivation methods. The probability pi of choosing technology in the cultivation process can be expressed as in (1), where φ represents the cumulative distribution of a standard normal random variable.

Here, the predictor Y_i can be written as:

$$Y_i = X_i\beta + \epsilon_i \qquad \textbf{(1)}$$

Y_i denotes the adoption of technology among farmers, with the likely values of 1 for adopting and 0 for not adopting technology. In this case, $X_i = [1, X_{i1}, X_{i2},\ldots\ldots., X_{ik}]$ is a vector that contains the variables in this study that can have an impact. $B= [\beta_1, \beta_2, \beta_3,\ldots\ldots\ldots., \beta_k]$ expresses the coefficients that are associated with the variables. Also, ϵ_i represents the stochastic term.

$$p_i = \text{prob}\,[Y_i = 1 \mid X_i] = \int_{-\infty}^{x_i'\beta} (2\pi)^{-.5} \exp\left(-\frac{z^2}{2}\right) dz$$

$$= \Phi(X_i'\,\beta)$$

$$\&\ \ p_i = \text{prob}\,[Y_i = 0 \mid X_i] = 1 - \Phi(X_i'\,\beta)$$

We can observe the relationship between a specific variable and the outcome of the probability by means of the marginal effect, which accounts for the partial change in the probability. In this model, r^2 is not given much importance because it is not an effective measure of goodness of fit, so statistical significance is given more importance while doing analysis.

This analysis provides statistically significant findings about which factors influence (increase or decrease) the probability of agricultural technology adoption among farmers. In our paper, we hold the assumption that infrastructure variables (total farm size and electricity connection), geographic access (distance variables and extension services), socioeconomic variables (annual harvest and loan), and demographic variables (gender, age, and years of education) of the farmers affect the preferences for adopting technology in the farming process.

Apart from gender and age, all of these are household-level variables. We have used Stata 17.0 to apply econometric analysis in this regard. Here, the dependent variables are *mod_seed_use* (whether farmers used improved seeds or HYV) and *mod_machine_use* (whether farmers used modern machines in their cultivation process). Thus, we intend to run separate regression models for these two dependent variables to estimate results for improved seed usage and technology usage, respectively.

The regression models of this paper are-

$$P(mod\_seed\_use=1)= \Phi(\alpha+\beta_{i1}(infrastructure\ variables)+\beta_{i2}(geographical\ access\ variables)+ \beta_{i3}(\text{socioeconomic variables})+ \beta_{i4}(\text{demographic variables})+\epsilon_{i1}) \quad (4)$$

$$P(mod\_machine\_use=1)= \Phi(\alpha+\beta_{i1}(infrastructure\ variables)+\beta_{i2}(geographical\ access\ variables)+ \beta_{i3}(socioeconomic\ variables)+ \beta_{i4}(demographic\ variables)+\epsilon_{i2}) \quad (5)$$

4. RESULTS OF THE PROBIT ANALYSIS

In this section, we have shown the results of the probit model analysis. Different independent variables have different effects on the adoption process of modern machines and improved seeds. We have tested seventeen independent variables to know whether they are statistically significant or not. The probit regression analysis can help us explain the significance of these variables. The parameters of the probit model are estimated by the traditional maximum likelihood method.

In our regression results, we see that there are different significant variables for agricultural machinery usage and seed usage.

At first, the results of modern machines are depicted. Then, we'll discuss seed usage patterns. We hold the level of significance at 5% or 0.05 while interpreting our results. At first, our regression analysis indicated that neither the gender nor the age of household members significantly influence the adoption of agricultural technology. Several potential explanations exist for this finding. Cultural norms, social structures, and economic conditions in the agricultural sector may influence the relevance of gender and age in technology adoption decisions. Additionally, the adoption pattern may be consistent across different demographic groups. This lack of significance holds true for both machinery and improved seed usage patterns.

Table 4.1: *Regression Results*

	mod_machine_use	mod_seed_use
gender	0.035	0.002
	(0.326)	(0.033)
age	0.001	0.000
	(0.412)	(0.278)
yrs_educ	0.018	0.011*
	(1.328)	(1.861)
tot_farm_size	0.003**	-0.000
	(1.967)	(-0.535)
electricity	-0.136	0.140*
	(-0.784)	(1.708)
agri_ext_cont	(.)	0.170***
	(.)	(3.117)
ln_harvest	0.441***	0.212***
	(12.003)	(7.032)
dist_seed_dealer_hhld	0.024	0.031***
	(0.796)	(2.850)
dist_town_hhld	0.020***	-0.005*
	(2.914)	(-1.824)
ln_loan	-0.003	-0.078***
	(-0.063)	(-4.073)
_cons	-1.047*	-2.806***
	(-1.853)	(-8.964)
N	6135	8117

Note: (⋆ ⋆ ⋆), (⋆ ⋆), (⋆) denote significance at the 10%, 5%, and 1% levels, respectively.

Source: Author's calculations.

Furthermore, when we observe years of education, we see that it is insignificant to modern machine use but significant (at 10%) to modern seed use. Modern seed varieties generally require specific knowledge. If farmers have higher number of years of education, there is a greater possibility of understanding and implementing the complex requirements of modern seed use. On the other hand, the adoption of modern machineries may be influenced by other determinants than years of education alone. Also, modern machineries require practical and hands-on skills, so formal education might not have significant impact here.

The significance of total farm size as a factor in agricultural technology adoption can be attributed to several potential reasons. Larger farms often have greater financial resources and economies of scale, making it easier for them to invest in and implement new agricultural technologies. Wordofa et al. (2021) suggested that households that have more resources are likely to have better access to information, which can have an impact on their adoption of agricultural technology. Using new varieties of seeds requires a lower amount of cost; however, to adopt modern machines, farmers need more knowledge and resources. Additionally, larger farms may have better access to information, training, and extension services related to new technologies. The risk associated with adopting new technologies can also be more manageable for larger farms due to their ability to diversify production and absorb potential losses. Furthermore, certain technologies may be more suitable or cost-effective for larger farm operations, incentivizing their adoption by farmers with larger landholdings. Ultimately, farm size can influence factors such as access to capital, information, and risk management capabilities, which in turn impact the ability and willingness of farmers to adopt new agricultural technologies. However, the insignificance of total farm size as a factor in the adoption of improved seed varieties suggests that this particular technology may be scale-neutral. Improved seeds are often developed to be suitable for a wide range of farm sizes, allowing both small and large-scale farmers to benefit from their potential yield increases and other desirable traits. Additionally, the cost of improved seeds may be relatively affordable, making them accessible to farmers regardless of their landholding size.

In 2023, the government of Bangladesh has declared 100% electricity coverage throughout the country. The significance of electricity access for improved seed adoption can be attributed to the fact that certain aspects of cultivating improved seed varieties, such as irrigation systems, storage facilities, or processing equipment, may rely on a consistent electricity supply. On the other hand, the insignificance of electricity for modern machine adoption could be because many agricultural machines are designed to operate independently of an electricity source, relying instead on fuel.

Electricity is really important in pre-harvest irrigation, post-harvest handling, and other processing activities of crops. We can describe that households with an electricity connection are prone to adopting agricultural technology, particularly improved seeds, and electricity facilitates communication channels such as the Internet, mobile phones, and radio, which play a crucial role in disseminating agricultural information, providing extension services, and connecting farmers with markets, suppliers, and agricultural experts.

Access to agricultural extension officers proves to be essential. In the case of modern machinery usage, this variable is found to be a perfect predictor of success, resulting in its exclusion from the regression results. In other words, all individuals who have had contact with agricultural extension officers have successfully adopted agricultural technology, or vice versa. Farmers actively seek guidance, assistance, and resources from these officers, who, in turn, provide technical expertise and advice. This assistance enables farmers to comprehend the benefits and costs associated with adopting machinery and utilising improved seeds, ultimately contributing to increased crop yields.

The amount of harvest is positively related to the adoption of agricultural technology. It is observed that at the 5% level of significance, we have got significant relationships between the amount of harvest and the adoption of agricultural technology (machines and improved seeds). According to Mwangi and Kariuki (2015), as the amount of harvest increases, it leads to an increase in the income of farmers, providing the financial means for farmers to spend and adopt technologies, including machines and HYV. Thus, farmers with higher harvest yields may have greater financial resources and incentives to invest in improved agricultural technologies that can further enhance their productivity and profits. The adoption of improved seed varieties often requires complementary inputs and management practices, which may be more feasible for farmers with larger harvest sizes. Similarly, the substantial capital investment required for modern machinery can be more justifiable and recoverable for farmers with larger operational scales and higher harvest volumes. Additionally, farmers with larger harvests may have better access to information, credit, and extension services, enabling them to explore and adopt productivity-enhancing technologies more effectively. Ultimately, the potential for increased returns and the ability to absorb the associated costs make harvest size a critical determinant in the adoption of both seed and machinery innovations.

Conversely, efficiency becomes a pertinent consideration in this context. Utilising multiple technologies enables farmers to accomplish a substantial amount of work within a small timeframe, thereby alleviating both psychological and physical strain and enhancing the farming process. Furthermore, in order to meet the demands of Bangladesh's expanding population, augmenting harvest yields with the existing resources becomes imperative. In our research, we have used the natural logarithm of this variable for mathematical convenience.

The significance of outstanding loans in relation to improved seed adoption could be attributed to the relatively lower capital requirements for purchasing improved seeds compared to modern machinery. Farmers with access to credit or outstanding loans may be more inclined to use those funds for adopting improved seed varieties, as the investment is relatively lower and can potentially lead to increased yields and returns in the short term. However, the acquisition of modern machinery often demands a substantial capital investment, which may not be feasible or practical for farmers with limited outstanding loans. Credit is a fantastic way to expand agricultural operations, but this negative coefficient tells us that credit is being used unproductively or for survival.

Living close to a town significantly affects farmers' decisions to adopt agricultural machinery and improved seeds. Towns provide convenient access to crucial resources like agro dealers, diverse markets, and other services, which are vital for enhancing farming activities. This convenience greatly influences farmers' adoption of advanced farming technologies, as it offers them essential support and benefits for their agricultural operations. The significance of the distance to seed dealers for improved seed adoption highlights the importance of access and proximity in the diffusion of this technology. Improved seeds often require timely availability and may have a shorter viable planting window, making the distance to seed dealers a crucial factor. Farmers located farther away from seed dealers may face challenges in accessing improved varieties, leading to lower adoption rates. However, the acquisition of modern machinery is typically a more infrequent and planned investment, where the distance to machinery dealers or suppliers may not be as critical. Farmers can plan and arrange for the transportation of machinery over longer distances or opt for alternative procurement channels.

5. LIMITATIONS OF THE STUDY

The study faced some challenges that had to be addressed. Due to constraints on time and funding, our research was carried out using secondary data sources rather than collecting primary data directly. While this approach had certain limitations, it allowed us to conduct the research within the practical boundaries defined by the available resources. Due to recall bias, it cannot be stated perfectly that all the respondents gave accurate information. Also, there's an issue with external validity or generalising this result for the entire population of Bangladesh because the sample size is not very large. That being said, we have tried to focus on some areas in order to let practitioners and policymakers know where to give importance over timeNext, the dataset we have used is rural representative, so we might not get to see the complete picture by using only quantitative analysis. The behavioural process that the farmers who choose to adopt agricultural technology go through before taking the decision of adoption cannot be identified by quantitative method. This is a limitation of this dataset. Additionally, to corroborate the significant variables, we must do further study with an even larger dataset to strengthen the overall knowledge. Additionally, we are using observational data in order to find associations between different factors and the modernization of agriculture. This is not strong enough to imply a causal relationship because we cannot intervene in this process and intentionally vary any statuses. We have taken access variables, not any exogenous intervention variables, so there is no room for quasi-experimental feature in this study. We cannot imply causation in our model, so interpreting the significant variables might be tricky. Also, it is a challenging thing to make a bridge between the results of this paper and policymakers. Moreover, although we are able to see the downstream impact of modernization of agriculture, the upstream impact is missing. Regional implications, where policy attention should be given, are missing in this study.

6. CONCLUSION AND POLICY IMPLICATION

This research highlights the multifaceted nature of factors influencing the adoption of agricultural technologies among farmers. The significance of electricity access underscores the importance of reliable power supply in enabling the use of certain technologies, such as irrigation systems, storage facilities, and processing equipment. Furthermore, the strong connection between farmers and agricultural extension services emerges as a crucial determinant, emphasising the role of knowledge dissemination, training, and advisory support in facilitating technology adoption. The study also reveals that farmers with larger annual harvests are more likely to adopt new technologies, possibly due to their greater financial resources and potential for higher returns on investment. Additionally, proximity to towns and seed dealers plays a significant role, as shorter distances enhance access to inputs, information, and markets, thereby promoting technology adoption. Finally, the availability of loans and credit facilities is a key enabler, providing farmers with the financial means to invest in and implement agricultural innovations.

Policymakers and stakeholders in the agricultural sector should prioritise several interventions to promote and accelerate the adoption of agricultural technologies.

If the government of Bangladesh puts more emphasis on proving uninterrupted and inclusive uninterrupted electricity connection to all rural regions and households in the country, it can have a positive impact on the crop harvest, as farmers are more likely to adopt technology, resulting in an increase in crop production. This is because better access to electricity can play a pivotal role in farmers adopting technology. In the next phase, the government needs to allocate more budget to the Department of Agricultural Extension so that this department can increase and expand its operations. If so, there will be more extension officers who will be working and sharing knowledge about the inclusion of technology in the farming process. It should also be checked whether the existing agricultural extension service officers are performing their respective duties properly in each region. The government has been continuously making investments to promote extension activities, but households of farmers can also get information from neighbours, relatives, and friends, and only a limited range of information from the government. Thus, conducting workshops with farmers can also be a very effective step in this regard. Stronger extension networks can bridge the information gap and increase awareness about available technologies and their benefits.

Traditional sources of information remain vital for extending technology adoption. The acceptance of new technologies heavily relies on insights gleaned from neighbours as well as from reading materials like books and newspapers; hence, these factors merit consideration. Our analysis reveals that adopting technology correlates with increased harvest yields and earnings per annum compared to non-adopters, underscoring the need to disseminate such findings to encourage wider adoption. Given the potential income benefits associated with technological uptake, incentivizing farmers becomes crucial. Governments could also incentivize seed, fertiliser, and pesticide dealers to support farmers in adopting technology. Additionally, enhancing supply-chain management to cater to farmers' needs and reducing dependency on intermediaries would maximise farmers' benefits. Direct access to markets should be facilitated for farmers to empower them further.

It should be made sure that the dealers can provide perfect and true information about the technological method. A significant relation between the distances of such dealers from farmers is a good indicator that providing incentives to the dealers would have a positive impact on technology adoption by farmers. There are various scopes for improvement in the proper implementation of agricultural policies. Also, targeted incentives and subsidies to encourage the adoption of specific agricultural technologies, particularly those with significant social or environmental benefits, should be considered. These incentives can help offset the initial costs and risks associated with technology adoption. Involving farmers, community leaders, and local stakeholders in the development and implementation of technology adoption programmes can enhance their relevance, acceptability, and sustainability. A participatory approach ensures that the technologies and interventions align with local needs, preferences, and constraints. Development agencies can create an enabling environment that fosters the widespread adoption of agricultural technologies, ultimately contributing to increased productivity, resilience, and sustainable development in the agricultural sector. The results from our analysis suggest that researchers and policymakers need to give thoughtful consideration to various social and economic factors before deciding on ways to increase the adoption of agricultural technologies by farmers in Bangladesh. Further research conducted in the future should concentrate on developing tools to assist farmers in their decision-making process to adopt proper technology in their agricultural methods, which can help boost their crop harvest.

APPENDIX

Table A1: *Definition of variables*

Variable	Definition	Mean	Std. Dev.
Gender	1=male; 0=female	1.526	.499
Age	Age of the member (years)	27.835	20.429
yrs_educ	Years of education	2.71	3.768
electricity	If there is electricity, then, electricity=1; 0=otherwise	.871	.335
agri_ext_cont	1=if farmers contacted agricultural extension service officers; 0=otherwise	.13	.336
tot_farm_size	The total farm size of the farmers	73.228	122.289
annual_hh_harvest	The average amount of harvest in a year (in kgs)	2433.477	4904.973
dist_seedD	Distance from households to seed dealer (in meters)	1263.813	1829.847
dist_town	Distance from households to town (in meters)	10791.836	16618.528
ln_loan	natural log of total amount of loan taken by household (in Taka)	10.642	1.371
mod_seed_use	1=if farmers used improved seeds; 0=otherwise	0.5406865	0.4983513
mod_machine_use	1=if farmers used technology; 0=otherwise	0.0260922	0.1594126

Source: BIHS 2018/19

Table A2: *Variance Inflation Factor*

	VIF	1/VIF
tot farm size	1.473	.679
ln harvest	1.379	.725
ln loan	1.113	.899
agri ext cont	1.068	.936
electricity	1.03	.971
yrs educ	1.025	.976
dist seed dealer h~d	1.016	.984
dist town hhld	1.009	.991
age	1.006	.994
gender	1.001	.999
Mean VIF	1.112	.

Source: Author's calculations

Table A3: *Pairwise Correlations*

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) gender	1.000									
(2) age	0.024	1.000								
(3) yrs_educ	0.007	-0.013	1.000							
(4) tot_farm_size	-0.026	0.035	0.089	1.000						
(5) electricity	-0.007	0.007	0.078	0.010	1.000					
(6) agri_ext_cont	-0.021	0.010	0.037	0.294	-0.006	1.000				
(7) ln_harvest	-0.013	0.026	0.046	0.505	0.046	0.184	1.000			
(8) dist_seed_deal~d	-0.021	0.022	0.041	0.200	0.063	0.159	0.116	1.000		
(9) dist_town_hhld	0.000	-0.013	0.015	0.017	-0.036	0.019	-0.030	-0.002	1.000	
(10) ln_loan	0.001	0.037	0.118	0.231	0.133	0.042	0.140	0.058	0.049	1.000

Source: Author's calculations.

Table A4: *Marginal Effects at Means*

	Marginal Effects of modern machine use	Marginal Effects of modern seed use
gender	0.000	0.000
	(0.324)	(0.033)
age	0.000	0.000
	(0.411)	(0.278)
yrs_educ	0.000	0.001*
	(1.286)	(1.863)
tot_farm_size	0.000**	-0.000
	(2.532)	(-0.536)
electricity	-0.001	0.012*
	(-0.770)	(1.710)
agri_ext_cont	0.000***	0.015***
	(.)	(3.121)
ln_harvest	0.004***	0.019***
	(3.648)	(7.315)
dist_seed_dealer_hhld	0.000	0.003***
	(0.785)	(2.852)
dist_town_hhld	0.000***	-0.000*
	(2.611)	(-1.832)
ln_loan	-0.000	-0.007***
	(-0.063)	(-4.099)
_cons		
N	6135	8117

Source: Author's calculations

Table A5: *Probit Regression (modern machine use) on STATA 17.0*

mod_machine_use	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gender	.035	.108	0.33	.745	-.177	.247	
age	.001	.003	0.41	.68	-.004	.007	
yrs_educ	-.018	.014	-1.33	.184	-.046	.009	
tot_farm_size	.003	.001	1.97	.049	0	.006	**
electricity	-.136	.173	-0.78	.433	-.476	.204	
agri_ext_cont	0	.	.	.	.	.	
ln_harvest	.441	.037	12.00	0	.369	.513	***
dist_seed_dealer_h ~d	.024	.031	0.80	.426	-.036	.085	
dist_town_hhld	.02	.007	2.91	.004	.006	.033	***
ln_loan	-.003	.042	-0.06	.95	-.084	.079	
Constant	-1.047	.565	-1.85	.064	-2.153	.06	*

Mean dependent var	0.987	SD dependent var	0.112
Pseudo r-squared	0.304	Number of obs	6135
Chi-square	254.485	Prob > chi2	0.000
Akaike crit. (AIC)	601.468	Bayesian crit. (BIC)	668.686

*** p<.01, ** p<.05, * p<.1

Source: Author's calculations

Table A6: *Probit Regression (modern seed use) on STATA 17.0*

mod_seed_use	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
gender	.002	.049	0.03	.974	-.095	.098	
age	0	.001	0.28	.781	-.002	.003	
yrs_educ	.011	.006	1.86	.063	-.001	.024	*
tot_farm_size	0	0	-0.54	.592	-.001	0	
electricity	.14	.082	1.71	.088	-.021	.302	*
agri_ext_cont	.17	.055	3.12	.002	.063	.278	***
ln_harvest	.212	.03	7.03	0	.153	.272	***
dist_seed_dealer_h ~d	.031	.011	2.85	.004	.01	.053	***
dist_town_hhld	-.005	.003	-1.82	.068	-.01	0	*
ln_loan	-.078	.019	-4.07	0	-.116	-.041	***
Constant	-2.806	.313	-8.96	0	-3.419	-2.192	***
Mean dependent var		0.047	SD dependent var			0.212	
Pseudo r-squared		0.042	Number of obs			8117	
Chi-square		130.586	Prob > chi2			0.000	
Akaike crit. (AIC)		2972.158	Bayesian crit. (BIC)			3049.176	

*** *p<.01*, ** *p<.05*, * *p<.1*

Source: Author's calculations

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