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Factors Affecting Farmer's Adoption of Hybrid Rice Varieties in Bangladesh -Regional Differences in Farmer's Union and Government Extension Services-

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Factors Affecting Farmer's Adoption of Hybrid Rice Varieties in Bangladesh

-Regional Differences in Farmer's Union and Government Extension Services-[1]

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Abstract

This study finds out socio-economic factors that affect farmers to adopt hybrid rice varieties and the level of adoption in 8 divisions, Bangladesh using Tobit model and the Double Hurdle model. In the Tobit estimation, factors such as household head age, farmer's union membership, plot size, the number of extension services by the government and NGOs, and usage of mobile for information collection positively affect the farmer's adoption rate of hybrid rice varieties. However, the results show that the signs and the coefficients of each district are different from those of the estimation including all the divisions. The estimates in Barisal district,

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the southern part of Bangladesh, are consistent with the overall estimation while the estimates in Rangpur, the northern part, are no longer consistent in terms of farmer's union membership and other factors. Also, many of significant factors that affect the adoption rate in the first stage of the Double Hurdle model are no longer statistically significant in the level of the adoption in the second stage of the model. As a result of the estimations, various socio-economic factors listed above help farmers adopt hybrid rice varieties. However, the factors no longer affect the level of the adoption. Therefore, consequent studies need to focus on the relationship between the level of adoption and socio-economic factors.

Keyword: Government extension, NGOs extension, hybrid rice varieties, farmer's organization, farmer's adoption, agricultural technology adoption, Bangladesh

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List of Abbreviations

ADB	Asian Development Bank
BADC	Bangladesh Agricultural Research Institute
BARC	Bangladesh Agricultural Development Cooperation
BRRI	Bangladesh Rice Research Institute
DIME	World Bank's Development Impact Evaluation Initiative
DPU	Demonstration Plot Evaluation
FAO	Food and Agriculture Organization
FAORAP	Food and Agriculture Organization Regional office for Asia and the Pacific
FFS	Famer Field School
FPMU	The Food Planning and Monitoring Unit
GAFSP	The Global Agriculture and Food Security Project
HRS	Household Responsibility System
HYVs	High Yielding Varieties
IRRI	International Rice Research Institute
MoA	the Ministry of Agriculture
MVs	Modern Varieties
NAEP	National Agricultural Extension Service
NAP	National Agriculture Policy

NARS	National Agricultural Research System
NGOs	Non-Governmental Organizations
OPE	Overall Project Evaluation
PSM	Propensity Matching Method
R&D	Research and Development
SA	Seed Act
SASDA	the South Asia Agricultural Development Team
SFYP	the Sixth Five-Year Plan
UNIDO	United Nations International Development Organization

1. Introduction

1.1 Background

Asia occupies approximately 60 percent of the world's population which mainly consume rice for their daily diet. FAO has expected the world paddy production in 2017 to be 758.9 million tons which are equal to 503.8 million tons milled basis (FAO, 2017). Asia plays an important role in producing rice about 680.1 million tons in 2016, more than 90 percent of the world's rice production (FAO, 2017). While there were losses in rice production from China (mainland), Viet Nam, Sri Lanka, and Malaysia due to climate-induced shortfalls, increasing absolute gains are projected in countries such as China (mainland), India, and Indonesia, where strong state-incentives are provided in rice production (FAO, 2017).

Bangladesh is one of the biggest populations around the globe, which is the 8th biggest in terms of the number of population. The country is a highly densely nation that has suffered from chronic insufficiency in rice production and depended on the import of rice. Meanwhile, Bangladesh has been overcoming the challenges through flood protection, appropriate use of agricultural inputs such

as fertilizers, improved technology adoption, use of irrigation system, and high yielding variety adoption (FAO, 2010). For the innovative agricultural technology adoption, international agricultural scientific research institutes have played an important role in the development of such technologies listed above, particularly biotechnology (FAO, 2010).

Even though Bangladesh has recently achieved an outstanding progress in rice production and has become one of the most successful countries in increasing rice production, the country has yet achieved self-sufficiency in rice. Rice production in Bangladesh increased from 13.63 million tons in 1981-92 to 31.97 million tons in 2009-2010 (Hossain et al., 2007). However, the annual rice import on average was 516,000 tons (Mottaleb et al., 2015). Bangladesh government has encouraged farmers to adopt hybrid rice since the 1990s to increase rice production for the growing demand (FAO 1997).

There have been a number of researches on hybrid rice varieties that have revealed numerous advantages of adopting High-Yielding Varieties (HYVs) of rice during the Green Revolution and improved crop management practices significantly contributed to overcoming the food security issues in Asia (Barker, 1985; Pingali et al., 1998).

Hybrid rice varieties, in general, produce 15 to 30 percent higher than modern types of rice seed (Ward & Pede, 2015). Besides, hybrid types of rice seed require only 67 percent less per acre than modern varieties in seeding rates by means of hybrid vigor and uniformity (Ward & Pede, 2015).

However, there have been a number of studies pointing out the poor rates of hybrid rice variety adoption in developing countries except for China. China is the first country commercializing hybrid rice varieties in 1970s (Virmani et al., 2002) and has expanded hybrid rice cultivated land up to 57 percent of the total rice production area (Pervez et al., 2017) . However, only 6.8 percent of the total rice cultivated area was under hybrid rice in Bangladesh, and 10 percent in Vietnam, 4.6 percent in the Philippines and India, and 4.9 percent in Indonesia (Spielman et al., 2012) even though there were strenuous government efforts to facilitate adopting hybrid rice varieties by farmers.

But, it is necessary to increase rice production in Bangladesh considering the increasing population, frequently-occurring natural disasters, and consequent rice consumption. As explained above, hybrid rice varieties can be a key component to boost agricultural productivity and the volume of yields for those countries that have

yet achieved self-sufficiency in rice production. For Bangladesh where diffusion of hybrid rice varieties has been stagnated, it is worth examining the factors that affect farmers to adopt hybrid rice varieties with socio-economic considerations.

1.2 Purpose of Study

The purpose of this study is to examine factors affecting farmer's adoption of hybrid rice varieties in Barisal and Rangpur districts, Bangladesh. The study used data obtained from World Bank Data Bank that were collected through Integrated Agriculture Productivity Projects(IAPP) Baseline Survey conducted in 2012. Using Tobit model in consideration of heteroscedasticity, this paper aims at finding out factors that affect farmer's adoption of hybrid rice varieties in Bangladesh. This study is distinguishing as it contains extension service by the government and NGOs and member of farmer's union and cooperative to explain how these socio-economic factors related to farmer's agricultural production behavior affect the adoption decision making.

This paper consists of the following contents. First, issues with hybrid rice variety adoption in neighboring countries will be

examined to compare the current status of hybrid rice variety adoption in Bangladesh. Second, factors affecting farmer's adoption on agricultural technology argued in previous researches will be discussed. Third, the history of hybrid rice variety in Bangladesh will be described. Fourth, theoretical studies, applied econometric models, and estimated results will be discussed. Lastly, implications based on the induced estimates will be suggested to help Bangladesh consider various factors affecting farmer's adoption of hybrid rice for higher rice productivity.

2. Review of Literature

2.1 Hybrid Rice Variety Adoption in Neighboring Countries

Rice productivity is a critical point to improving the living conditions of households across Asian countries (Spielman et al., 2013). Increasing rice productivity helps not only contributing to food security, but also benefiting rural areas (Duvick, 1999). Adopting and exploiting hybrid rice variety is one of the key solutions in agriculture (Virmani et al., 2002). It is possible with hybrid rice varieties to achieve important avenue growth through its higher productivity and yields (Spielman et al., 2013). Increasing yields help farmers gain more on-farm incomes and ensure and stabilize rice price for both the urban and rural where households suffer from food-insecure issues (Lin & Pingali, 1993).

Particularly, rice constitutes one of the major shares in cereal consumption in Southeast Asian countries that ranges from as low as 40 percent in India to as high as 97 percent in Myanmar (Mottaleb et al., 2015). While neighboring countries of Bangladesh including Thailand, Vietnam, Cambodia, and Laos have achieved self-sufficiency in rice production, Bangladesh has not achieved the rice

production goal for self-sufficiency. Since the Green Revolution, there has been an increasing growth rate. Nevertheless, total rice production in recent years has not met the increasing demand of rice consumption in Bangladesh due to constantly increasing population, natural disasters, and technological limitations.

Rice is one of the biggest crops in the rate of hybrid varieties commercially used among a variety of crop species as hybrid varieties can realize average production about 20 to 25 percent higher than the inbred High Yielding Varieties (HYVs) (Virmani et al., 2002). Besides, a lower rate of seeding is required for hybrid varieties than traditional varieties and HYVs, usually requiring 70 percent less per acre (Ward & Pede, 2015). Accordingly, exploiting and adopting hybrid rice varieties is considered a feasible option to increase rice yields in the world (Janaiah & Hossain, 2000; Longping, 1994; Virmani, 1994).

Hybrid rice is defined as a type of inbred rice from two genetically different types of rice (IRRI). The firstly-produced seed from the two genetically different parents is called hybrid variety. Due to its self-pollinating, identifying and crossing the genetically different is complicate so that the hybrid rice seed production is mostly done by commercial producers. Nonetheless, hybrid rice has

been recommended to farmers by many rice cultivating countries for its 25 to 30 percent higher yield than traditional inbred varieties.

Currently, there are a number of countries that cultivate rice using hybrid rice varieties around the world. In the late 1970s, China firstly commercialized rice hybrids. In addition, since 1990 countries such as Vietnam, India, the Philippines, Bangladesh, and the United States have also started selling hybrid rice in the commercial markets (Virmani et al., 2002). Even though there were strenuous efforts by governments for hybrid rice variety diffusion, the numbers in adoption rate in the countries including India, Vietnam, and Bangladesh were poorly low compared with China(mainland) (Mottaleb et al., 2015).

Different from the case of Bangladesh, India produces much higher yields than Bangladesh. India produces one of the highest portion in the world which is approximately 20 percent of the world rice production. Rice production in 1992 reached 181.9kg which was ranked second only after China which produces 182kg (Pervez et al., 2017). However, while hybrid rice production in China accounts for 57 percent in the total rice cultivating land (AIS 2016), it was only 4.6 percent in India (Spielman et al., 2012). Since the two major rice producing countries have different approaches to hybrid rice

production, it would be interesting to see the differences in hybrid rice adoption and diffusion policies.

China

China has been a successful model in hybrid rice variety adoption and its diffusion. The size of arable lands for hybrid rice cultivation is about 15 million ha, which is almost 50 percent of rice field in China and 6.9 mt/ha of hybrid paddy are produced annually (Virmani et al., 2002). Considering the amount of high yielding variety paddy produced in the other half of the lands which is 5.4 mt/ha, hybrid rice varieties on average yield 27% more than the inbred types of high yielding varieties (Virmani et al., 2002).

In China, approximately 30 percent of rice cultivation acreage was under F1 hybrid rice (Lin, 1991b). Household-level studies represented that hybrid rice varieties yield 15 percent more than the conventional semi-dwarf varieties considering that there is no major difference in input costs and labor requirements (He et al., 1984). Also, F1 hybrid rice variety requires similar environmental conditions compared to conventional types of rice varieties so that F1 hybrid rice could replace all the farmlands where conventional rice was cultivated across China (Lin, 1991a).

However, several problems arose along with the diffusion of F1 hybrid rice. At household-level, the F1 hybrid rice variety, like any other innovation, was risky to farmers. Besides, at the initial stage, the hybrid rice cultivating area was small and rice-growing conditions were diverse. Also, there was an issue, especially for those areas with two crops of rice a year, with the growing period of F1 hybrid rice which lasted 125 to 140 days which was longer than that of most conventional varieties (Lin, 1991b). In addition, at the initial stage, the cooking quality became an issue due to the poor quality of F1 hybrid rice.

At the institutional level, private seed producing companies played an important role in disseminating hybrid rice varieties to farmers. In the face of extraordinarily successful hybrid distribution, government's efforts to put more investment in agricultural extension services including infrastructure, extension, research, and other related activities decreased from 11 percent of the annual government budget to about 5 percent in 1984 (Lardy, 1986). It affected extension workers whose basic salaries were only covered but not the trips to contact farmers (Diakosavvas, 1989). As the reasons explained above, private seed companies should be responsible for their profits and survival.

After the end of the collective system under Chairman Mao, the government started paying attention to incentives provided for individual farmers and farmers had more autonomy in decision making in farming (Lin, 1991b). China started the new system in 1979, which was based on individual households called 'Household Responsibility System'. Most people, 97 percent in 1983, were under the household responsibility system. Under the new system, individual households leased plots of land from the government with a 15-year contract. Once they fulfilled the state quota obligation on grain procurement, then they could keep the rest of the production. Thanks to the reforms, China experienced unprecedented success in its agricultural production (Lin, 1991b).

Even though the history of hybrid rice showed that China properly changed its policies for hybrid rice adoption, there remain some constraints in hybrid rice (YUAN, 2015). First, the arable land for hybrid rice production has been still for years due to the decreased area where hybrid rice cropping was doubled. Second, there have been numerous hybrid rice varieties officially released every year. Although a number of hybrid rice varieties were developed, there have been very few successful combinations. Third, there exists a tremendously big difference in yield for hybrid rice.

For example, while the potential of hybrid rice in Huan Province is 14.82 t ha^{-1}, the average yield was only 6.84 t ha^{-1} in the past five years. Last, there needs to be an innovative change in hybrid rice production along with mechanization. Particularly, rice seed production heavily relies on the labor-intensive techniques, which plays obstacles to develop hybrid rice in China.

India

India is the second most populated nation on the earth and one of the fastest developing countries in the world. Rice is a major staple crop in India, which accounts for about 40 percent in the total grain production in the nation. The Indian success in the increase of agricultural production, particularly in rice, have received worldwide appreciation due to the tremendously increased amount of rice from 50.8 million tons in 1951 to 182.57 million tons in 2003 so that rice plays a key component to sustain food production in the nation (Wanjari et al., 2006).

Despite the great success in rice production, the paddy yield, 4.2 t ha^{-1} was lower under irrigated system than other neighboring countries namely, 6.1 t ha^{-1} in China and 9.3 t ha^{-1} in Egypt (Wanjari et al., 2006). Besides, only 51 percent of the total rice

cultivating area was irrigated, which could severely affect the amount of production as irrigation is one of the key components in rice cultivation. In addition to the lack of irrigation system, India has faced a variety of challenges such as low agricultural input, poorly less fertile soils, pest control, and a low rate of technology adoption by farmers (Wanjari et al., 2006).

While China made a successful story of hybrid rice adoption, India has been left far behind in terms of hybrid rice adoption. Like other neighboring countries except for China, the adoption rate of hybrid rice areas to the total arable area was only 4.6 percent in 2010, which is far lower than that of China, 52 percent in the same period, currently 57 percent. Even though there has been an increasing demand of rice, hybrid rice varieties which could produce 20 percent of rice more than HYVs and MVs have not been disseminated. A number of studies have found that there are constraints hampering the adoption of hybrid rice by farmers at the institutional and farmer's level.

The initial development of hybrid rice varieties in India was introduced in 1989 as a small scale program of the Indian Council of Agricultural Research, which focused on hybrid rice for irrigated cultivation (Janaiah, 2002). For programs related to the development

of hybrid rice varieties, approximately 8 million US dollars have been funded mainly by international organizations such as United Nations of Industrial Development Organization (UNIDO), Food and Agriculture Organization (FAO), the Asian Development Bank (ADB), International Rice Research Institute (IRRI), and the World Bank. Also the Ministry of Agriculture of India was an important stakeholder.

Despite high investments by the government and international donors, in India the research and development, and delivery of hybrid rice faced several challenges that had stagnated the goal set by government of introducing hybrid rice in about 25 percent of all cultivated rice lands by 2015. India slowly invested in hybrid rice development and that attracted private sector to invest in the research. Five companies such as Bayer Cropscience, Pioneer Hi-Bred International, Nath Seeds, Advanta, and Ganga Kaveri, listed from largest to smallest, dominated more than 75 percent of the market volume (Baig, 2009; Viraktamath & Nirmala, 2008). It implies that Indian government did not play a leading role in the development of hybrid rice varieties. Instead, the government encouraged the private firms to participate in the development along with the international institutions.

With the constraints of the development policy of hybrid rice varieties, there exist substantial concerns and criticisms over the lucrative benefits of hybrid rice in developing countries like India. The first concern is that the purchasing price of hybrid rice varieties during the seasonal and annual periods is too costly for those small farmers whose resources are very limited (Kuyek, 2000). Using such hybrid seeds is one of the ways to get an access to improved technology. However, those farmers who are reluctant to purchasing expensive improved-rice varieties such as hybrid rice varieties hardly have the access to such technologies (Spielman et al., 2014). Another concern arises after the price issue, which is highly related to the inferior grain quality that could lead to poor yield gains so that farmers are discouraged to adopt the intensive rice system in India despite the recognition of the benefits of hybrid rice varieties (Janaiah, 2000).

2.2 Factors Affecting Farmer's Adoption of Agricultural Technology

Many studies carried out in developed and developing countries have shown that policies for the traditional supplies alone could not be efficient to ensure an appropriate level of technological

innovation for farmers (Long et al., 2016). Numerous studies also have found that a variety of factors such as household's assets, types of technologies, and the risk bearing capacity of a household affect adoption decisions for agricultural technologies (Calatrava-Leyva et al., 2005; Nowak & Korsching, 1983). Various social scientists investigating adoption of agricultural technologies by farmers have shown convincing evidence that complex factors such as household characteristics, information sources, types of technologies, group characteristics, attitude, and awareness significantly affect adoption behavior (Oladele, 2006). Therefore, farmer's adoption of agricultural technologies is a critical prerequisite component for economic growth in less developed countries (Nkonya et al., 1997).

Innovation adoption can be referred as to a decision made to apply a new innovation and use it continuously(Rogers & Shoemaker, 1971). Numerous studies on adoption across the continents have identified that a variety of factors including agricultural related factors, policy related factors, institutional factors, and environmental factors could explain the patterns and degree of adoption(Oladele, 2006). Particularly, Igodan et al. (1988) showed that farmers who had access to formal extension information were more likely to adopt new agricultural technologies than those

who did not have access to such benefits. A number of studies argued that household characteristics explain the patterns of technology adoption by farmers. However, it is still controversial that household characteristics such as household size do not have a significant impact on adoption (Voh, 1982). Nevertheless, Arene (1994) reported that there surely exists a significant and meaningful relationship between household size and adoption intensity.

Alabi et al. (2014) conducted the Probit model analysis to find out factors affecting farmer's decision to use agro chemical input in Nigeria. The study included several socio-economic variables such as household size, farm size, education level, extension services, off-farm income, access to credit, and farming experience. The results imply that farmers in the study areas get access to information through government extension workers, print media, and neighboring farmers. Despite the importance of the role of government extension services, the conclusion of the paper is that those technologies provided by the government should be proven by other notable farmers' magazines or newspapers which farmers periodically read as reference materials. Also, they put an emphasis on the distance from farms to the government office as the longer distance from the government office to a farm is, less likely to have

the benefits of given technologies the farmers are.

Adeogun et al. (2008) tried to explain the factors affecting the adoption of hybrid cat fish using Logit model which is based on cumulative logistic probability functions. Logit model is easily computed compared to other models and it could predict the probability of farmer's adoption of any technologies. In a number of studies on the adoption behavior, the dependent variable is lied in between 0 and 1 and the modified forms of univariate and multivariate Probit and Logit models have been dominated in studies on farmers and consumers (Adeogun et al., 2008). The results are also consistent with the previous researches that education, access to extension services, access to inputs and market distance are closely related to the farmer's adoption of agricultural technologies. Furthermore, the authors insist that in order to make the adoption successful after the decision made, there should be the proper amount of catfish seeds and the seeds should be distributed during the appropriate period by the government and private firms responsible for the seed distribution.

Paul et al. (2017) conducted a study to find out factors affecting farmer's adoption of compost use in small tropical Caribbean islands

using a discrete binary choice model. The Logit model used for this study was very helpful to analyze the impact of the socio-economic variables as well as the biophysical variables on the compost adoption by each type of farmers. The results found that the low-rate of farmer's adoption of the compost was mainly associated with the lack of use of compost and the socio-economic factors such as the input cost, the education level of farmers, and the number of professional organization specialized in some production sectors. Like many of other previous studies, this also has an emphasis on the role of organizations and household characteristics in consideration of dissemination of agricultural technologies and farmer's adoption of such technologies.

The findings of previous studies conducted in different continents, as shown above, are consistent with some factors affecting farmer's adoption of new agricultural technologies such as household characteristics and institutional involvement. Particularly, a number of studies have identified the government extension and private firms as a critical component in farmer's adoption of agricultural technologies. There have been a variety of adoption related researches conducted in Bangladesh where rice plays a substantial role in sustaining the society.

Shah et al. (2014) also studied factors influencing farmers to adopt hybrid rice in Bangladesh using a Logistic model. Not only he carried out the logistic model to figure out the influencing factors for the adoption variation, but also he studied variety adoption variations by region using a panel data and regional information. Unlike other related studies, the results showed that the educational level was significantly affecting the adoption level. Nevertheless, it adversely influenced the farmer's willingness for hybrid rice adoption. Even though some of previous studies are in the similar context with the findings as above, it is still controversial as there have been numerous papers stating that there is a positive correlation between household head education and the level of adoption of newly introduced agricultural technologies. However, the background should be introduced in detail as most Bangladeshi farmers are illiterate and those educated work for the government or non-governmental organizations. Since the majority of farmers do not have the education background, it might well explain the findings from the analysis. As the results, the important finding from the study is that the factors affecting such technologies could vary depending on the characteristics of households, areas, and proposed technologies.

Mottaleb et al. (2015) also studied to examine factors influencing hybrid rice adoption in Bangladesh using the multinomial logit model as there are more than two options for a dependent variable to be selected by farmers. The research classified the adoption levels into three types, 1) traditional variety which is set as the baseline variety (0); 2) 1 if hybrid rice had ever been produced by the farmer otherwise 0; 3) 2 if MV rice had ever been produced by the farmer otherwise 0. The results are basically consistent with a number of previous studies. The factors such as irrigation facilities and informal loans positively and significantly influence the adoption of hybrid rice compared to that of traditional varieties. Moreover, the results also demonstrate that basic infrastructure and a reliable source of seed supply help farmers to make a decision on adopting hybrid rice in their farm lands. On the other hand, the results showed that the land types (represented as 'very high' and 'very low') seems adversely related to the farmer's adoption of hybrid rice. This finding also suggests that there are more factors to be considered such as geographical conditions when it comes to finding out factors affecting farmer's adoption of agricultural technologies.

Ward and Pede (2015) specifically paid attention to technology

adoption looking into the social network effects in Bangladesh. In many of previous studies, it has been constantly argued that social network is more effective than government extension services. However, it has yet been clear that which factors is more influential than the other. The authors tried to find out the factor using a generalized spatial two-stage least squares procedure with near-ideal instruments for the causal influences (Ward & Pede, 2015). The results showed that having a network involving less distant hybrid rice farmers is more influential than having a network involving more distant hybrid rice farmers. Also a network that merely involve a large number of adopters is relatively meaningless if those farmers are far away. The results showed that spatial differences could significantly and positively affect the farmer's decision on hybrid rice adoption.

A study conducted in Bangladesh by Mendola (2007) investigated the relationship between poverty reduction and agricultural technology adoption employing a propensity-score matching method (PSM). The author gives a special attention to the propensity matching, which requires conditions for a randomized experiment as to evaluate a causal effect as if the experiment were controlled. The PSM estimates show that adopting HYVs of rice

significantly affect farm household wellbeing. Also, the interaction terms between adopting agricultural technologies, namely seed adoption and other income determinants could be used to quantify the direct impact of adopting technologies on resource-poor farmers particularly for the matters of poverty reduction and the rise of income like previous studies. Furthermore, the estimates resulted from the farm sizes show that potential gains from the technology adoption are less for near-landless than for small and medium-scale farmers.

A number of previous studies have shown that socio-economic factors such as household characteristics and government extension services are the key components to lead farmers to adopt new agricultural technologies (Feder et al., 1985; Hossain et al., 1990; Nkamleu et al., 1998; Rahman & Thapa, 1999). However, most of the related studies have not much paid attention to farmer's group which could enable farmers to share ideas and information on newly introduced agricultural technologies especially for higher production. This study is distinguishing as it includes the factor which contains individual information on any form of farmer's organizations such as farmer's union and corporative in order to find out whether there exists a significant impact of farmer's union on the hybrid rice

adoption rate. In addition, this paper looks into the factors by district as the two districts in the study are located far from each other and the characteristics of the districts are quite different and unique. Therefore, this paper is dedicated to finding out the positive and negative factors that affect farmer's adoption of hybrid rice varieties and it will be investigated by region as well.

3. Government Policies on Hybrid Rice in Bangladesh

3.1 Hybrid Rice in Bangladesh

Bangladesh that is a densely populated nation has achieved a great success in increasing rice production in history since its independency. However, the arable land per capita rapidly decreased from 0.153 hectare in 1961 to 0.048 hectare in 2013 (World Bank DataBank). So, it is quite doubtful that such a country could possibly meet the constantly increasing demand of rice without adopting new agricultural technologies, namely here hybrid rice (Pervez et al., 2017). Thus, adopting hybrid rice varieties could be a suitable option for the food security in developing countries, especially Asia where rice is the main staple grain (Hossain & Bayarsaihan, 2006). Despite the needs of hybrid rice variety adoption in the country, its adoption rate of hybrid rice has been stagnated over years (Pervez et al., 2017; Spielman et al., 2012). Hybrid rice in Bangladesh was firstly introduced by the Ministry of Agriculture of Bangladesh in 1998. One variety imported from China and three varieties from India were cultivated in 1999. In accordance with its high yield performance, it became a huge popularity so that hybrid rice cultivating areas increased dramatically by 4,263 percent from 1999 to 2008 (Hari

Prasad et al., 2014). Furthermore, Bangladesh government approved a diversity of hybrid rice varieties, 75 varieties from 1998 to 2000, of which 60 varieties were imported from China, five varieties from India, one variety from the Philippines, four were developed by Bangladesh Rice Research Institute (BRRI), and the other five by private companies (Anonymous et al., 2012; Masuduzzaman, 2011).

There have been a number of policies and planning strategies propelled by Bangladesh government such as New Agriculture Policy 2013 (NAP), National Agriculture Policy (1999), New Agricultural Extension Service (NAEP, 2016), Seed Policy 1993, Seed Rules 1998, and Plan of Action on National Agriculture Policy (NAP, 2013). Particularly, New Agriculture Policy 2013 put an emphasis on the land use plan which has been concentrated on certain crops (NAP, 2013). As described in the previous paragraph, more than 90 percent of the arable areas for rice cultivation is heavily focused on producing inbred types of rice varieties despite the existence of higher production of hybrid rice. The document suggests that land use plans have to be modified to enhance productivity of high value agricultural products (NAP, 2013)

Bangladesh government increased its budget for National Agricultural Research System (NARS) including Bangladesh

Agricultural Research Institute (BARC) under the Ministry of Agriculture from 4.5 billion Taka in 2012/13 to 5.2 billion Taka in 2013/14, but its share about 0.23 percent in the total annual budget was lower than three of other institutes reflecting its lower budget allocated to Bangladesh Rice Research Institute (BRRI). One of the research priorities published by BARC is hybrid rice varieties with high iron, zinc, and vitamin A in consideration of its insufficient rice production and mal-nutrition.

Bangladesh Agricultural Development Cooperation (BADC) established in 1971 contributed to provision of hybrid rice. It plays a role as a provider of seeds developed by BRRI and NARS so that it supplied 1,440,200 tons of quality seeds of MVs/HYVs/Hybrids of the main notified crops such as rice, wheat, jute, and seed potato in 2014. Even though Bangladesh rice industry were in need of quality seed of all crops, only 25 percent of the seeds were supplied and 75 percent of the seeds was fulfilled through informal seed systems such as farmer's own saved seeds in 2005. Due to the efforts of BADC, 43 percent of the required amount of the rice seeds including MVs, HYVs, Hybrids in 2012 were supplied by BADC and its contribution to supplying seeds alone became significant accounting for 39 percent against 10 percent in 2005.

In addition to the effort to provide hybrid rice seeds, Bangladesh government also facilitated private sectors to participate in hybrid rice seed production (NAP, 2013). The policy was based on the Seed Act (SA) which was revised based on the initial Seed Act published in 1977. The policy stated that the act of favorable policy preparation, training, technical support, and other relevant needs will be strengthened to encourage private sector to participate in seed development and preservation. NAP specifically stated that the policy under the SA 1997 will provide adequate government support for those enterprises that are involved in developing improved-technology based seed production.

In the Sixth Five-Year Plan (SFYP) which was from 2011 to 2015, there was a strong emphasis on crop sector in the context of increasing agricultural productivity and ensuring food security. The main goal of the sector was set as sustainable achievement of self-sufficiency in rice production. Particularly, a special emphasis was put in research and development (R&D) to increase productivity up to 20 percent higher production of hybrid rice by realizing technological progress and stress-tolerant varieties such as submergence, drought, and salt tolerance.

However, since 2008, the cultivating areas have continued to

decrease and currently the areas for hybrid rice cultivation accounts for only 0.63 million hectares in the total rice cultivating area 11.8 million hectares in 2014 (Hari Prasad et al., 2014). A number of previous studies have claimed that high seed costs, poor management skills, and inferior rice quality are the main factors hampering hybrid rice adoption in Bangladesh (Azad et al., 2008; Husain et al., 2001). Some of the issues with diffusion of hybrid rice in Bangladesh will be discussed below.

One of the issues is a poor institutional policy related to rice development. Despite the effort of the government in developing quality rice varieties, the quality hybrid seeds developed by national research institutes such as BRRI and NARS do not meet the standard which has been internationally agreed (Pervez et al., 2017). It can be assumed that it arose from 1) the Bangladesh Seed Certification Agency (SCA) did not play its role to assure the quality of hybrid rice seeds and 2) BRRI does not have proper personnel in the hybrid rice development (Pervez et al., 2017). The evidence for this could be that currently 119 hybrid rice varieties are available in the Bangladeshi market. In fact, only 4 varieties have been released from BRRI while the others, more than one hundred, are imported from India, China, and the Philippines by private sector and NGOs.

Also, despite the government efforts to install more cultivation facilities, particularly irrigation facilities, in the site, the number of facilities have not met the required amount of the facilities in Bangladesh. Irrigation is one of the key components in adopting hybrid rice varieties as hybrid rice cultivation needs to be carefully managed with water supply (Pervez et al., 2017). In this regard, the diesel fuel crises happened for water pump in Bangladesh also could explain the reasons for the sharply decreasing of rice yields in Bangladesh.

Other constraints that hamper farmer's hybrid rice adoption are that there is little know-how on hybrid rice cultivation among farmers and even those who are supposed to help farmers receive appropriate knowledge and skills, extension workers, have little understanding on hybrid rice adoption (Pervez et al., 2017). HYV cultivating farmers fairly have knowledge about input use and management but, approximately 98 percent of the farmers responded that they do not have relevant knowledge about hybrid rice production (Salam et al., 2012). Therefore, farmers who do not have knowledge in hybrid rice cultivation may be doubtful about the benefits of cultivating hybrid rice varieties.

Even though there have been a number of efforts by the

government, NGOs, and international institutes to promote hybrid rice adoption in Bangladesh, the goal of increasing the number of hybrid rice cultivation areas has yet been achieved due to the constraints listed above at the institutional and farmer's level. At this point, it is very important to examine the factors affecting farmer's hybrid rice adoption as the results of examination could explain what factors could help or discourage farmers to adopt hybrid rice adoption in the country. In this context, this study will be dedicated to finding out the substantial factors affecting positively or negatively farmer's hybrid rice variety adoption.

According to the IAPP report by FAO (2014), there existed farmer's unions of 198,114 in Bangladesh, 80 percent of the unions supported by the government, 14 percent by national NGOs, 5 percent by international NGOs, and only 0.01 percent, 12 organizations, were organized autonomously. IAPP report (FAO 2014) also states that even though a great number of farmer's organizations (FOs) exist across the country, there are several issues with the currently existing FOs. First, the majority of FOs are small, for example community level, and disconnected. As those large farmers and their organizations mostly have a voice at a national level and have connections with political parties rather than their

membership base, there needs to be supportive policies for smaller farmers. The second issue is that many of FOs are promoted and organized by the government, NGOs, and projects. These FOs are mainly involved with the government when there is need to deliver activities and services rather than as a sustainable and independent organizations capable of cooperation with other development sector stakeholders.

3.2 Integrated Agricultural Productivity Project in Bangladesh

Bangladesh has achieved progressive growth and poverty reduction over the previous two decades. Despite its visible growth of stable agricultural production, the country has suffered from the poverty-related food insecurity. Bangladesh's poverty rate is over 30 percent which is recorded as one of the highest in the world. Its malnutrition and poverty are widespread and prevalent across the country so that Bangladesh government has been trying to push for the increase in use of advanced and improved agricultural technologies and intensive farming practices to face the increasing demand of staple grains. With the same context of the government strategies, IAPP was aimed at developing improved crop varieties and facilitating

farmer's adoption of improved varieties and farming techniques through the farmer field schools approach (FFS).

The Global Agriculture and Food Security Project (GAFSP) provided financial supports to the Integrated Agricultural Productivity Project (IAPP) in Bangladesh. The evaluation part, particularly was implemented under the multi-cooperation of World Bank's Development Impact Evaluation Initiative (DIME), the South Asia Agricultural Development team (SASDA), and IAPP project implementation unit on the Bangladesh government side. Furthermore, external research partners such as the Yale University School of Management and the NGO Innovations for Poverty Action participated with pleasure in the evaluation tasks.

The IAPP project was kicked off to improve the income and living conditions of crop, livestock, and fish farmers in the country. The project mainly consists of four components; 1) Technology Generation and Adaptation; 2) Technology Adoption; 3) Water Management; 4) Project Management. Due to the limited resources, the project took place in eight districts. Four districts including Patuakhali, Jhalokathi, Barguna, and Barisal division located in the southern part of Bangladesh and the other four districts including Kurigram, Nilphamari, Lalmonirhat, and Rangpur division in the

northern part of Bangladesh. The distinctive characteristics of the two districts, the southern and the northern part, will be described in detail in the next section.

3.3 Characteristics of Districts

Figure 1 displays the map of Bangladesh. Bangladesh consists of eight administration districts including Dhaka in which the capital city of Bangladesh is located, Chittagong, Barisal, Khulna, Mymensingh, Sylhet, Rajshahi, and Rangpur. The study areas are two districts far from each other. One of the districts is Barisal district which is a coastal district near Bay of Bengal.

According to BBS (2015), Barisal district was recorded as the poorest district in the country. This area faced lots of flooding issues in the last decade and it is seemingly related to the livelihood of the district (BBS 2015). As it is a coastal district which has the coastal line and riverside around the district, the fish industry is one of the biggest economic sector in the region. On the other hand, Rangpur district shares its border with India and its living standard is not as bad as Barisal district. Its biggest industry is known as the agriculture industry that produces more than half of the economic activities

Figure 1. The Map of the Study Areas in Bangladesh

Source: Wikipedia (2017.11.17), marked by authors.

Table 1 shows the comparisons of the eight divisions which are the study sites to see whether there is any difference in the adoption rate of hybrid rice varieties. The F-test shows that the difference across the divisions is statistically significant. Thus, this paper investigate other regional information related to livelihoods of the

people in the eight divisions. There are differences by district in the total population, female using internet, tab in dwellings, and daily wage. Interestingly, two divisions including Barisal and Rangpur whose names are the same as their districts have much higher rates in the total population, government extension service visits and the rate of members of farmer's union. The reason could be that Barisal and Rangpur are the central divisions of each district and main cities, in general, and are more likely to have access to newly-introduced policies. As described above, the degree of the regional information given in the table varies across the divisions. This paper will find out factors affecting farmer's adoption of hybrid rice varieties.

Table 1. Statistics of Socio-Economic Factors of Bangladesh by Region

	Barisal District (South)				Rangpur District (North)				
	Patuakhali(S)	Jhalokathi(S)	Barguna(S)	Barisal(S)	Kurigram(N)	Nilfamari(N)	Lalmonirhat(N)	Rangpur(N)	F-test
Average rate of hybrid rice variety adoption (%)[1)]	0.09 (0.2272)	0.05 (0.1678)	0.17 (0.1239)	0.10 (0.2197)	0.23 (0.3242)	0.39 (0.3482)	0.22 (0.3102)	0.21 (0.2528)	71.97
Total population[2)]	343,963	157,231	214,594	508,586	505,627	420,555	289,470	715,270	
Female using internet (%)[2)]	23.3	20	28.3	19.3	37.5	16.3	13.6	21.1	
Tab in their dwelling (%)[2)]	37.5	77.8	22.2	67.6	100	60	75	100	
Daily wage (Taka) [3)]	286	383	333	300	215	230	235	265	
Land ownership proportion (%)[3)]	0.75	0.75	0.71	0.69	0.64	0.70	0.62	0.66	
Government extension visit (1=yes, otherwise 0) [1)]	0.15	0.13	0.12	0.34	0.19	0.15	0.17	0.34	
Number of government extension services[1)]	1.06	0.29	0.32	2.17	0.86	0.50	0.85	2.29	
Member of farmer's union (%)[1)]	0.07	0.03	0.03	0.77	0.04	0.03	0.01	0.98	

1)Source: Integrated Agriculture Productivity Project (IAPP) baseline survey 2012
2)Source: Yearbook of Agricultural Statistics 2015, Bangladesh Bereau of Statistics (BBS)
3)Source: Population and Housing Census 2011, Bangladesh Bereau of Statistics (BBS)

4. Data and Procedure

4.1 Methodology

Independent variables examined in this study are socio-economic variables that affect farmer's adoption on hybrid rice varieties. A number of studies on farmer's adoption of new agricultural technologies have confirmed that factors such as irrigation, farm size, household size, plot size, and extension services positively affect farmers to adopt new technologies such as irrigation, tractors, and other agricultural inputs (David & Otsuka, 1994; Estudillo & Otsuka, 2006; Feder et al., 1985; Moser & Barrett, 2003).

The rate of the number of hybrid rice varieties in the total cultivating lands represents a censored distribution as some farmers would be assumed as a value of zero for none-adoption. Thus, there exists a group of farmers with zero rate of hybrid rice variety adoption in their lands. The censored Tobit model is used with the assumption that factors that affect farmers adopt new agricultural technologies also increase the intensity of adoption (Lin et al., 1984; Kachova et al., 2004). Non adoption possibly could occur, even in those areas with diffusion of the targeted technologies (Baidu-

Forson, 1999). Tobit analysis is preferred in these types of cases as it employs both, data at the lower limit as well as the upper limit (Mac Donald, 1980). Therefore, the factors affecting farmer's adoption of hybrid rice varieties can be estimated from a censored Tobit model (Feder et al., 1985).

A Tobit model will be employed to estimate the factors of adoption of hybrid rice varieties (Tobin, 1958), represented as

$$A_i^* = \beta x_i + \varepsilon_i,$$

$$A_i = 0 \ \ if \ \ A_i^* \leq 0, \text{and}$$

$$A_i = A_i^* \ \ if \ \ A_i^* > 0 \qquad (1)$$

where A_i represents the rate of the number of hybrid rice varieties planted in the total paddy cultivation area (observable variable); A_i^* is the latent variable that stands for the adoption rate of hybrid rice varieties; x is a vector of socio-economic variables; β is unknown parameter to be estimated; ε is the independently and normally distributed error term.

The Tobit model is estimated using maximum likelihood estimation (MLE) (Tobin, 1958). There are two parts in the likelihood function. The first one is for the adopters and the second one is for the non-adopters. For the adopters, which is $A_i = A_i^*$, the density function is as below

$$\frac{1}{\sigma}\phi\left[\frac{A_i - \beta x_i}{\sigma}\right] \tag{2}$$

The likelihood contribution for the non-adopters is given by

$$1 - \Phi\left(\frac{\beta x_i}{\sigma}\right) \tag{3}$$

$\phi(.)$ is the probability density function and Φ is the standard normal cumulative distribution functions. The likelihood function can be represented as

$$\mathrm{L} = \prod_{A_i=0}\left[1 - \Phi\left(\frac{\beta x_i}{\sigma}\right)\right]\prod_{A_i>0}\frac{1}{\sigma}\phi\left[\frac{A_i - \beta x_i}{\sigma}\right] \tag{4}$$

So, in the Tobit model, β and σ values maximize the likelihood function L. Also, the marginal effect of an independent variable can be calculated as below

$$\frac{\partial E(A|x)}{\partial x_k} = \beta\left\{1 - \lambda\left(\frac{\beta x}{\sigma}\right)\left[\frac{\beta x}{\sigma} + \lambda\left(\frac{\beta x}{\sigma}\right)\right]\right\} \quad (5)$$

With the marginal effects above, it is possible to measure the variation of the possibility of farmer's adoption of hybrid rice varieties as each independent variable increases or decreases.

A number of studies have identified that heteroscedasticity should be considered when a variance of the disturbance term is likely to be proportional to another regressor in the regression (Goldfeld et al., 1972; Kmenta, 1986; Park, 1966). A regression model including multiplicative heteroscedasticity can be formulated as below:

$$y_i = x_i'\beta + u_i \quad (6)$$

$$\sigma_i^2 = e^{z_i'\alpha} \quad (7)$$

According to Harvey (1976), the equation terms can be described as below: x_i stands for a $k \times 1$ vector of observations on independent variables, β stands for a $k \times 1$ vector of parameters, z_i is a $p \times 1$ vector of observations on a set of variables that are usually however, not necessarily related to the regressors in equation (2), and α is a $p \times 1$ vector of parameters. This study assumes that the independent variable, total paddy plot size is related to the adoption rate of hybrid rice varieties as heteroscedasticity is found between the two variables. Thus, in this study the plot size is considered a factor that may cause heteroscedasticity issue.

$$p_i^* = \alpha z_i + \mu_i \tag{8}$$

$$y_i^* = \beta x_i + \varepsilon_i \tag{9}$$

It has been found that adoption decisions may precede the intensity of adoption. According to Cragg (1971), two equations are represented in the Double-Hurdle model. In the first stage, a Probit model is used to analyze factors that determine adoption, and the second stage of Cragg's model is a truncated regression for determinants that affect the level of adoption (Cragg, 1971).

Where p_i^* is the latent variable showing farmer's decision to adopt hybrid rice varieties, the value is 1 if the farmer adopts any given hybrid variety or the value is 0 if the farmer does not adopt any hybrid variety. y_i^* is the latent variable representing his or her decision on the amount of varieties used on the total paddy plots. z_i is the vector of explanatory variables that are supposed to affect the adoption and x_i is the vector of explanatory variables to affect the level of the adoption. μ_i and ε_i are, respectively, the error terms of the first and second stage. The equations above are assumed to be independent therefore, the error terms in the equations are randomly and independently distributed. With the assumption, the likelihood function which is the sum of the Probit model and the truncated model can be given as below.

$$\mathrm{L} = \Pi_{y_i=0}\left[1-\Phi(z_i\alpha)\Phi\left(\frac{x_i\beta}{\sigma}\right)\right] + \Pi_{y_i>0}\left(\Phi(z_i\alpha)\frac{1}{\sigma}\phi\left(\frac{y_i-x_i\beta}{\sigma}\right)\right) \qquad (10)$$

4.2 Data

This study used Integrated Agricultural Productivity Project (IAPP) 2012 survey data obtained from World Bank Data Bank. There are

Figure 2. The Map of Bangladesh

Source: Google Map (2017.11.28), marked by authors.

two districts selected for the project sites and each district includes 4 divisions. Barisal, Patuakhali, Barguna, and Jhalokathi divisions are in the southern part, Barisal district, and Rangpur, Kurigram,

Nilphamari, and Lalmonirhat divisions are in the northern part, Rangpur district. 6 districts such as Kugrigram, Nilfamari, Lalmonirhat, Patuakhali, Barguna, and Jhalokathi were selected only for Overall Project Evaluation (OPE), while 2 districts including Rangpur and Barisal are selected for Demonstration Plot Evaluation (DPU). Thus, there are a little of differences between OPE and DPU. However, the collected data were used regardless of the differences since the data of OPE and DPU contain all the necessary variables for this study. The total observations are 4,970 from the study areas. There are 244 observations from Pauakhali, 230 from Jhalokhati, 239 from Barguna, 1,445 from Barisal, 227 from Kurigram, 224 from Nilphamari, 237 from Lalmonirhat, 2,124 from Rangpur division.

4.3 Variables and Descriptive Statistics

The dependent variable for this study is the ratio of the number of hybrid rice varieties chosen in the total rice varieties in the rice production areas of households. There are three types of varieties used in the districts as follows: 1) traditional varieties; 2) high yielding varieties (HYVs); 3) hybrid varieties. Currently, there are

75 hybrid rice varieties commercially sold in the domestic market and this study contains 10 hybrid rice varieties used in the districts. Some households never adopted any hybrid variety last year from the survey date. On the other hand, some households adopted hybrid rice varieties in the entire farmlands in a given period.

Independent variables used in this study are based on previous studies and the hypothesis of the authors on factors influencing farmer's adoption of hybrid rice varieties. Household head age is one of the independent variable, which represents the important characteristics of households as most decisions are made by the heads. Generally, as farmers become old, they accumulate more assets such as personal capital and that shows a likelihood of more investing in innovations (Nkamleu et al., 1998). On contrary, as farmers become less old, then they are more active and adventurous when new technologies are provided.

Gender of household head is another independent variable, which is reflected as a dummy variable (male=1, female=0) in this study. Chithtalath (2006) stated that female household heads have limited access to adopting new agricultural technologies because female household heads have limited access to information. Similar to other Asian countries, male farmers have dominated agricultural

sector in Bangladesh. Male household heads account for 88.1 percent in 2011 in Bangladesh (BBS 2011) and the percentage of male households in Barisal divisions was 89.4 and 89.6 in Rangpur divisions.

Two important variables, education level and literacy of household heads were considered in this study. Generally, education helps farmers acquire abilities to perceive, interpret, and properly react to new information faster than those without education (Feder et al., 1985). Considering the thought, there is a higher possibility that those who have higher education adopt new technologies faster and more. The average of literacy level in rural areas, Bangladesh, was 44.7 percent in 2010 which was doubled compared to 21.2 percent in 1991 (BBS 2011).

A member of farmer's union (cooperative) is another independent variable in our study. There is a huge difference across the region, a rate of members from 1 percent in Lalmonirhat division to 89 percent in Rangpur division. In general, farmers in developing countries tend to refuse to join farmer's unions or cooperatives as the fee for the membership could be burdensome. However, cooperatives provide not only benefits such as credit, public goods, education programs, and supplies but also costs related to the

member's agribusiness (Hopfensitz & Miquel-Florensa, 2017). In this regard, through the cooperatives or farmer's union, there is a higher possibility that those who joined any form of cooperatives adopt more hybrid rice varieties.

To investigate the labor availability in a household, the number of household members was included in this study. In developing countries, particularly in rural areas, the number of household members is critical as the number reflects the labor availability. In agricultural sector, labor is one of the three most important factors to be considered, which are labor, inputs, and lands. Labor availability affects farmer's decision making in adopting new agricultural technologies (Jo, 2017). Furthermore, adopting new technologies could increase a seasonal demand for labor. Thus, adoption could be little attractive to those with limited family members or those in areas with limited access to labor markets (Feder et al., 1985).

The amount of savings and the amount of loans were also included as one of the household characteristics. Capital such as savings and access to loans is required when farmers pursue new agricultural technology adoptions (Feder et al., 1985). There is a strong correlation between wealth or income and other critical socioeconomic characteristics including market information, access

to credit, or access to extension services (Azad et al., 2008). Considering that a number of people are still under poverty line in Bangladesh, it can be assumed that there is a significantly huge difference in new agricultural technology adoption depending on household assets.

Total paddy plot size and average distance to household from plots were independent variables used in this study with the assumption that plot size and its distance to household would positively affect farmer's decision on hybrid adoption. Farmers, particularly larger, with access to credit tend to adopt hybrid and the hybrid adoption is, indeed, independent on overall household wealth (Ward & Pede, 2015). Besides, farmers who own larger lands are highly likely to adopt tractors, irrigation equipment, and other modern variable inputs (Feder et al., 1985). In Asia, the average of farm holding size is 1 ha and the average in Bangladesh remains 0.3 ha. The number could be accounted to be the densely-populated nature of the nation. As there is a variation among the households in the data, plot size may explain the relationship with household hybrid adoption.

Irrigation, another independent variable used in this study, is a key factor in agricultural production. Several studies have found that

access to modern types of irrigation facilities is a pre-requisite factor for growing modern rice varieties, particularly in dry season and lack of access to such irrigation facilities has been found as one of the main reasons for stagnating the expansion of modern rice (Hossain et al., 1990; Rahman & Thapa, 1999). For example, it is possible to cultivate double of traditional varieties during the main monsoon season, called Aman season in the region, only if proper supplementary irrigation with water control is provided (Rahman, 2003). Therefore, irrigation availability is included to examine its influence in farmer's hybrid rice variety adoption.

Two independent variables, number of government extension service visits and number of NGOs extension service visits are incorporated in this study. Agricultural extension service is one of the key source of information dissemination which could be directly relevant to agricultural production related practices, especially for nations like Bangladesh where access to information is hardly given to farmers (Rahman, 2003). Several studies have found that extension services significantly affect adoption of land-improving technologies (Adesina & Zinnah, 1993; Baidu-Forson, 1999). Also, extension services are currently considered comprising a wide range of services providing information and knowledge to farmers to lead

themselves to change use of technologies and their behavior (Uddin & Qijie, 2013). Therefore, these two variables are incorporated to account for its influence if they are proved useful.

Use of mobile for information collection is another independent variable used in this study to examine whether differences of access to information using mobile could affect farmer's adoption on hybrid rice varieties. Respondents were asked whether they have had any agricultural information through mobile in a given period. Not only capacity but also access to information on the technical sides related to modern technologies could affect crop production decision (Rahman, 2003). Also several studies have found that information has been proven to help farmers successfully adopt new agricultural technologies (Bindlish & Evenson, 1997; Feder et al., 1985). The variable is a dummy variable so if a respondent has received any information related to agricultural production using mobile, it is represented as one, otherwise zero.

Lastly, 8 divisions in this study are included as dummy variables with the assumption of this study that there exist regional differences in certain variables influencing farmer's adoption of hybrid rice varieties. Patuakhali in Barisal district was set as a default division to examine regional differences in independent variables may affect

adoption rates so that the results could lead to comparing estimates of the other divisions to the default division, Patuakhali. Besides, the two districts Barisal and Rangpur, located in the southern and the northern part respectively, were separately studied to see the regional differences by districts. As Barisal and Rangpur have a diversity of differences in terms of livelihood, environment, and geography, it would be interesting to see whether there exists any difference in factors affecting adoption rates. Table 2 summarizes the dependent variables and independent variables used in this study.

The descriptive statistics shown in Table 3 is from the entire observations including the 8 divisions. The average age of household heads in the divisions is 47 years old ranging from 18 to 95 years old. Among the respondents, more than 97 percent are male household heads. Education level of household heads is 3 on average which is relatively low as the highest education that they could get is 11. In terms of literacy, more than 68 percent of household heads can read and write. About 65 percent of respondents had joined any form of corporative or farmer's union. A big difference is found among the divisions which ranges from 1 percent in Lalmonirhat division to 98 percent in Rangpur division even though these two districts belong to the same district, Rangpur. Number of family members on average

is 5 and the number of household members ranges from 1 to 24. Another interesting point is that amount of loans is much bigger than that of savings. It could be assumed that farmers need any form of loans for agricultural activities such as purchasing seeds, fertilizers, and other inputs. Total paddy plot size is from zero to 3,036 decimals and average distance from household to plots ranges from zero to 2,855.556 feets. Only 5 percent of respondents had irrigation accessibility. Average frequency of government extension service visits is 1.8 while that of NGOs extension service visits was 0.13. However, for both government and NGOs extension service visits, some households had up to 70 and 40 times of their visits respectively in a given period. And 13 percent of respondents received information using mobiles.

Table 2. Description of the Variables for the Hybrid Rice Variety Adoption

Variable type	Variable name	Description	Type of variable
Dependent variable			
	Hybrid rice variety adoption rate	Rate of the number of hybrid rice varieties in the total number of selected rice varieties	Continuous [0,1]
Independent variables			
Household head characteristics	Household head age (years)	Age of household age (years)	Continuous
	Gender of household head (1=male)	The gender of the household head	Dummy (1=yes, 0=no)
	Education level (from 1 to 11)	The education that the household head has (the lowest 1 to the highest 11)	Discrete
	Literacy (1=yes, otherwise 0)	Respondents can understand written texts	Dummy (1=yes, 0=no)
	A member of farmer's union (1=yes)	Respondents join any farmer's union or any cooperative	Dummy (1=yes, 0=no)
	The number of household members	The number of household members	Continuous
	The amount of savings	The amount of savings that the household deposits (Taka)	Continuous
	The amount of loans	The amount of loans that the household borrows (Taka)	Continuous
Plot characteristics	Total paddy plot size (decimals)	The size of all the paddy plots that the household cultivates (decimal)	Continuous
	Average distance to household from plots	The average distance between the household and its plots (ft.)	Continuous
	Irrigation availability (1=yes)	Respondents have access to irrigation facilities	Dummy (1=yes, 0=no)

Extension services	Number of government extension service visits	Frequency of government extension service officer's visit to the household in a year (2012)	Continuous
	Number of NGOs extension service visits	Frequency of NGOs extension service officer's visit to the household in a year (2012)	Continuous
	Usage of mobile for information collection	Respondents have ever used the mobile for any information collection	Dummy (1=yes, 0=no)
Regional dummies	PautaKhali Jhalokathi Barguna Barisal Kurigram Nilphamari Lalmonirhat Rangpur	Regional dummies are added to compare the 4 divisions in Barisal district with the 4 divisions in Rangpur district.	Dummy (1=selected, or 0=not selected)

Table 3. Descriptive Statistics of Variables

VARIABLES	Mean	Standard deviation	Min	Max
Dependent Variable				
Hybrid rice variety adoption rate (%)	0.1669	0.2586	0	1
Independent Variables				
[Household Characteristics]				
Household head age(years)	46.7457	12.5032	18	95
Gender of household head (1=male)	0.9726	0.1632	0	1
Education level (from 1 to 11)	3.2193	2.1926	1	11
Literacy (1=yes, otherwise 0)	0.6861	0.4641	0	1
A member of farmer's union (1=yes)	0.6533	0.4760	0	1
Number of household members	5.2131	2.0341	1	24
Amount of savings (x 1,000,000 Taka)	12.5021	77.2060	0	4
Amount of loans (x 1,000,000 Taka)	57.9358	1450.794	0	88.8889
[Plot Characteristics]				
Total paddy plot size (decimal)	163.2825	144.4188	0	3036
Average distance to household from plots (ft.)	171.849	216.0596	0	2855.556
Irrigation availability (1=yes, otherwise 0)	0.0513	0.2206	0	1
[Extension services]				
Number of government extension service visits	1.7932	5.0994	0	70
Number of NGOs extension service visits	0.1835	1.3754	0	40
Usage of mobile for information collection	0.1345	0.3412	0	1
Patuakhali	0.0491	0.2161	0	1
Jhalokathi	0.0463	0.2101	0	1
Barguna	0.0481	0.2140	0	1
Barisal	0.2907	0.4542	0	1
Kurigram	0.0457	0.2088	0	1

Nilphamari	0.0451	0.2075	0	1
Lalmonirhat	0.0477	0.2131	0	1
Rangpur	0.4274	0.4947	0	1

5. Results

5.1 Mean and Marginal Effects

Table 4 represents the estimation results. In the beginning of this study, it was assumed that socio-economic factors such as household head age, household size, gender of household head, farm size, irrigation availability affect farmer's adoption of hybrid rice varieties based on the evidence from a number of previous studies. Those variables that are statistically significant marked as * are defined, in this study, as the factors affecting farmer's adoption of hybrid rice in the study areas. According to the estimation results, the following factors are statistically confident and significant on hybrid rice variety adoption: household head age, gender of household head, a member of farmer's union, total paddy plot size, average distance to household from plots, irrigation availability, number of government extension service visits, number of NGOs extension service visits, and usage of mobile for information collection. However, there are some differences with signs and significance of coefficients as they are estimated by region. The differences by region will be discussed in the next section.

Household head age is positively related to farmer's adoption of

hybrid rice varieties. Household head age has been selected as an important independent variable in previous studies on adoption of new technologies. Farmers, in general, are not willing to change farming techniques and agricultural technologies as they are required to take risks. However, as younger a new technology receiver is, the more active and positive on the adoption of new technologies they are. Younger people have more access to new information and willing to take risks while it is not easy and comfortable for aged farmers to get such information and adapt to the newly introduced technologies.

Also, gender of household head positively affects the hybrid rice variety adoption rate. A variety of studies have found that most of the farmers in Asian countries are male and they do social activities such as going to market for business, dealing with extension services, making decisions when it comes to important matters. Besides, male farmers lead household farming business and those related to agricultural activity should be discussed with the male household farmers. It is consistent with the assumption provided in the beginning of this study.

Another factor, a member of farmer's union, also positively affects the adoption rate of hybrid rice varieties. It is, again,

consistent with the assumption that the factor affects the adoption rate as being a member of corporative or farmer's union provides numerous benefits including technology transfer, market access, and credit. Corporative and farmers' union play an important role in rural areas as farmers can exchange information on farming practices and new agricultural technologies for higher productivity.

Total paddy plot size, as expected, is positively related to farmer's adoption of hybrid rice varieties. In general, as discussed in the previous section, larger farmers could adopt new technologies as they are capable of having new agricultural technologies despite the existence of risk of loss. Most of the farmers in this study own more than two plots for rice paddy cultivation and it could be assumed that the more plots farmers have for rice production, more active and willing to try newly developed technologies that promise higher production the farmers are.

Peculiarly, a factor considered in this study, average distance to household from plots, also positively affect farmer's adoption of hybrid rice varieties unlike the assumption that its sign would be negative, which means the increase of distance from household to plots increase the probability of hybrid adoption rates. One possible assumption for the issue is that farmers far away from their

farmlands are less likely to manage their farmlands than those who live close to their plots and they may prefer varieties that require lower degree of management. Considering that there are a variety types of resilient hybrid rice varieties and that management is less required than other inbred varieties, adopting hybrid rice variety could be appealing to those whose farmlands are far from their dwellings.

Regarding the factor, irrigation availability, it is positively related to farmer's adoption of hybrid rice varieties. The result implies that those who had irrigation availability in their farming are more likely to adopt hybrid rice varieties. As a number of previous studies have discovered the importance of irrigation system in agricultural productivity, we could assume that it is also a critical factor to be considered in adopting hybrid rice varieties by farmers.

As the hypothesis of this study assumed, number of government extension service visits is positively related and affects farmer's adoption of hybrid rice varieties. The likelihood of farmer's adoption of hybrid rice varieties increases as the number of visits of government extension service also increases. It implies that government extension service and its visit to farming households play an important role in increasing hybrid rice variety rates.

Similar to the result for number of government extension service visits, number of NGOs extension service visits also shows a positive impact on farmer's adoption of hybrid rice varieties. In the descriptive statistics, it could be found that the average visit of NGOs extension service was far less than that of government extension service in the divisions. However, the result implies that NGOs extension service and its visit to farming households positively and significantly affect farmers to adopt hybrid rice varieties despite the smaller number of visits. Accordingly, it can be assumed that NGOs extension service plays an important role in farmer's adoption of hybrid rice varieties.

Usage of mobile for information collection also shows a positive impact on farmer's adoption of hybrid rice varieties. As the hypothesis of this study, information collection by receiver is a final part of information diffusion and it may affect the adoption rates. The result implies that farmers who have ever used mobile for information collection are more likely to adopt hybrid rice varieties than those who did not use mobile for the purpose. Accordingly, information collection through mobile is an important factor to be considered in adopting hybrid rice varieties.

The regional dummy variables including seven divisions, where

Patuakhali division is set as a default division, show differences by division. The three divisions including Jhalokathi, Barguna, Jhalokati show negative impacts compared to Patuakhali on the probability of farmer's adoption of hybrid rice while the negative impact of Barisal division is not statistically significant. A common feature of the divisions listed above is that they belong to Barisal district located in the southern part of Bangladesh. On the other hand, the other divisions, namely Kurigram, Nilphamari, Lalmonirhat, and Rangpur, show statistically positive impacts compared to Patuakhali on farmer's adoption of hybrid rice varieties. Interestingly, these divisions also belong to one district, Rangpur which is located in the northern part of Bangladesh. The results suppose that there exist regional differences between the two district, Barisal and Rangpur so that it would be worth investigating the differences by comparing the divisions by their geographical location. The regional difference comparison will be shown and discussed in the next section.

In the Tobit model used in this study, the coefficients of the variables could be estimated and, the degree of the impacts could be explained. The degree of impact can be calculated with marginal effects. Marginal effects can be interpreted as a percentage change of the probability of adoption rates, the dependent variable, when

each unit increases or decreases. The calculated marginal effects in table 4 are the mean values of all the individuals' marginal effects and it is statistically significant at 95 percent confidence interval. With the estimated results of Tobit model, in table 4, calculated marginal effects are represented.

The probability of farmer's adoption of hybrid rice varieties increases 0.07% as age decreases by one year. The coefficient of household head age was positive. On the contrary, its marginal effect shows that it does not affect significantly as only 0.07 percent of the probability increases as the age becomes younger by one year. Despite its small number of increase, this study also identifies the statistically significant impact and effect of age that has the same impact in previous studies.

The probability of farmer's adoption of hybrid rice varieties also increases 6.16% as the household head is male. It implies that male farmers who are mainly responsible for farm activities are more likely to adopt hybrid rice varieties by 6.16 percent. It can be assumed that those male households who do social networking by communicating with other farmers or neighbors are highly engaged in agricultural activities and this may affect farmers to adopt hybrid rice varieties.

The marginal effect results also show that those farmers who joined any form of corporative or farmer's union are more likely to adopt hybrid rice varieties by 6.12 percent. A number of households in Bangladesh have yet enjoyed the benefits of corporative and farmer's unions due to lack of the policies that facilitate farmers to participate such organizations to share information and benefits. As table 1 shows the ratio of the number of members of corporative and farmer's unions, only Barisal and Rangpur divisions have a high percentage of farmers in the case. Another constraint, we could think of, is that small farmers who barely produces rice surplus to sell in market do not have enough assets, which could enable farmers to pay the membership fee.

Farmers are also more likely to adopt hybrid rice varieties as farmers have one more decimal of land by 1.11 percent. It is consistent with the hypothesis of this study and it implies that larger farmers have the higher possibility of adopting the varieties as a number of previous studies have shown that the size of farming lands is positively and significantly related to farmer's adoption of new agricultural technologies.

Even though it is statistically significant at 90 percent confidence interval, farmers are more likely to adopt hybrid rice

varieties by 2.78 percent as the distance from households to their plots increases by one feet away. The result seems peculiar however, it could be understandable that farmers may prefer hybrid rice varieties which are resilient to climate change and pests and insects particularly as it is hard for the farmers to reach to their plots for farming management.

The probability of farmer's adoption of hybrid rice varieties, as expected, increases by 3.22 percent as the farmers have irrigation availability. The result may be obvious considering that rice cultivation is still heavily relied on rain-fed techniques and irrigation is one of the most important components in rice production. There is no direct correlation between irrigation and the adoption of hybrid rice varieties. It could be assumed that those who have ever experienced and enjoyed the benefits of newly developed technologies are less reluctant to adopting other new farming techniques.

The result also shows that farmers are more likely to adopt hybrid rice varieties by 0.15 percent as their meeting with the government extension officers increases by one time. Also, the probability of farmer's adoption of hybrid rice varieties increases by 0.5 percent as farmer's meeting with NGOs extension officer

increases by one time, even though the average number of government extension service visits is 10 times higher than that of NGOs extension service visits. It can be explained with the previous studies mentioning that NGOs, mostly international non-governmental organizations, particularly related to technologies, have played a critical role in improving the farming techniques in Bangladesh. Compared to the capacity of research and budget of NGOs, that of government could be weaker due to limited budget constraints that most developing countries have faced.

Also, the probability of farmer's adoption of hybrid rice varieties increases by 3.32 percent as farmers use their mobile for information collection. Even though the question was not specified in hybrid rice varieties related, sharing information through personal mobiles plays a significant role and the marginal effect of usage of mobile for information collection is very similar to that of irrigation availability so that diffusion of information through mobile should be considered in the process of advertising hybrid rice varieties.

We have observed that there exist differences by district as well as division. Surprisingly, with the calculated marginal effects of all the divisions, the differences are clearly visible. Compared to the default division, Patuakhali, three divisions including Jhalokati,

Barguna, and Barisal show the negative probability of farmer's adoption hybrid rice by 6.1 percent, 10.96 percent, 0.05 percent, respectively. However, the marginal effect of Barisal division should not be examined as it was calculated based on the insignificant coefficient. On the other hand, those divisions located in the northern part of Bangladesh show the higher positive marginal effects in the probability of farmer's adoption of hybrid rice varieties. The average probabilities of farmer's adoption of hybrid rice varieties are 16.27 percent, 26.69 percent, 14.85 percent, and 11.15 percent in Kurigram, Nilphamari, Lalmonirhat, and Rangpur, respectively. Accordingly, it would be worth looking into the regional comparison to see what factors made such differences by districts. This will be discussed in the next section with table 5.

Table 4. Estimation of Tobit Model with Heteroscedasticity and Marginal Effects

Variable	Tobit with heteroscedasticity	Marginal effect
Household head age (years)	-0.0017**	-0.0007**
	(0.0007)	(0.0003)
Gender of household head (1=male)	0.1467**	0.0616**
	(0.0582)	(0.0246)
Education level (from 1 to 11)	0.0011	0.0005
	(0.0049)	(0.0002)
Literacy (1=yes, otherwise 0)	0.0273	0.0115
	(0.0231)	(0.0046)
A member of farmer's union	0.1458***	0.0612***
	(0.0336)	(0.0245)
The number of household members	0.0041	0.0017
	(0.0042)	(0.0007)
The amount of savings (×1,000,000 Taka)	-0.0779	-0.0327
	(0.1190)	(0.1309)
The amount of loans (×1,000,000 Taka)	0.0111	-0.0046
	(0.0177)	(0.0019)
Total paddy plot size (decimal)	0.0264***	0.0111***
	(0.0055)	(0.0044)
Average distance to household from plots (ft.)	0.0663*	0.0278*
	(0.0390)	(0.0111)
Irrigation availability (1=yes, otherwise 0)	0.0767**	0.0322**
	(0.0402)	(0.0129)
Number of government extensions service visits	0.0037**	0.0015**
	(0.0015)	(0.0006)
Number of NGOs extension service visits	0.0120**	0.0050**
	(0.0055)	(0.0020)
Usage of mobile for information collection	0.0792***	0.0332***
	(0.0228)	(0.0133)
Jhalokati	-0.1454**	-0.0610**
	(0.0660)	(0.0238)
Barguna	-0.2612***	-0.1096***

	(0.0692)	(0.0439)
Barisal	-0.0013	-0.0005
	(0.0510)	(0.0002)
Kurigram	0.3876***	0.1627***
	(0.0564)	(0.0651)
Nilphamari	0.6359***	0.2669***
	(0.0557)	(0.1068)
Lalmonirhat	0.3538***	0.1485***
	(0.0562)	(0.0594)
Rangpur	0.2658***	0.1115***
	(0.0531)	(0.0446)
Constant	-0.5533***	
	(0.0803)	
σ	0.4371***	
	(0.0147)	
H.Size	-1.1829***	
	(0.3326)	
Observation	4,965	4,965

Standard errors are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.2 Regional Comparison of Tobit Estimates with Heteroscedasticity

As the results shown in table 4, factors such as household head age, gender of household head, a member of farmer's union, total paddy plot size, average distance to household from plots, irrigation availability, number of government extension service visits, number of NGOs extension visits, and usage of mobile for information collection have positive impacts on farmer's adoption of hybrid rice varieties in the eight divisions. However, the sign of coefficient of each district is different from one another. Besides, there is a common feature that divisions that belong to the same district have the same sign either positive or negative. So, it is worth comparing the divisions by district to investigate what factors make the differences across the divisions.

Table 5 contains Tobit estimates with heteroscedasticity and marginal effects by district. The southern part is Barisal district and the northern part is Rangpur district. Surprisingly, most coefficients of the variables that were statistically significant in the overall Tobit model estimation become insignificant and the sign of a member of farmer's union in the northern part becomes contrariwise. The results will be discussed in this section

The coefficient of household head age in the northern part is consistent with the overall Tobit estimates while the coefficient of the variable in the southern part is no longer statistically significant. The marginal effect of household head age in northern part becomes 0.12 percent compared to 0.07 percent in the overall estimates. It implies that farmers adopt hybrid rice varieties in the northern part as farmer become younger even though it shows not related to the adoption of hybrid rice varieties in the southern part of Bangladesh.

Like household head age, the coefficient of household head gender is only statistically significant at 10 percent level in the northern part. Its marginal effect is similarly consistent with the one in the overall estimates. As farmers are more likely to adopt hybrid rice varieties by 6.54 percent a household head is male in the northern part. In the same context with the age factor, gender of household head is seemingly not related to the adoption of hybrid rice varieties in the southern part.

It is interesting to see the difference in a member of farmer's union between the two parts. In the overall estimates, the factor is positive and statistically confident. However, the signs are opposite to each other even though the statistical significance remains strong for both the parts. A member of farmer's union positively affects

farmer's adoption of hybrid rice varieties in the southern part while it negatively affects farmer's adoption of hybrid rice varieties in the northern part. Besides, the difference in marginal effects for both the part clearly shows the opposite impact on the farmer's adoption. The marginal effect in the southern part is quite similarly consistent with the one in the overall estimates 6.58%. However, farmers are less likely to adopt hybrid rice varieties by 13.03 percent in the northern part. It seemingly shows that being a member of any form of corporative and farmer's union plays a different role by district.

Estimates of total paddy plot size for both the parts are still consistent with the result in the overall estimation even though the number in the estimates become much smaller than that of the one in the overall estimates. Besides, the marginal effects are 0.01 percent and 0.02 percent in the southern and the northern part, respectively, compared to 1.11 percent in the overall estimates. It implies that total paddy plot size statistically affects farmer's adoption of hybrid rice varieties. However, the magnitude of affecting the adoption rate is quite smaller than expected in the overall estimates.

Also the estimate of irrigation availability in the northern part shows a difference compared to that of the southern part and the one

in the overall estimation. While the coefficient in the southern part is statistically significant, the coefficient in the northern part is no longer statistically significant. In terms of the marginal effect in the southern part, it becomes almost doubled 12.38% compared to the effect 7.67% in the overall estimation. It implies that irrigation availability plays a critical role in farmer's adoption of hybrid rice varieties while it is not seemingly related to the adoption rate in the northern part. Accordingly, farmers are more likely to adopt hybrid rice varieties in the southern part as they have access to irrigation.

For government and NGOs extension service visits, the marginal effects for the southern part are constantly consistent with the result in the Tobit estimation while the marginal effects of the two factors in the northern part become statistically no longer significant. For example, Barisal had one scheme for Deep Tube Well (DTW) while there were more than 5,000 schemes for Dhaka, 4,000 for Rajshahi by BADC in 2011. In this regard, Barisal district, in absolute, needs more government extension services (FAO 2014).

One possible response to the issue is that people in rural areas like the northern part, especially in developing countries, do not enjoy the benefits of certain policies by the government as the distance to the capital city or big cities is far away from their

community. Another possibility for this issue is that districts in the southern area whose agriculture industry has been severely affected by a number of climate change-induced natural disaster are supported by the government and NGOs. The divisions in the southern part have faced numerous floods over years in history. Interestingly, the marginal effect of number of NGOs extension service visits is 6 times higher than that of government extension service visits. It could be assumed that international agricultural technology institutes do more work in the areas like the southern part of Bangladesh where natural disasters such as flood severely and negatively affect agriculture as hybrid varieties that are climate change resilient are more suitable in those areas.

Farmers are more likely to adopt hybrid rice varieties by 3.78% as they use mobiles for information collection in the southern part while it does not statistically affect farmer's adoption of hybrid rice varieties. In 2011, about 22 percent of women in the two districts, the southern part, use internet while women in the other districts in the same district use about 16 percent on average. In developing countries, in general men are more active in social networking (Chithtalath, 2006) while women have limited to access using such technology. It can be assumed that the information in the community

travels more among the users if women are given time to use internet as men. Accordingly, information also significantly increases farmer's adoption of hybrid rice varieties.

As the assumption proposed based on the Tobit estimation in the previous section, there are differences between the two districts. Among the divisions in the southern part, they are statistically significant except for Barisal as the previous overall estimation. The results imply that farmers in Jhalokati and Barguna are less likely to adopt hybrid rice varieties than Patuakhali by 3.23 percent and 7.89 percent, respectively. However, the divisions in the northern part, Rangpur district, show statistically significant marginal effects except for Lalmonirhat. Farmers in Nilphamari and Rangpur are more likely to adopt hybrid rice varieties than Kurigram by 14.35 percent and 11.78 percent, respectively. Through the comparison of divisions by district, it clearly shows the differences exist across the districts.

Table 5. Regional Comparison of Tobit Estimates with Heteroscedasticity

Variable	Southern part (Tobit hetero)	Southern part marginal effects	Northern part (Tobit hetero)	Northern part marginal effects
Household head age (years)	-0.0014 (0.0015)	-0.0003 (0.0002)	-0.0021*** (0.0008)	-0.0012*** (0.0002)
Gender of household head (1=male)	0.1961 (0.1375)	0.0460 (0.021)	0.1158* (0.0623)	0.0654* (0.01)
Education level (from 1 to 11)	0.0024 (0.0116)	0.0006 (0.0003)	0.0004 (0.0052)	0.0003 (0.0000)
Literacy (1=yes, otherwise 0)	0.0559 (0.0492)	0.0131 (0.006)	0.0060 (0.0262)	0.0034 (0.0001)
A member of farmer's union	0.2807*** (0.0494)	0.0658*** (0.031)	-0.2306*** (0.0665)	-0.1303*** (0.019)
The number of household members	0.0030 (0.0080)	0.0007 (0.0003)	0.0050 (0.0051)	0.0028 (0.0042)
The amount of savings (×1,000 Taka)	0.0283 (0.2505)	0.0066 (0.003)	-0.1288 (0.1541)	-0.0728 (0.011)
The amount of loans (×1,000 Taka)	-0.0015 (0.0023)	-0.0004 (0.0002)	-0.0025 (0.0095)	-0.0014 (0.0002)
Total paddy plot size (decimal)	0.0003*** (0.0001)	0.0001*** (0.0000)	0.0003*** (0.0000)	0.0002*** (0.0000)
Average distance to household from plots (ft.)	0.0001 (0.0001)	0.0000 (0.0000)	0.0001 (0.0000)	0.0000 (0.0000)
Irrigation availability (1=yes, otherwise 0)	0.5283*** (0.1009)	0.1238*** (0.0580)	-0.0452 (0.0419)	-0.0256 (0.004)
Number of government extensions service visits	0.0082** (0.0034)	0.0019** (0.0009)	0.0023 (0.0016)	0.0013 (0.0002)
Number of NGOs extension service visits	0.0216* (0.0112)	0.0051* (0.002)	0.0076 (0.0064)	0.0043 (0.0006)
Usage of mobile for information collection	0.1612*** (0.0593)	0.0378*** (0.018)	0.0623*** (0.0238)	0.0352*** (0.005)
Jhalokati	-0.1377* (0.0840)	-0.0323* (0.015)		

Barguna	-0.3367***	-0.0789***		
	(0.0840)	(0.037)		
Barisal	-0.0169	-0.0040		
	(0.0680)	(0.002)		
Nilphamari			0.2539***	0.1435***
			(0.0465)	(0.021)
Lalmonirhat			-0.0207	-0.0117
			(0.0470)	(0.002)
Rangpur			0.2085***	0.1178***
			(0.0726)	(0.017)
Constant	-0.8682***		-0.0497	
			(0.0826)	
	(0.1658)			
Sigma	0.4815***		0.4109***	
			(0.0129)	
	(0.0321)			
H.Size	-0.3876		-1.5973***	
			(0.4274)	
	(0.2375)			
Observations	2,154		2,811	

Standard errors are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

5.3 Double Hurdle Model Estimation

Table 6 shows the estimates of variables used in the Double Hurdle model. The first stage, hybrid rice adoption, shows the estimates of factors of those who actually adopted hybrid rice varieties in their cultivating plots. The first stage only shows the results of whose hybrid rice variety adoption rate is more than 0 to specify the impacts of the factors affecting the adoption behavior. The significant estimates of the variables in the Tobit estimation have the same significance in the first regression stage except for the regional dummy variable, Jhalokathi. Besides, the important factors in this study such as farmer's union and extension services are statistically significant and positively affect the adoption behavior.

On the other hand, the second stage shows how the factors affect the level of the adoption rate of hybrid rice varieties. Peculiarly, the results show big differences compared to the estimates in the participation of the hybrid rice variety adoption. Only household head age, total paddy plot size, and the regional dummies such as Kurigram and Nilphamari are significant estimates while the other factors that are significant in the participation are no longer statistically significant. It implies that various factors shown in the estimation help farmers adopt hybrid rice varieties. However, these

factors did not affect the adoption rate of hybrid rice varieties when farmers decided to adopt the hybrid rice varieties.

Table 6. Double Hurdle Model Estimation

Variable	Hybrid rice adoption	Adoption rate
Household head age (years)	-0.0036**	-0.0042***
	(0.0016)	(0.0016)
Gender of household head (1=male)	0.3420***	-0.0626
	(0.1253)	(0.1509)
Education level (from 1 to 11)	0.0010	-0.0057
	(0.0116)	(0.0106)
Literacy (1=yes, otherwise 0)	0.0308	0.0755
	(0.0538)	(0.0536)
A member of farmer's union	0.3481***	-0.0964
	(0.0763)	(0.0877)
The number of household members	0.0111	-0.0093
	(0.0100)	(0.0093)
The amount of savings (×1,000,000 Taka)	-0.0001	0.0004
	(0.0003)	(0.0004)
The amount of loans (×1,000,000 Taka)	-0.0000	0.0001
	(0.0000)	(0.0001)
Total paddy plot size (decimal)	0.0006***	-0.0002***
	(0.0001)	(0.0001)
Average distance to household from plots (ft.)	0.0002***	-0.0001
	(0.0001)	(0.0001)
Irrigation availability (1=yes, otherwise 0)	0.2558***	-0.0759
	(0.0964)	(0.0883)
Number of government extensions service visits	0.0118***	0.0007
	(0.0038)	(0.0032)
Number of NGOs extension service visits	0.0396***	-0.0103
	(0.0152)	(0.0112)
Usage of mobile for information collection	0.2202***	0.0418
	(0.0564)	(0.0476)
Jhalokati	-0.2325	0.0307
	(0.1427)	(0.2000)
Barguna	-0.4631***	0.0015

	(0.1495)	(0.2092)
Barisal	0.0035	-0.0755
	(0.1143)	(0.1364)
Kurigram	0.7063***	0.3315**
	(0.1265)	(0.1471)
Nilphamari	1.2563***	0.4768***
	(0.1306)	(0.1374)
Lalmonirhat	0.6930***	0.1179
	(0.1267)	(0.1450)
Rangpur	0.6700***	-0.0104
	(0.1193)	(0.1376)
Constant	-1.3432***	-0.7570***
	(0.1743)	(0.2071)
lnσ	-0.0969	
	(0.0058)	()
Observation	4970	4970

Standard errors are in parentheses
*** p<0.01, ** p<0.05, * p<0.1

6. Conclusion

With the results of the Double Hurdle model as well as the marginal effects of statistically significant coefficients in the Tobit estimation, meaningful results could be deduced for the farmer's adoption of hybrid rice varieties in Bangladesh. First, Bangladesh government need to encourage farmers to join famer's organization to facilitate the provision of hybrid rice varieties. Even though the result of farmer's union in the second stage of the Double Hurdle model shows the insignificant impact on the level of adoption, it is still positive in the first stage of the Double Hurdle model for the participation and the Tobit estimation shows that farmers are more likely to adopt hybrid rice varieties by 6 percent when they are members of farmer's organizations. In order to increase the level of adoption, the government or any other project related personnel should not only provide improved rice varieties but also help farmers organize such farmer's union or corporative so that farmers could build social networks to gain needy information in their neighborhood. Also, there should be consequent investigations and studies to find out the rationale that farmer's unions do not perform properly in terms of hybrid rice adoption and the level of the

adoption.

Second, those farmers with larger size of farm lands are more likely to adopt hybrid rice varieties in the previous studies (David & Otsuka, 1994; Estudillo & Otsuka, 2006; Moser & Barrett, 2003). However, it should be considered that not only those farmers need higher production but also small-scale farmers do need the improved productivity. Even though it is not necessarily for farmers with larger farm to be members of any form of farmer's union or corporative, there might be a higher possibility that mostly large-land owned farmers are the members of those organizations as they can afford the fee that they should contribute to be a member of the unions. Thus, it is recommended that the entrance fee should be as low as the amount that most farmers could afford to pay and the government should provide a variety of useful information for the farmers through the channel.

Third, irrigation also plays a critical point in this study as hybrid rice varieties need well maintained irrigation system for higher production. This study has found that farmers with access to irrigation are more likely to adopt hybrid rice varieties by 3 percent. Besides, a number of previous studies have already discovered that irrigation facilities are the major component that should not be

missed when it comes to cultivating hybrid rice varieties (Mottaleb et al., 2015; Pervez et al., 2017). However, unlike the positive estimates of the Tobit model and the first stage of the Double Hurdle model, irrigation has been found no longer statistically significant in determining the level of the adoption. For the reason, once farmers with access to irrigation facilities decide to adopt hybrid rice varieties, irrigation does not help farmers increase their level of the adoption of hybrid rice varieties. Nevertheless, the government should focus on investing in expanding irrigation facilities as the result shows that access to irrigation facilities helps farmers participate in the adoption.

Fourth, the government should keep working on providing extension services to farmers, particularly related to hybrid rice cultivation practices. The results show that the visit of government and NGOs extension services also positively affects the farmer's adoption of hybrid rice varieties and farmers are more likely to adopt hybrid rice varieties as the previous studies (Adeogun et al., 2008; Hossain et al., 1990; Nkamleu et al., 1998; Rahman & Thapa, 1999). However, extension services by the government and NGOs are no longer significant in the level of adoption. As farmers who are used to cultivating the traditional types of rice do not have much

knowledge on hybrid rice, the government should not only help farmers adopt the hybrid rice varieties but also provide enough knowledge and courses to facilitate the expansion of hybrid rice variety adoption.

Fifth, as the results of previous studies, sharing information from one to another is a key factor for the farmer's adoption of hybrid rice varieties (Bindlish & Evenson, 1997; Chithtalath, 2006; Rahman, 2003). Its marginal effect shows that farmers are more likely to adopt hybrid rice varieties by 3 percent as they use their mobile for information collection. A number of studies also have found that diffusion of information helps farmers to receive newly–introduced agricultural technologies. However, as shown in the Double Hurdle model estimation, information collection via mobile is no longer statistically significant in the level of the adoption. Mobile could be a suitable option to receive new information related to agricultural technologies for those farmers who reside far away from the major cities and hardly meet extension workers due to distance and it is also an effective way for famers to cultivate their lands with proper guidelines received via their mobile. Therefore, more information sharing system via mobile should be available for farmers to collect and this could be accomplished by the government or international

institutes along with the seed development.

Last, regional characteristics and differences should be considered as the signs for the districts are different from each other. The estimates show that farmers in Rangpur district located in the northern part are more likely to adopt hybrid rice varieties than farmers in Barisal district in the southern part. Also, in the second stage of the Double Hurdle model, only Kurigram and Nilphamari districts are statistically significant to affect the level of the adoption. The government needs to investigate the differences made by divisions so that policies and provision programs for hybrid rice varieties can be effectively implemented by divisions.

Even though this study has gained interesting findings on farmer's adoption of hybrid rice varieties in Bangladesh, there still remain a few limitations that consequent studies should consider. First, even though farmer's unions play an important role in the findings, due to lack of information it was difficult to explain how these unions could affect farmers in positively for Barisal and negatively for Rangpur. Second, it does not specify which hybrid rice varieties could be useful for the different regions even though these varieties have differently distinctive advantages. Better and more precise results could be expected if the varieties in the study were

clearly specified. Third, the findings for Barisal and Rangpur were very different from each other. However, the rationales were not provided due to lack of background information on the divisions. Last, many factors used in the second stage of the Double Hurdle model were no longer statistically significant and these could not be explained with the given information. Nevertheless, this study gives ideas about important factors including farmer's union, government and NGOs extension services, and other socio-economic factors when it comes to diffusing hybrid rice varieties to farm households examining the case of IAPP project that reflects some parts of Bangladesh farm households. Therefore, this study could lead policy makers and project practitioners to making effective strategies for the hybrid rice variety diffusion in Bangladesh.

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Abstract (Korean)

국 문 초 록

방글라데시 농가의 잡종벼 종자 채택 의향 요인
-지역 정부 영농 교육과 농민조직을 중심으로-

최정만
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본 연구는 방글라데시의 8개 지역의 농가들이 지니고 있는 사회경제적 요인들이 농가들의 잡종벼 채택에 미치는 영향과 잡종벼 채택 비율에 미치는 영향을 보려고 하였다. 또한 남쪽과 북쪽 지역의 지역적 차이를 고려하여 분석하였다. 2012년 방글라데시에서 시행된 통합 농업 생산성 프로젝트(IAPP) 2012년 베이스라인 조사에서 수집된 4,970개의 농가 정보를 이용하였으며, 잡종벼 채택비율과 경지면적의 이분산성을 고려한 Tobit모델과 Dobule Hurdle 모델을 사용하여 분석하였다.

Tobit모델 분석과 Double Hurdle 모델 1차 분석에서 금융정보를 제외한 대부분의 사회경제적 요소에서 유의미한 결과를 보였다. 반면, 채택비율을 증대시키는데 미치는 영향을 보기 위해 사용된 Double Hurdle 모델 2차

분석에서는 나이와 경지면적, 2개 지역에서만 유의미한 값이 나왔다. 결과적으로 이 연구에서 사용된 농가의 사회경제적 요인인 정부 및 NGOs의 영농 교육 및 농민조직이 잡종벼 채택에 유의한 영향을 미치는 반면, 잡종벼 채택에 영향을 미치는 변수들이 잡종벼 채택율에 영향을 미치지 않는 것으로 나타났다. 따라서, 잡종벼의 효과적인 보급을 위해 잡종벼 채택율을 증가시킬 수 있는 영농 교육과 농민조직의 역할이 제고되어야 한다.

주요어: 방글라데시, 농민조직, 영농 교육, 잡종벼, 농업기술채택

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