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Master in Economic Development and Growth

Adoption and continued use of hybrid rice : Case of Haryana State, India

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Abstract: India's productivity of rice production lags behind China's. Given its status as global food supplier, it is not only national but also world's concern. As part of an effort to improve rice productivity, India increased investments in research on breeding, which has resulted in many new varieties with higher yield suitable and available for Indian farmers. Despite the effort to encourage hybrid rice adoption, the rate of adoption of the technology remains low because of both insufficient adoption and high rate of disadoption. This calls for more research focused on socioeconomic factors influencing the adoption decision and continued use of hybrid rice. Hence, this study investigated the socioeconomic determinants of adoption and continued use decision of hybrid rice among farming households in Haryana State, India.

Key words: Adoption, Continued use, Technology, Hybrid rice, Probit, Heckman Probit

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Chapter 1

Introduction

1.1 Objectives and Scope of the Study

Agriculture has been considered the backbone of the Indian economy. Being the main source of income for about 58 per cent of the population, it contributes about 17 per cent of the GDP. At the same time, Indian agriculture plays an important role in the world market as a leading supplier of many agricultural products (WTO, 2015; World Bank, 2013; IBEF, 2017).

Despite its contribution to the overall Indian economy and global food security, studies indicate that India's agricultural productivity has not improved significantly last few decades (FAOSTAT, 2014A; Nin-Pratt et al., 2010). The low productivity of agriculture can be attributed to failure to adopt a new technology adequately to some extent. As one option for increasing the agricultural productivity and reducing absolute poverty in rural areas, adopting an improved technology is considered (Zeller et al., 1998; Mendola, 2007; Datt & Ravallion, 1998). Although one of improved technologies available to Indian farmers include hybrid rice seeds that are more suitable to farming conditions and higher yield is expected, in India the hybrid rice is not as widely adopted as in China. In addition, the rate of the technology abandonment is high as well. Therefore, understanding inhibitors affecting farmers' adoption and disadoption decisions can help India design better-targeted policies and more effectively tackle the challenges that Indian farmers often face in choosing to adopt an improved technology and whether or not to continue using the technology.

Some attempts have been made to study what hinders agricultural technology adoption in India (Harriss, 1972; Janaiah, 2002; Janaiah & Fangming, 2010). However, there has been not many attempts to identify the factors that influence households' decision of technology abandonment in India. Thus, my thesis aims to identify those factors that hinder the continued use as well as the adoption of an improved technology – in my case, hybrid rice – to draw out implications for Indian policymakers.

1.2 Structure of Thesis

The remaining of the thesis is organized as follows: Chapter 2 describes the background of India, including the agriculture sector, its development and importance in socioeconomic context. Chapter 3 examines literature dedicated to addressing the determinant factors that affect technology adoption and disadoption. Chapter 4 discusses the study area and data. Chapter 5 describes the analytical framework and empirical model with selected variables. Chapter 6 presents regression results, and Chapter 7 concludes with policy implications.

Chapter 2

The India Background

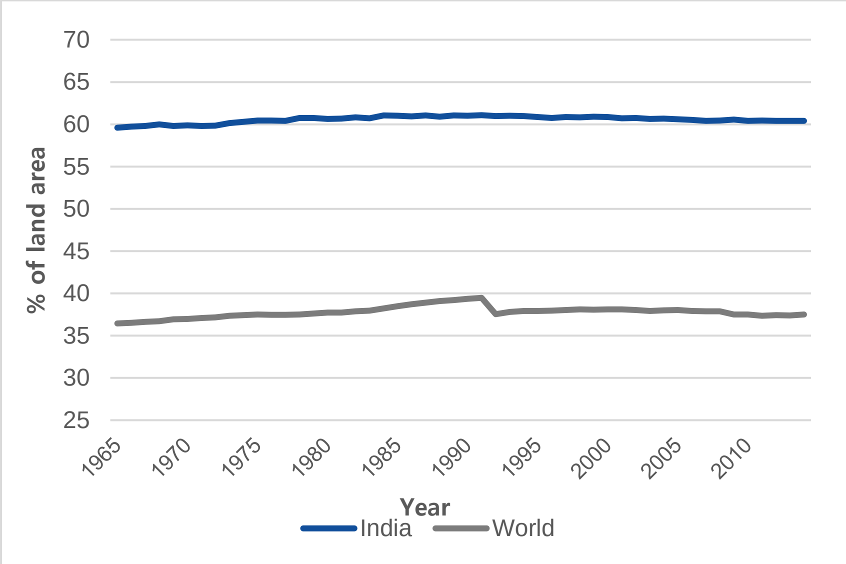
2.1 Agricultural Development

Located in Southeast Asia, India is a peninsular country that extends into the Indian Ocean and borders the Arabian Sea and Pakistan to the West and Bangladesh, Myanmar and the Bay of Bengal to the East. In the North, it is bordered by China, Bhutan, and Nepal. This country occupies most of the Indian subcontinent[1], ranked as the world's seventh-largest country with a total area of 3.287 million km^2.

India is also characterized by a great diversity of agro-ecological conditions. The world's highest mountains, the Himalayas, stretches to its North, the Thar desert to its West, and vast plain areas between the Indus River and the Ganges River, and the Deccan Plateau to its South. The climate in India varies due to its large size and varied terrain in geographic regions across the country. It ranges from a dry and subarctic in the North to temperate or subtropical inland, to humid and tropical climate in coastal areas of the peninsula. More importantly, the effect of Monsoons, a seasonal change of winds moving up and down the Indian subcontinent, is significant on Indian economy. Characterized by the summer monsoon with torrential rainfall that creates a humid atmosphere and the winter monsoon with dry and cool air, it determines India's four seasons governing the agricultural calendar of this country — a dry and relatively warm season from December to March, a hot season in April and May, a rainy season from June through September, a less-rainy season in October and November. India receives 50 - 75 per cent of the annual rainfall during the summer monsoon period itself. India's varying terrain as well as wide variation in climatic condition provide favorable environment for agriculture. In fact, at 157.35 million hectares India's agricultural land area is the second largest in the world, just behind the United States. Data from the World Bank show that India holds about 60.4 per cent of its land as agricultural land (see Figure 2.1). The estimated figure of India is about 60 per cent higher than that of the world. This indicates that India has ample land for farming.

[1] The term Indian subcontinent (or South Asia) refers to the southern region of Asia, generally including India, Pakistan and Bangladesh. The term South Asia is used interchangeably with Indian subcontinent. Definition retrieved March 14, 2017, from https://en.oxforddictionaries.com/definition/Indian_subcontinent

Figure 2.1: India and World Agricultural land (% of land area), 1965-2014



Source: World Bank

In addition, it is important to note India's recent growth as one of the world's largest economies with fast growth. In 2015, the country was seventh-largest economy measured by nominal gross domestic product (GDP) and third-largest by GDP at purchasing power parity according to the World Bank[2]. The Indian economy is projected to grow further. According to the Global Economic Prospect 2017, the World Bank estimates that India will grow by 7 per cent in fiscal year 2017 and 7.6 per cent in 2018[3]. Through economic liberalization in the mid-1980s and market-based economic reforms since 1991, India underwent a transformation of its economic structure and grew rapidly with the expansion of the non-farm sector. However, it is important to note that agriculture has been considered the backbone of Indian economy. Data from the World Bank show the share of economic sectors in GDP of India from 1960 to 2015 (see Figure 2.2). By the mid 1970's, the agriculture sector was a single largest contributor that accounted for approximately 4o per cent of the GDP of India, whereas 20 per cent of the economic value added originated from the industry sector and 38 per cent from the service sector. This could be attributed to the India's Green Revolution that started in the mid-1960s.

In the pre-Green Revolution period, India imported a massive amount of food grains per year to provide for its large population. However, the revolution changed India's status from a food-deficient country with chronic dependence on grain imports to one of the world's largest producers of food crops with net exports. The introduction of the Green Revolution helped the country overcome poor agricultural productivity by fostering several agricultural reforms such as selective breeding, expansion of irrigation infrastructure, and distribution of high-yielding modern variety of seeds (HYV) and agrochemicals to farmers. The main benefit of the Green Revolution was the

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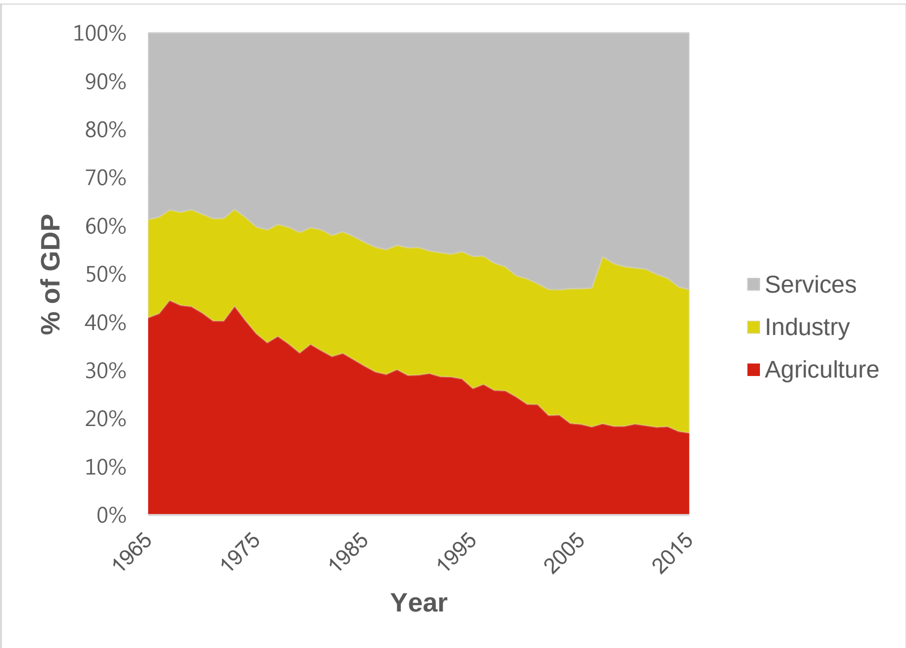
[2] The World Bank, World Development Indicators (2015). GDP (current US$) & GDP, PPP (current international $). Retrieved from http://data.worldbank.org/indicator/NY.GDP.MKTP.CD?locations=IN

[3] The World Bank Group. (2017). *Global Economic Prospects, January 2017: Weak Investment in Uncertain Times.* Available on http://www.worldbank.org/en/publication/global-economic-prospects

phenomenal increase in production of food grains. As a result of which, India could reduce its high level of imports of food grains drastically and decreased the reliance on foreign food imports. Now India is self-sufficient in food grains and it is one of the largest producer, consumer and exporter of many agriculture products in the world. According to FAOSTAT statistics[4], in 2014 the country ranked first in producing pulses, jute, spices and fruits such as bananas, lemons and mangoes. Apart from India being the world's largest producer of pulses, jute and several fruits, the country is also the second largest producer of rice, wheat, sugar cane, lentils and tea in the world. The Foreign Agricultural Service (FAS) of the United States Department of Agriculture (USDA) reports that in recent years the country has emerged as one of the leading exporters of agricultural products in the international market, with total exports rising from about $5 billion in 2002 to more than $38 billion in 2013. As per the World Trade Organization (WTO), India was the world's ninth-largest exporter of agricultural products in 2015, which shows its global competitiveness in agriculture and importance as a principal food supplier affecting world food security as well.

Figure 2.2: India Sectoral Composition of GDP (%), 1965-2014



Source: World Bank

2.2 The Role of Agriculture: Socio-economic Contexts

Employment and Poverty Reduction

Along with the country's gradual shift toward an economy that gives more emphasis to industry and service sectors, agriculture has been steadily brought down in Indian economy in terms of its

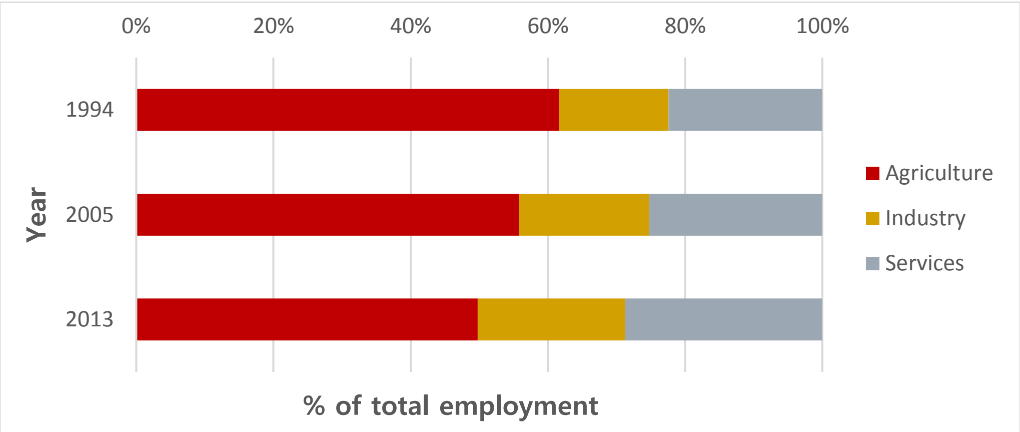
[4] Food and Agriculture Organization of the United Nations (FAO), FAOSTAT. (2014). Crop Statistics. Retrieved March 17, 2017 from http://www.fao.org/faostat/en/#data/QC/

contribution to GDP of the country. In Figure 2.2, we can see that in 2015 the Indian economy is dominated by the services sector, which accounted for 53.2 per cent of the GDP while agriculture and its allied sectors made contribution of only 17 per cent and industry sector of 29.7 per cent. However, the decreased contribution of agriculture does not necessarily mean a decrease in the influence of agriculture on the lives of Indian people. In fact, agriculture still remains vital in the Indian economy as a primary employment source across the country despite its decreased contribution to GDP.

India has taken a path to economic development which differs from a traditional development model that involves a transition from agriculture to industry, and later to services. India moved directly from agriculture to the service sector. Since the service sector created only jobs for skilled workers and the industry sector has not grown fast enough to provide jobs to the agricultural workers, a non-absorption problem arose in India. The non-absorption prevented the labor force from moving to higher-productivity sector, leading to an inefficient resource distribution in the economy.

Consequently, we can see that the shift of workforce moving from agriculture to other sectors has not yet taken place to the same extent of the shift of GDP contribution. Still a large proportion of the Indian population is involved in the agricultural sector, despite its gradual decrease over past years (see Figure 2.3). The India Brand Equity Foundation (IBEF) reports that agriculture is a principal source of income and employment for over 58 per cent of India's population. Particularly, the agriculture is influential on the livelihoods of rural people in India in terms of providing employment and food. According to the World Bank (2013) and NSSO (2014), almost 70 per cent of Indian population live in rural areas and 57.8 per cent of which rely primarily on agriculture sector for their livelihoods.

Figure 2.3: Sectoral employment shares (%), 1994-2013



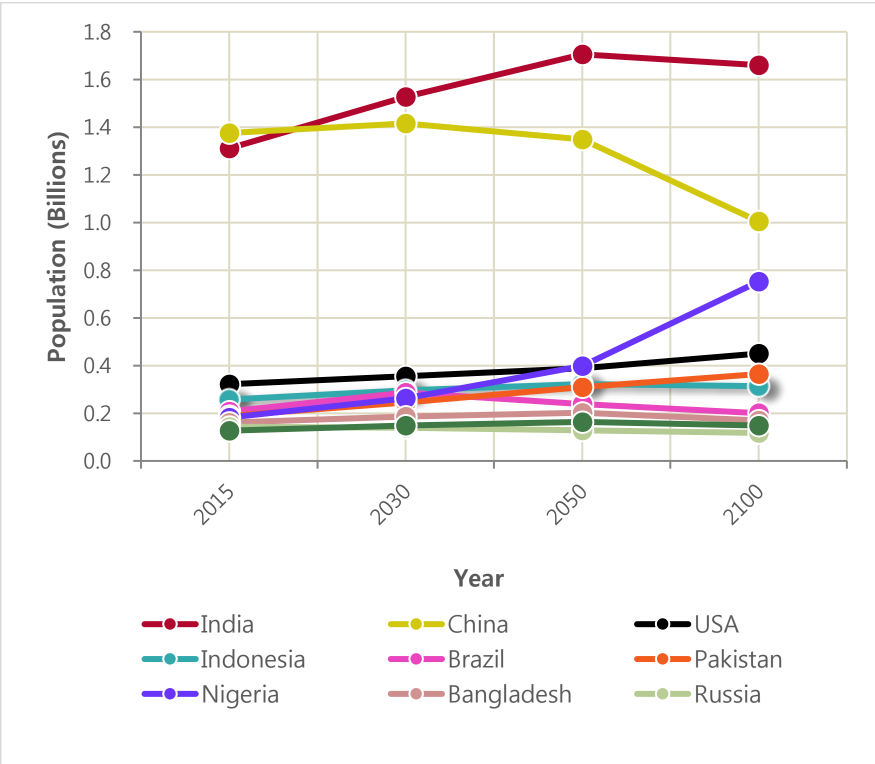
Source: World Bank

Furthermore, the importance of agriculture sector cannot be undermined in terms of its potential contribution to poverty reduction. As the prevalence of poverty in India is well known, poverty remains an issue of great concern of the country. India has the largest number of people living under the World Bank's international poverty line of US$1.90 per day. At 224 million, about 30 per cent of its population lives below poverty line (BPL) in 2013, accounting for 30 per cent of the world's poor population according to the report 'Poverty and Shared Prosperity 2016' by the World Bank. There are studies that show a strong poverty-reduction effects of agricultural growth (Irz et al., 2001; Mendola, 2007). Irz et al. (2001) explain the effects of agricultural growth on poverty alleviation with theoretical expectations. The authors explain that agricultural growth can directly contribute to poverty reduction by bringing in higher incomes for farmers. Mendola (2007) also finds that technology adoption positively influenced resource-poor farmers in Bangladesh, in terms of increased income and poverty reduction.

Growth in Population and Food Security

Another important role of the Indian agriculture is to feed its growing population. Estimated in 2015, India ranked second in the world's population with a population of 1.31 billion. The population constituted 17.8 per cent of the world's population according to the United Nations (2015). Furthermore, the World Bank (2015) recently reported that the India's population annually grow by 1.21 per cent. Figure 2.4 presents the projected population growth of the ten countries with the largest population today in the world. It shows that by 2030 India will surpass China and become the most populous country in the world. A problem which arises here is that the population of India grows at a faster pace than its ability to produce food, which poses a great threat to India's national food security. In addition, it is also important not to forget that India has grown as a major supplier of food grains for not only India herself but also for many other countries. In other words, this means that the world food security cannot be considered in isolation from India's agriculture because of its status as global food supplier.

Figure 2.4: Population Projections of Current Top 10 populated countries, 2015-2100



Source: UN Population Division, "World Population on Prospects, the 2015 Revision"

2.3 Rice Production

Low Agricultural Productivity

Rice is a dominant food crop in India providing necessary energy for the people, and plays an important role in the Indian economy by providing source of income to many people. Given its influence on Indian people's lives, it is often called the lifeline for India. India also has the largest area under rice cultivation in the world according to data gathered by the International Rice Research Institute (IRRI) in 2009. According to Muthayya et al. (2014), India as the second largest producer of rice, produced up to 50 per cent of rice consumed in the world together with China.

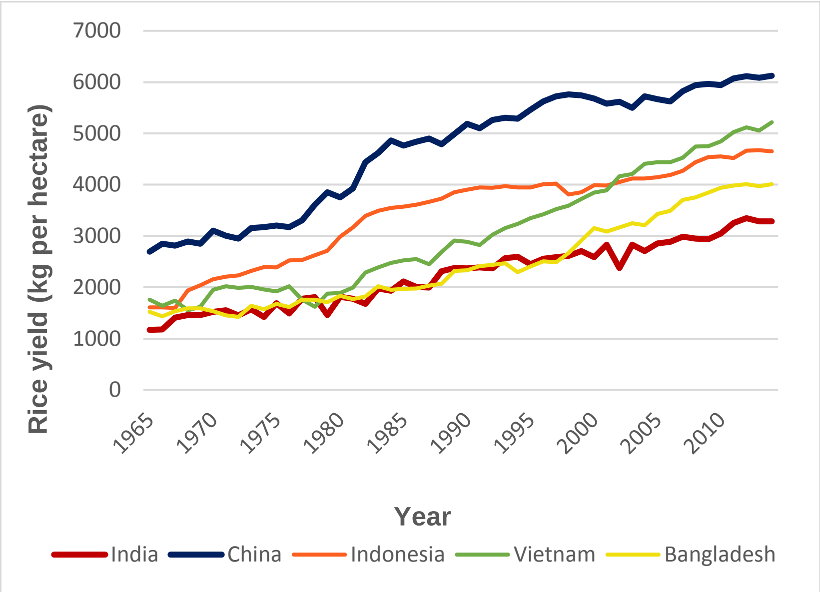
In fact, India's rice sector has experienced notable progress during the last three decades of the twentieth century, mainly driven by technological innovation. The Green Revolution transformed Indian agriculture through the introduction and adoption of modern high-yielding modern varieties(HYVs) of cereals, especially dwarf wheat and rice, in association with modern agricultural technologies that included heavy doses of chemical fertilizers, irrigation and mechanization. This combination replaced Indian traditional technology that had been used, and succeeded in increasing the average yield of rice per hectare. For example, yields of rice in India almost doubled from 1,123 kg per hectare in 1970-71 to 2,239 kg per hectare in 2010-11 according to the open government data (OGD) of India. As a result of which, India witnessed the unprecedented increase in rice production during the last five decades. Rice production increased from 42.2 million tons in 1970-71 to 105.5 million tons in 2014-15 according to the OGD of India. The success of Green Revolution significantly reduced India's dependence on food grain imports, enhanced national food security and further reduced poverty (Lipton & Longhurst, 2010; Pingali, 2012).

However, the rice sector still has relatively low productivity, compared to other leading rice-producing countries such as China, Indonesia, Bangladesh and Vietnam. Figure 2.5 presents rice yield (kg per hectare) of the top 5 rice-producing countries in the world from 1965 to 2014. As shown in Figure 2.5, in 1965 India had the lowest rice yield per hectare among five leading rice producers. Though, there was not a wide disparity in the countries' rice yield. However, we need to focus on the yield gap between India and China growing noticeably larger over next decades. Although India shares similarities with China — for instance, large territory with similar-sized populations and similar food consumption habits, China's rice production is greater while its area harvested is lower than India's (Maclean et al., 2013). In 2014, India yielded only about one-half of China's rice yield. Behind this yield gap, there was hybrid rice. In fact, China successfully adopted hybrid rice that yields 15-20 per cent more than conventional rice (IRRI, 2009) and significantly increased the rice production in the 1970s and 1980s (Lin, 1991 and 1994; Virmani *et al*, 1998).

Low Rate of Hybrid Rice Adoption

Inspired by the great success of Chinese hybrid rice, Indian policymakers perceived hybrid rice as an innovative technology that could break the yield ceiling and overcome the stagnating growth rate of rice production. As proven in the case of China, hybrid rice was superior to existing rice varieties in terms of higher yield. Starting from the late 1980s, India has focused on research and development of hybrid rice and about 20 different rice hybrids were released in 1990s. It was reported that India's rice hybrids outyielded the conventional one by 15-20 per cent (Janaiah et al, 2002). However, the farmers who were enthusiastic about cultivating hybrid rice soon started abandoning the technology after one or two seasons, and as a result the area planted with hybrid rice was accounted for only 0.3 per cent of total rice area (Janaiah, 2002). In the view of 'failure' of hybrid rice adoption, India faces an important question to be answered: why have Indian farmers not adopted or continued the present hybrid rice technology? Given that the basic science used to develop hybrid rice is same in India and in China, are there other factors that hinder Indian farmers' use of hybrid rice, apart from factors related to technology itself?

Figure 2.5: Rice yield (kg per hectare) of the Top 5 Rice producers, 1965-2014



Source: FAO

Chapter 3

Literature Review

Due to the potential benefits that a new technology brings to the adopters, there is a large number of literature that has dealt with what influences farmers' technology adoption decision and continued use. In general, the studies on technology adoption and disadoption have analyzed the decisions, perceiving it either as a discrete or a continuous decision. Discrete analysis focuses on whether a farmer adopts, and disadopt a given technology or not, whereas continuous analysis gives more attention to the extent at which the technology adoption or disadoption takes place. In fact, most studies have approached technology adoption and disadoption by employing a dichotomous choice (Lin, 1991; Neill & Lee, 2001; Tura et al., 2010; Hayes et al., 1997), although a few studies have included a continuous element in their analysis and frequently employed the Tobit model as methodological approach (Adesina & Zinnah, 1993; Adesina & Baidu-Forson, 1995; Oladele, 2006).

3.1 Three Paradigms

The two decisions on technology adoption and whether to continue using it or not are complex because they involve not only internal but also external factors such as crop prices and institution. As Feder et al. (1985) states in their work, in fact, constraints to the rate of adoption of a given technology are various and multifaceted. The literature has traditionally focused on explaining the adoption (or lack of adoption) with factors such as lack of access to quality information, economic constraints (access to credit and land), labor and input availability, risk attitude and education level of a farmer, and a household's socio-economic characteristics. More recent studies have dealt with the impacts of the social networks and learning on technology adoption decision. One of the recent studies finds that community and family networks play an important role in providing information, thus lowering the costs of searching credit sources (Okten & Osili, 2004). On the other hand, Foster & Rosenzweig (1995) presents that barrier to adoption diminishes together with learning spillovers.

In general, the literature on technology adoption uses the following three paradigms: (1) the innovation-diffusion; (2) the economic constraint; and (3) the adopter perception. Firstly, the innovation-diffusion model assumes that the technology is appropriate in both technical and cultural contexts and it is expected that desirable improvement in outcomes are to be made through adopting a given technology. According to the innovation-diffusion paradigm, however, asymmetric information and high-searching cost are main problems that make farmers constrained from adopting a new technology (Feder & Slade, 1984; Smale et al., 1994; Shampine, 1998). On the other hand, the economic constraint paradigm gives emphasis on endowment of household that is asymmetrically distributed (Aikens et al., 1975). For instance, Croppenstedt et al., (2003) finds that credit is a major constraint on supply side and underlines the importance of increasing the credit availability to farmers. Feder & O'Mara (1981) also shows, the bigger size of land holding a farmer has the more likely he or she is to adopt the HYV technology. Last model is so-called 'adopter perception' paradigm. This model suggests that farmers' subjective perceptions may condition their adoption decision. While several authors in this paradigm have focused on whether farmers seriously perceive problems that they face in cultivation such as soil erosion (Gould et al., 1989; Norris & Batie, 1987), others explore farmers' perceptions regarding new technology itself. (Adesina & Zinnah, 1993; Adesina & Baidu-Forson, 1995; Negatu & Parikh, 1999).

Chapter 4

Data

4.1 Cereal Systems Initiative for South Asia (CSISA) Baseline Household Survey (2010-2011)

The data used to analyze factors influencing households' technology decisions come from the Cereal Systems Initiative for South Asia (CSISA) Baseline Household Survey. The survey was initially designed with the aim to promote the inclusive deployment of sustainable technologies, with ambition to accelerate sustainable intensification of cereal productivity growth. Through which, it was believed to be able to improve food and income security, and ultimately the livelihood of poor in the region. Carried out in late-2010 and early-2011, the survey covered a total of 144 villages across nine states (or provinces) of four countries, namely India, Bangladesh, Nepal and Pakistan. From within each of these villages, 18 households were selected at random. Of these nine states (or provinces), five were located in India (Punjab, Haryana, Eastern Uttar Pradesh, Bihar, and Tamil Nadu), two were in Bangladesh (Dinajpur and Gazipur), one in Nepal (Terai region), and lastly one in Pakistan (Faisalabad and Punjab). A total of 2567 households were interviewed. The household survey data include the demographic and socioeconomic dimensions of the households, as well as their crop production.

Study Area: Haryana State

Because of high level of potential heterogeneity in the characteristics of households across states and provinces of countries covered in the CSISA data, I decided to restrict sample households to those residing in Haryana, India. For the analysis, only data on households in Haryana, India were used. Haryana is a state located in northwestern India and known for high agricultural fertility. Despite the recent industrial development, the economy of Haryana is primarily based on agriculture. The main crops produced in Haryana are wheat, rice, sugarcane, cotton, pulses, barley, maize etc. However, the dominant cropping pattern throughout the state is rice-wheat[5]. The state has a favorable rice-wheat environment which are characterized by relatively high level of irrigation. Due to fertile land as well as irrigation available in the state, the Haryana State was reported to contribute to national food grain production considerably, together with the Punjab State accounting for 21 per cent of the national production. Nevertheless, the land area accounts only for 3 per cent of the total area of India (Erenstein et al., 2007). This shows high fertility of the land, and at the same time centralized grain production in these states. Although the sample was not restricted to rice growers, I found that nearly all households in the sampled state cultivated at least

[5] From now on throughout the thesis, when specifying cropping system the first crop referenced will be for the Kharif (rainy season) and the second referenced will be for Rabi (dry season).

some rice. Therefore, I believe the Haryana State is suitable candidate for analyzing the determinants of adoption and the continued use of hybrid rice.

Table 4.1: Summary Statistics, Sample Households in Haryana

	Adopter						Non-Adopter	
	Continued use		Discontinued		All adopter			
Variable	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
AGE (years)	48.46	14.04	49.22	11.51	48.81	12.89	46.91	12.99
EDUYR (years)	9.00	3.71	7.78	4.46	8.43	4.11	8.09	4.41
HHSIZE	7.36	4.09	7.69	4.32	7.51	4.19	7.17	4.48
MADULT	2.87	1.69	2.88	1.79	2.87	1.73	2.85	1.86
FADULT	2.70	1.53	2.85	1.41	2.77	1.47	2.54	1.72
FREQUENT	1.74	1.13	1.33	1.39	1.54	1.27	0.64	1.08
LNOWN (acre)	6.58	6.72	7.14	8.98	6.84	7.83	7.07	7.80
NFINCOME (%)	20.65	24.72	20.90	26.95	20.77	25.71	21.44	26.36
Total	89		78		167		153	

4.2 Limitations of the Data

Since data used to estimate the model are cross-sectional, the data do not reflect the attributes and situation that households had in the year when technology took place. In recognition of the inter-temporal problem, for the first equation I included variables that are highly stable over time. For the second equation, variables that reflect current situation of households and their farming were included. However, there is still possibility of distorted estimates arising from data with limited reflection of farmers' activities and situation in the past adoption year. In addition, the data do not have price variables such as price of hybrid rice and cost of the seed that are often reported to be influential on adoption decision. Finally, there are several missing factors that are expected to affect both decisions, which include farmers' experience in farming; distance to market; attitude towards risk-taking; and perception of the technology.

Chapter 5

Methodological Framework

5.1 Descriptive Analysis

The analysis involves two different decisions — (1) adopt; and (2) continue. The second is contingent to the first decision. Neill and Lee (1999) helps understanding by visualizing the subsequent process of two different decisions into decision tree:

Figure 5.1: Decision Tree

$$\text{(1) Adopt}\begin{cases}\text{Yes} \quad \text{(2)Continue}\begin{cases}\text{Yes}\\ \text{No}\end{cases}\\ \text{No}\end{cases}$$

Given that the dependent variables are dichotomous, choosing classical linear models is apparently not the best choice for this analysis, because of the possibility to lead to heteroscedastic variances (Aldrich & Nelson, 1984). As an alternative, maximum likelihood estimation (MLE) was proposed and in the form of either Probit or Logit has been widely used in studies with dichotomous dependent variables. Hence, it seems suitable to use Probit model to analyze the adoption decision, if there is only one decision to make, whether to adopt or not.

However, it is important to keep in mind that decision on continued use of a given technology involves a two-stage process: (1) Adopt the technology; and (2) Deciding whether or not to continue using it. This means that the continuation decision comes only if household has already chosen to adopt hybrid rice. This is called sample selection problem, arising from the decision framework. The potential correlation of the error terms of two decision equations suggests that some unobservable variables may cause correlation in adoption and continued use. In recognition of the problem, several studies employed the Heckman's sample selectivity Probit model, instead of applying simple Probit or Logit model (Deressa et al., 2008; Lambrecht et al, 2014).

5.2 Analysis of Technology Adoption Decision

Analytical Framework

The decision whether or not to adopt hybrid rice is assumed to be made, based on the general framework of utility maximization (Uaiene et al., 2009; Akudugu et al., 2012). It means, farmers adopt the technology only when utility that they gain from using such a technology is significantly bigger than utility gained without using it. Even though it is not possible to observe utility, farmers' adoption decision is observed, and through which their utility is indirectly inferred. The utility function that underlies farmers' technology adoption decision can be specified as:

$$U_{i1} = \beta_1 X_i + \varepsilon_{i1} \qquad \text{for adoption} \qquad (1)$$

$$U_{i0} = \beta_0 X_i + \varepsilon_{i0} \qquad \text{for non} - \text{adoption} \qquad (2)$$

where U_{i1} and U_{i0} represent perceived utilities of two choices, adoption and non-adoption, respectively. X_i is the vector of independent variables that are hypothesized to affect the household's perceived utility. β_1 and β_0 are coefficients to be estimated. Lastly, ε_{i1} and ε_{i0} are error terms having a zero mean.

If *i*th household decides to adopt the technology, it follows that the perceived utility from adoption is greater than the utility from non-adoption, which can be depicted as:

$$U_{i1}(\beta_1 X_i + \varepsilon_{i1}) > U_{i0}(\beta_0 X_i + \varepsilon_{i0}) \qquad (3)$$

Thus, the probability that the *i*th household will use the technology can be defined as:

$$P(1) = P(U_{i1} > U_{i0}) \qquad (4)$$

$$P(1) = P(\beta_1 X_i + \varepsilon_{i1} > \beta_0 X_i + \varepsilon_{i0})$$

$$P(1) = P(\varepsilon_{i0} - \varepsilon_{i1} < \beta_1 X_i - \beta_0 X_i)$$

$$P(1) = P(\varepsilon_i < \beta X_i)$$

$$P(1) = \Phi(\beta X_i)$$

where P is a probability function and U_{i1}, U_{i0} and X_i are as defined above. β is a vector of parameters to be estimated by maximum likelihood. Φ is a cumulative distribution function of the standard normal distribution.

Empirical Model

The Probit model is used for this analysis. The model is used by a number of studies on technology adoption (Uaiene et al., 2009; Hill & Kau, 1973). The advantage of the Probit model is that it permits the analysis of farmers' decision between adoption and non-adoption, allowing a binary variable as dependent variable. It is generated by a latent model in the form shown as following equation:

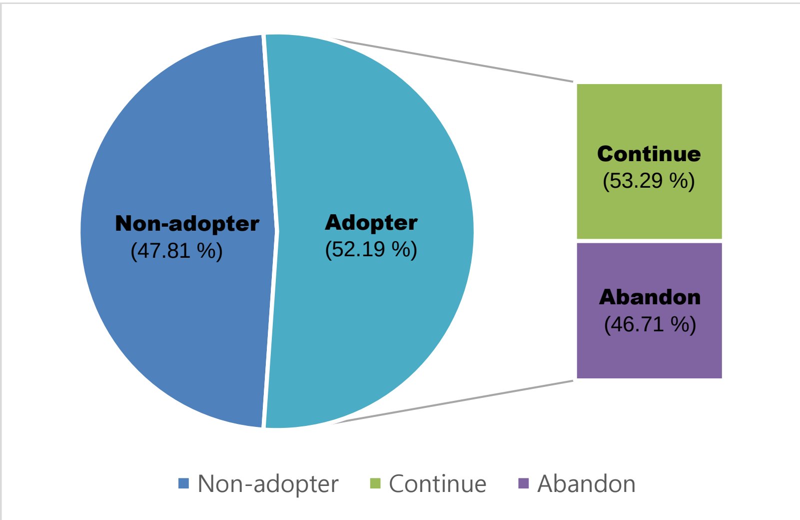
$$y^* = x\beta + \varepsilon \quad y = \begin{cases} 1 \ if \ y^* > 0 \\ 0 \ if \ y^* \leq 0 \end{cases} \tag{5}$$

Where y^* is latent variable representing the *i*th household's utility from adopting hybrid rice and depends on a vector of independent variables, x. y denotes a observable variable taking on the binary values 0 or 1.

Dependent Variable

The dependent variable has a binary value – either adopt or not adopt. For the analysis of technology adoption, farmers are considered "adopters" if at least once they have used hybrid rice. Figure 5.2 shows farmers' decisions visually.

Figure 5.2: Farmers' Hybrid Rice Adoption



As indicated in Figure 6.2, about 52 per cent of sampled farmers reported that they had adopted hybrid rice. However, 46 per cent of them reported that they discontinued their use on hybrid rice. Only 53 per cent of hybrid rice adopters kept their use.

Independent Variables

As noted, different characteristics of a household are important for determining whether or not to adopt a new technology. I therefore include a range of explanatory variables in the equation that describes the probability that a farmer adopts hybrid rice. Following literature on technology adoption, the explanatory variables for this thesis include characteristics of household such as age and education of household head both measure in years, size of household, number of adults within household, size of land owned by the household, farm size under his or her production, membership, share of off-farm income, land under rice cultivation (Uaiene et al., 2009; Akudugu et al., 2012; Neill & Lee, 2001). Additionally, a variable that measures female bargaining power is used to see how female decision-making power within the household influences a technology adoption. Table 5.1 presents a list of independent variables with expected signs. The choice of explanatory variables and reason for expected sign are explained in more detail.

Table 5.1: Description of Explanatory Variables and Expected Signs

Explanatory Variable	Description	Expected sign for Adoption
Age	Age of the household head (years)	±
Education	Education level of household head (years)	±
HHsize	Number of household members	±
Adult	Number of adults in household	+
Owned Land Size (acre)	Total land area owned (acre)	+
Farm Size (acre)	Total land cultivated (acre)	+
Membership	1 if household has membership of association, 0 otherwise	+
Off-farm Income	Share of off-farm income (per cent)	±
Rice Size	Total land area under rice cultivation (acre)	±
Female Bargain	Female bargaining power index within a household	+

In regard to the impact of a farmer's age, empirical studies have shown that age could influence adoption decision, either positively or negatively. Age of a household's head somewhat captures his or her farming experience. There are studies that reveal a positive relationship between age and likelihood of technology adoption (Adesina & Baidu-Forson, 1995; Uaiene et al., 2009). Adesina & Baidu-Forson (1995) finds that age influenced positively on adoption of sorghum in Burkina Paso and attributed it to older farmers' experience in farming. However, studies by Polson & Spencer (1991) and Bultena & Hoiberg (1983) indicate that the younger farmers are, the more risk-taking and willing they are to uptake an improved technology. Thus, expected sign for age is indeterminate.

Years of education of the household head are believed to be associated with his or her ability to access to information on the technology, understand and eventually use the technology (Lin, 1991). According to Rogers (2010), complexity that a technology has is one of barriers for people to adopt the technology. The author believes that this barrier can be overcome by more education. Hence, a positive relationship is hypothesized between education level of the household head and technology adoption.

Human capital endowment, such as household size and the number of adults within the household, are also included as explanatory variables. We can have two assumptions about the influence of household size on technology adoption. First assumption sees a household as source of labor supply. In other words, larger household size means higher labor endowment available for agricultural tasks. Croppenstedt et al., (2003) finds that more labor availability within a household increases the likelihood that farmers adopt fertilizer as well as intensity of the use. The other assumption in regard to the effect of household size on technology adoption is that larger household can also impose consumption pressure, and it may discourage a household to adopt the technology. Hence, household size can be either positively or negatively associated with technology adoption. Following the intuition about household size, the number of adult in a household is hypothesized to influence positively on technology adoption.

When it comes to land owned by a household, Tura et al. (2010) finds that the size of land owned by the farmer positively influenced adoption of improved maize seeds in Ethiopia. Size of land owned can also imply the family's wealth. In addition, size of farm under the household's cultivation has a positive effect on technology adoption (Feder & O'Mara, 1981; Lin, 1991; Neill & Lee, 2001; Polson & Spencer, 1991). Therefore, in my study it is hypothesized that the sign of both size of owned land and cultivated land increases probability of adoption.

Additionally, I include the size of land under rice cultivation. It is hypothesized that the larger rice cultivation a household has, the more likely the household is to invest in hybrid rice. I believe, a farmer may expect higher return from adopting hybrid rice if he or she already cultivates rice on a large size of land. However, it can be also the case that farmers with large size of rice cultivation may be more risk averse and less willing to adopt the technology.

Membership of a cooperative is hypothesized to have a positive effect on adoption decision. By joining a cooperative, a farmer can access to information required to make the decision on whether or not to adopt a given technology and can be more easily provided with complementary inputs necessary for the technology adoption. Tura et al. (2010) finds a significantly positive relationship between membership of a cooperative and an improved maize adoption in Ethiopia.

Evidence from studies on technology adoption indicates that there is a positive relationship between off-farm income and the adoption of an improved technology. Since non-farm income also represents wealth, higher income influences positively on adoption (Franzel, 1991). However, in my thesis share of non-farm income is included, not income itself. Therefore, I believe higher share of non-farm income may imply less dependence of household on farm income. This can indicate less incentive for a household to invest in a given agricultural technology. Hence, the influence of share of off-farm income is inconclusive.

Finally, female bargaining power is included in the equation. Doss (2013) finds that women's bargaining power has influences on intrahousehold decisions, including labor allocation. Von Braun (1988) demonstrates that women's insufficient bargaining power within the household is negatively related to the labor allocation, affecting agricultural production decisions and its production level. Therefore, female bargaining power is hypothesized to have a positive effect on hybrid rice adoption.

Barriers to Adoption

The CSISA survey reports the reasons why those households chose not to adopt the hybrid rice. As far as hybrid rice variety is concerned, the reason most frequently reported by non-adopters was information constraints (56.7 per cent). Another major reason for non-adoption was misconception and fear of side effects (40 per cent). This suggests that disseminating information about the technology and giving proper advices is crucial to increase the rate of hybrid rice adoption among farmers in Haryana.

Table 5.2: Farmers' Stated Reasons for Non-adoption

Reason for Non-adoption	Proportion of Non-adopters
Information constraints	56.7%
Misconception and Fear of Side effects	40.0%
More costly/ Less profitable	3.3%

5.3 Analysis of Technology Continuation Decision

Empirical Model

The Heckman Probit model with sample selection allows two equations and assumes that there is underlying relationship between two equations. The first-stage model looks at whether the farmer adopted hybrid rice (hereafter called the selection model). The second-stage model considers whether the farmer kept using the hybrid rice seed, and this is conditional on the selection model. This second is called the outcome model.

The specification for Heckman Probit model consisting of two stages is given by:

$$y_{i1}^* = x_{i1}\beta_1 + \varepsilon_{i1}, \quad y_{i1} = \begin{cases} 1 \ if \ y_{i1}^* > 0 \\ 0 \ if \ y_{i1}^* \leq 0 \end{cases} \qquad \text{(1) Selection}$$

$$y_{i2}^* = x_{i2}\beta_2 + \varepsilon_{i2}, \quad y_{i2} = \begin{cases} 1 \ if \ y_{i2}^* > 0 \\ 0 \ if \ y_{i2}^* \leq 0 \end{cases} \qquad \text{(2) Outcome}$$

Where y_{i1}^* and y_{i2}^* are latent variables representing the utility that the i th household receives from adopting hybrid rice and continuing the use respectively. It depends on a vector of explanatory variables, $x_{i1}\ or\ x_{i2}$. β is the coefficients to be estimated. Observable binary variables, y_{i1} and y_{i2}, have the value of 1 when $y_{i1}^* > 0$ and $y_{i2}^* > 0$ respectively.

$$y = y_{i2}^* \text{ if } y_{i1}^* > 0, \qquad y \ is \ a \ missing \ value \ if \ y_{i2}^* \leq 0 \qquad (3)$$

The latent variable y_{i2}^* is only observed if $y_{i1}^* > 0$. In other words, if and only if a household adopted hybrid rice ($y_{i1}^* > 0$), it is possible to observe y_{i2}^* (continuation decision of the household). The equation (2) represents continued use of the technology. One important thing to keep in mind here is that now smaller number of households enters the second equation. This can be called the censoring of original sample. Since not entire sample but only a subset of original sample adopts the technology, continued use is observed only for those who adopt the technology. From here arises a self-selection problem. To embrace this and ensure that estimation of model parameters is not distorted, the standard bivariate Probit model is used given that the correlated errors are jointly and normally distributed and they are homoscedastic. Additionally, the following assumptions are necessary for straightforward estimation.

$$\varepsilon_1 \sim N(0,1) \qquad (4)$$

$$\varepsilon_2 \sim N(0,1)$$

$$Corr(\varepsilon_1, \varepsilon_2) = \rho$$

Where x_{i1} is a *k* vector of explanatory variables, x_{i2} is an *m* vector of regressors. ε_1 and ε_2 are error terms and jointly normally distributed, idependent of x_{i1} and x_{i2}, with zero expected mean. When $\rho \neq 0$, if standard Probit model is used for estimation, it yields biased results. Furthermore, if I insist to regress using standard Probit model while ignoring the sample selection problem, then the estimor of β_2 will be biased. Hence, the Heckman Probit selection model is employed to analyze the farmers' decision on continued use of the technology in the Haryana State of India. Dealing with potential problems, the model is believed to provide consistent and efficient estimates (StataCorp, 2009).

With the two-stage Heckman Probit model, three types of outcomes can be expected. Firstly, the probability that a household adopts and continues using hybrid rice, secondly the probability that a household adopts and stop using it and lastly the probability that a household never adopts the technology. Three probabilities can be specified as follows:

$$\begin{cases} y_{i1} = 0 \ : \quad prob(y_{i1} = 0) = \Phi(-x_{i1}\beta_1) & (5) \\ y_{i1} = 1, y_{i2} = 0 : \ prob(y_{i1} = 1, y_{i2} = 0) = \Phi(x_{i1}\beta_1) - \Phi_2(x_{i1}\beta_1, x_{i2}\beta_2, \rho) & (6) \\ y_{i1} = 1, y_{i2} = 1 : \ prob(y_{i1} = 1, y_{i2} = 1) = \Phi_2(x_{i1}\beta_1, x_{i2}\beta_2, \rho) & (7) \end{cases}$$

Where Φ is the univariate normal distribution, whereas Φ_2 is the bivariate normal distribution. The log-likelihood of the bivariate Probit model, based on the probabilities, is specified as:

$$\ln L = \sum_{i}^{N} \begin{Bmatrix} y_{i1}y_{i2} \ln \Phi_2(X_1\beta_1, X_2\beta_2, \rho) + y_{i1}(1 - y_{i2}) \ln[\Phi(X_1\beta_1) - \Phi_2(X_1\beta_1, X_2\beta_2, \rho)] + \\ (1 - y_{i1}) \ln \Phi(-X_1\beta_1) \end{Bmatrix}$$

Model Variables

As mentioned previously, the two-stage Heckman Probit model is used for the analysis of technology continuation decision. The first stage of the Heckman Probit model looks at whether the household adopted hybrid rice; I call it the selection equation. The second stage model is called the outcome equation and it considers whether the household continued to use hybrid rice. This is conditional on the first stage. The explanatory variables hypothesized to affect adoption and continued used are presented in Table 6.1 along with their respective dependent variables.

Table 5.3: Description of Model Variables for the Heckman Probit Selection model

Outcome equation			**Selection equation**		
Dependent variable			**Dependent variable**		
Continue (%)	Abandon (%)		Adopt (%)	Not adopt (%)	
53.29	46.71		52.19	47.81	
Independent variable			**Independent variable**		
Description	Mean	Standard deviation	Description	Mean	Standard deviation
Age	47.90	12.95	Age	47.90	12.95
Education	8.27	4.25	Education	8.27	4.25
Off-farm Income (%)	21.09	25.98	Off-farm Income	21.09	25.98
Household Size	7.35	4.32	Owned Land Size (acre)	6.95	7.80
Farm Size (acre)	8.44	9.09	Membership	0.66	0.47
Membership	0.66	0.47	Land Size under Rice Cultivation (acre)	4.59	4.89
Years of Use	7.16	5.05			

Explanatory Variables for the Selection Equation

For the selection model, I hypothesize that, age, education of the household head, off-farm income, size of land owned by the household, membership of cooperative, and lastly size of land under rice cultivation, have effect on farmers' adoption decision. The justification for the inclusion of these variables in the selection equation has been discussed earlier in the second section of this chapter. To reduce unnecessary redundancy, the explanation is omitted in this section.

Explanatory Variables for the Outcome Equation

The variables to be included in the outcome equation are age, education level of the head of household, size of household, off-farm income, size of land under the household's cultivation, membership of cooperative and years of hybrid rice use. The justification for most of these variables can be found in the second section of this chapter, except years of hybrid rice use. I additionally include number of years since the household first used hybrid rice. It is hypothesized to influence continued use of hybrid rice positively. I believe, the longer the household observes and experience hybrid rice once it is adopted, the more likely the household is to continue using it.

Barriers to Continued Use

The reasons why those households chose not to continue using the hybrid rice are reported in the CSISA survey. The reason most frequently reported by dis-adopters was misconception and side effects (86.6 per cent). In comparison, other reported reasons for abandonment were minor problems. This suggests that first analyzing the reported side effects and seeking to reduce them are critical to increase continued use of hybrid rice.

Table 5.4: Farmers' Stated Reasons for Disadoption

Reason for Disadoption	Proportion of Disadopters
Misconception and Side effects	86.8%
More costly/ Less profitable	5.9%
Information constraints	2.9%
Lack of enough land and low risk taking capacity	1.5%
Not available in time	1.5%
Low market price	1.5%

Chapter 6

Model Results

6.1 Determinants of Hybrid Rice Adoption

The model results along with the marginal effects for adoption and the levels of statistical significance are presented in Table 6.1. They indicate that the adoption was driven by several factors, namely age of the head of household, size of land owned, farm size under the household's cultivation, membership, size of land under rice cultivation and female bargaining power.

Table 6.1: Results of the Probit model

Explanatory variable	Regression		Marginal effect	
	Coefficient	P level	Coefficient	P level
Age	0.011[a]	0.086	0.004[c]	0.081
Education	0.022	0.227	0.008	0.223
Household Size	0.020	0.660	0.007	0.66
Number of Adults	0.001	0.988	0.000	0.988
Owned Land Size (acre)	-0.035[b]	0.041	-0.013[b]	0.037
Farm Size (acre)	0.056[a]	0.004	0.021[a]	0.003
Membership	-0.315[c]	0.056	-0.118[c]	0.052
Off-farm Income (%)	-0.001	0.682	0.000	0.682
Land Size under Rice cultivation (acre)	-0.068[b]	0.013	-0.025[b]	0.011
Female Bargain	0.050[b]	0.025	0.019[b]	0.022

a significant at the α=0.01 level

b significant at the α=0.05 level

c significant at the α=0.1 level

Firstly, the older the head of household is, the more likely the household is to adopt hybrid rice technology. A unit increase in age of the household head would result in 0.4 per cent increase in the probability of hybrid rice adoption. Perhaps it is because age indirectly represent experience in farming as Adesina & Baidu-Forson (1995) argues. However, having larger size of land owned diminishes the probability of the household adopting, whereas larger farm size under the household's cultivation strongly increases the probability of hybrid rice adoption. A one-acre increase in size of land owned decreases the probability of adoption by 1.3 per cent. The negative relationship between size of land owned and adoption is contrary to what Tura et al. (2010) finds in their work. In contrast, A unit increase in farm size under cultivation results in 2.1 per cent increase in the probability of the technology adoption as expected in relevant studies. Furthermore, contrary to prior expectation, membership of cooperative significantly and negatively affects the household's adoption decision. Households that are member of cooperative are 11.8 per cent less likely to adopt hybrid rice. The negative relationship could be attributed to negative peer effects in technology adoption. According to Oster & Thornton (2012), friends are very important in learning about a new technology. The authors find strong evidence of peer effects in the adoption of a new technology. It also appears that larger land under rice cultivation negatively influences adoption. This can be associated with risk aversion. Lastly, women's intrahousehold bargaining power has significantly positive effect on hybrid rice adoption. This is consistent with the idea of Doss (2013) and Von Braun (1988). There are, however, no evidence that the level of education of household's head, size of household, number of adults within the household, and share of income from off-farm activities influence the probability of adoption. From the factors turned out to influential give important implications of what should be done to effectively increase the rate of hybrid rice adoption among farmers in Haryana.

6.2 Determinants of Continued Use of Hybrid Rice

The regression results of Heckman Probit model shows ρ (*rho*) which is significantly different from zero (Wald $\chi^2 = 6.27$ with $p = 0.012$). Significant ρ (*rho*) indicates that the unobservable attributes that affect adoption are also associated with continuation decision. This correlation justifies why I chose to use the Heckman Probit model over the standard Probit model. Furthermore, the likelihood function of the Heckman Probit model is significant (Wald $\chi^2 = 36.09$ with $p = 0.000$). From which, it is inferred that the chosen model explains the continued decision well. Results of the Heckman Probit selection model are presented in Table 6.2, along with the levels of statistical significance.

The results from the regression indicate that only a few variables have significant influence on probability of continuation of technology use – namely, off-farm income, size of the household and years of use. Variables that appear to affect continuation significantly are household size, years of use and the share of off-farm income. First two variables are positively correlated with continued use and the last is negatively. A one-person increase in the household size raises the probability of continued use by 1.2 per cent. This is consistent with Croppensted et al. (2003). Also, I find that a one-year increase in years of use increases the probability of continuation by 7.3 per cent. This positive relationship between years of use and continued use is intuitive because years of use represent experience in using hybrid rice as well. In contrast, the share of off-farm income is significantly and negatively related to continuing the use of hybrid rice, which is different from the prior expectation of positive relationship between off-farm income and adoption that was argued by Franzel (1991). The probable reason for the negative effect of share of off-farm income on continued use could be due to less dependence of the household on income accruing from on-farm activities. In other words, there may be less incentive for a household to stick to hybrid rice for higher yield and income.

Table 6.2: Results of the Heckman probit selection model

	Continued Use model (Outcome)				Adoption model (Selection)			
	Regression		Marginal effect		Regression		Marginal effect	
Explanatory variable	**Coefficient**	**P level**	**Coefficient**	**P level**	**Coefficient**	**P level**	**Coefficient**	**P level**
Age	-0.005	0.519	0.001	0.662	0.013[b]	0.022	0.005[b]	0.019
Education	0.024	0.321	0.012[c]	0.060	0.021	0.249	0.008	0.246
Off-farm Income (%)	-0.008[c]	0.052	-0.003[b]	0.013	-0.002	0.608	-0.001	0.608
Household Size	0.034[c]	0.097	0.011[c]	0.100				
Owned Land Size (acre)					0.001	0.926	0.000	0.926
Farm Size (acre)	-0.007	0.494	-0.002	0.490				
Membership	-0.112	0.601	-0.122[b]	0.043	-0.409[a]	0.010	-0.157[a]	0.008
Years of Use	0.221[a]	0.000	0.073[a]	0.000				
Land Size under Rice cultivation (acre)					-0.011	0.421	-0.004[a]	0.008
Constant	-0.504	0.332			-0.384	0.282		
Correlation (ρ)	-0.975							
Total observations	310							
Censored	146							
Uncensored	164							
Wald Chi square	36.09[a]							

[a] significant at the $\alpha=0.01$ level
[b] significant at the $\alpha=0.05$ level
[c] significant at the $\alpha=0.1$ level

As expected in the previous section 6.1, the likelihood of adopting hybrid rice is positively related to the age of household' s head and negatively related to membership of cooperative. One-year increase in the age of household's head increases the probability of adopting hybrid rice by 0.5 per cent. Contrary to prior expectation, members of cooperative are 0.8 per cent less likely to adopt hybrid rice.

Chapter 7

Conclusion and Policy Implications

7.1 Summary

For a country like India, widespread adoption of high-yielding agricultural technology is critical in feeding its large population and reducing poverty prevalent in the country. Increasing India's agricultural productivity in rice production is also the world's concern in terms of ensuring global food security. As a means of lifting rice yield, hybrid rice varieties with yield advantages of 15-20 per cent have attained national and international attention. However, in India the rate of hybrid rice use remains low, because of both insufficient adoption and high rate of the technology abandonment. Consequently, rice yield per hectare of India still lags behind other leading rice producers'.

To understand why it is so, this thesis has focused on the factors associated with households' decision about whether to adopt hybrid rice and whether to continue using it. Two models, a standard Probit model and Heckman Probit model with sample selection, were developed to investigate the factors that influence adoption of hybrid rice and its continued use respectively. In the Probit model, the dependent variable has a binary value in regard to hybrid rice adoption and the independent variables include a range of explanatory variables specific to household such as age and education level of household head, size of land owned or cultivated, membership of cooperative and etc. The results demonstrate that the adoption was driven by several factors, namely age of the head of household, size of land owned, farm size under the household's cultivation, membership, size of land under rice cultivation and female bargaining power. The analysis of households' continuation decision indicates that about 47 per cent of adopters decide to abandon hybrid rice. The employed Heckman Probit model consists of two stages – adopting hybrid rice in the first stage and then continuing the use of hybrid rice in the second stage. The empirical results of the Heckman Probit model further show that size of the household and years of use positively influence farmers' adoption, while factors affecting adoption (in selection equation) are similar to the results of Probit model demonstrated earlier.

7.2 Policy Implications

In terms of policy implications, the analysis of the factors that influence technology adoption in the Haryana State of India suggests several policy options, including an institutional support for women's empowerment as implied in the positive relationship between female bargaining power within the household and the technology adoption; delivering essential information in regard to the characteristics of hybrid rice and by which reducing information constraints; and promising to provide complementary technologies, such as pesticide and fertilizer, to reduce both misconception and fear of side effects if necessary. In addition, it is worth giving attention to social learning and peer effects as seen in the significant effect of membership on adoption. A successful use of hybrid rice of peers would help farmers learn about the technology and incline them to adopt it. Moreover, in regard to reducing the rate of technology disadoption, it seems critical to provide complementary technologies practical to resolve some adverse effects of hybrid rice varieties, such as pesticide to complement the susceptibility of hybrid rice to pests and diseases.

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Appendices

Appendix A

Regression A.1: Technology Adoption (Probit Model)

```
Iteration 0:   log likelihood = -215.62045
Iteration 1:   log likelihood = -203.37218
Iteration 2:   log likelihood = -203.32307
Iteration 3:   log likelihood = -203.32307

Probit regression                               Number of obs   =        312
                                                LR chi2(10)     =      24.59
                                                Prob > chi2     =     0.0062
Log likelihood = -203.32307                     Pseudo R2       =     0.0570
```

adopt	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHHEAD_AGE	.0108053	.0062927	1.72	0.086	-.0015281	.0231388
HHHEAD_EDUC	.0220324	.0182236	1.21	0.227	-.0136853	.0577501
HHsize	.0197049	.0448442	0.44	0.660	-.0681881	.107598
nAdult	.0009718	.0631048	0.02	0.988	-.1227113	.1246549
fbargain	.0504252	.0225152	2.24	0.025	.0062963	.0945541
membership	-.3151812	.1650832	-1.91	0.056	-.6387384	.008376
TCUL_OWN	-.0346924	.0169491	-2.05	0.041	-.067912	-.0014728
CULT_TAREA	.0560135	.0193327	2.90	0.004	.0181221	.0939049
nfincome	-.0012831	.0031313	-0.41	0.682	-.0074203	.0048541
Rice_size	-.0675993	.027291	-2.48	0.013	-.1210888	-.0141099
_cons	-.8662864	.4177824	-2.07	0.038	-1.685125	-.0474479

Regression A.2: Marginal Effects

```
. margins, dydx(*)

Average marginal effects                          Number of obs   =        312
Model VCE    : OIM

Expression   : Pr(adopt), predict()
dy/dx w.r.t. : HHHEAD_AGE HHHEAD_EDUC HHsize nAdult fbargain membership TCUL_OWN CULT_TAREA nfincome
               Rice_size
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHHEAD_AGE	.00404	.0023185	1.74	0.081	-.0005042	.0085841
HHHEAD_EDUC	.0082376	.0067612	1.22	0.223	-.0050142	.0214893
HHsize	.0073674	.0167532	0.44	0.660	-.0254684	.0402031
nAdult	.0003634	.0235939	0.02	0.988	-.0458798	.0466065
fbargain	.0188532	.0082071	2.30	0.022	.0027676	.0349388
membership	-.1178415	.0606409	-1.94	0.052	-.2366955	.0010125
TCUL_OWN	-.012971	.0062263	-2.08	0.037	-.0251743	-.0007676
CULT_TAREA	.0209426	.0069789	3.00	0.003	.0072643	.0346209
nfincome	-.0004797	.0011696	-0.41	0.682	-.0027722	.0018127
Rice_size	-.0252744	.009944	-2.54	0.011	-.0447642	-.0057845

Appendix B

Regression B.1: Continued Use of Technology (Heckman Probit Model)

```
Probit model with sample selection              Number of obs      =        310
                                                Censored obs       =        146
                                                Uncensored obs     =        164

                                                Wald chi2(7)       =      36.09
Log likelihood = -264.7741                      Prob > chi2        =     0.0000
```

	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
Continuation						
HHHEAD_AGE	-.005127	.0079589	-0.64	0.519	-.0207261	.0104721
HHHEAD_EDUC	.023993	.0241703	0.99	0.321	-.02338	.0713659
nfincome	-.008118	.0041813	-1.94	0.052	-.0163131	.0000772
HHsize	.0336572	.0202535	1.66	0.097	-.0060389	.0733533
CULT_TAREA	-.007069	.0103263	-0.68	0.494	-.0273082	.0131702
membership	-.1121332	.2144844	-0.52	0.601	-.532515	.3082485
USEyear	.2209188	.0381485	5.79	0.000	.1461491	.2956885
_cons	-.5039821	.5200269	-0.97	0.332	-1.523216	.5152519
adopt						
HHHEAD_EDUC	.0206907	.0179642	1.15	0.249	-.0145185	.0559
HHHEAD_AGE	.0132663	.0058139	2.28	0.022	.0018712	.0246614
nfincome	-.0015125	.0029494	-0.51	0.608	-.0072933	.0042683
membership	-.4087164	.1591366	-2.57	0.010	-.7206184	-.0968145
TCUL_OWN	.0008519	.009201	0.09	0.926	-.0171817	.0188854
Rice_size	-.0112792	.0140271	-0.80	0.421	-.0387719	.0162134
_cons	-.3840546	.3573369	-1.07	0.282	-1.084422	.3163128
/athrho	-2.192354	.882233	-2.49	0.013	-3.921499	-.4632096
rho	-.975374	.0429168			-.9992153	-.4326965

```
LR test of indep. eqns. (rho = 0):   chi2(1) =     6.27    Prob > chi2 = 0.0123
```

Regression B.2: Marginal Effects (Selection Equation)

```
Average marginal effects                           Number of obs   =        166
Model VCE    : OIM

Expression   : Pr(adopt), predict(psel)
dy/dx w.r.t. : HHHEAD_AGE HHHEAD_EDUC nfincome membership TCUL_OWN Rice_size
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHHEAD_AGE	.0051062	.0021769	2.35	0.019	.0008395	.0093728
HHHEAD_EDUC	.0079637	.00687	1.16	0.246	-.0055012	.0214287
nfincome	-.0005821	.0011343	-0.51	0.608	-.0028053	.001641
membership	-.1573126	.0589421	-2.67	0.008	-.272837	-.0417883
TCUL_OWN	.0003279	.0035413	0.09	0.926	-.0066128	.0072686
Rice_size	-.0043414	.0053875	-0.81	0.420	-.0149007	.0062179

Regression B.3: Marginal Effects (Outcome Equation)

```
Average marginal effects                          Number of obs   =        166
Model VCE    : OIM

Expression   : Pr(Continuation=1|adopt=1), predict(pcond)
dy/dx w.r.t. : HHHEAD_AGE HHHEAD_EDUC nfincome HHsize CULT_TAREA membership
               USEyear
```

	dy/dx	Delta-method Std. Err.	z	P>|z|	[95% Conf.	Interval]
HHHEAD_AGE	.0010758	.0024629	0.44	0.662	-.0037514	.005903
HHHEAD_EDUC	.0122318	.006503	1.88	0.060	-.0005138	.0249774
nfincome	-.0029938	.0012101	-2.47	0.013	-.0053657	-.000622
HHsize	.0111045	.0067966	1.63	0.102	-.0022166	.0244257
CULT_TAREA	-.0023323	.0033753	-0.69	0.490	-.0089477	.0042832
membership	-.1222516	.060476	-2.02	0.043	-.2407825	-.0037208
USEyear	.0728868	.0043779	16.65	0.000	.0643062	.0814674