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Factors Encouraging Complete Adoption of Agricultural Technologies: The Case of Hybrid Rice Cultivation in India

by

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Abstract: Hybrid rice is one of the technologies which has the potential to push the production frontier to meet the growing demand of rice in India. The technology was introduced in India in 1994 and is yet to see widespread adoption. The purpose of this paper is to identify the factors that influence the partial/ complete adoption of hybrid rice technology by the farmers in India. This study also assesses the factors behind difference in the share of land allocated to hybrid rice cultivation by farmers.

Design/methodology/approach ï The study employs a Tobit model to evaluate the impact of factors related to technology, farmer-specific variables and geographical location on the decision to adopt hybrid rice partially or completely. Data for this study is compiled from surveys conducted during 2012-13 on 441 hybrid rice growing farmers across 3 states.

Findings ï The paper finds that farmers with smaller landholdings, higher education and more experience of growing hybrid rice are more likely to be the complete adopters. At the same time, farmers who report good demand for hybrid rice output and availability of subsidy on hybrid rice seeds have higher probability of being complete adopters. However, cultivation of multiple kharif crops is found to be negatively related to the extent of hybrid rice adoption. Also, there is state wise variation in adoption. The results suggest insignificant impact of age, family size, ownership of cattle and machinery and performance of the technology on the adoption level of hybrid rice by the farmers.

Research limitations/implications ï Although the sample for this study has been collected from 3 different states with different agro-climatic zones, the results cannot be generalized for other states. There is a great potential to increase the area under hybrid rice cultivation in India. This study is one of the first attempts to look at the adoption levels of hybrid rice in India and determine the factors which might be hindering the complete adoption of the technology.

Keywords India, Hybrid rice, complete adoption, Tobit model, agricultural technology

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1. Introduction

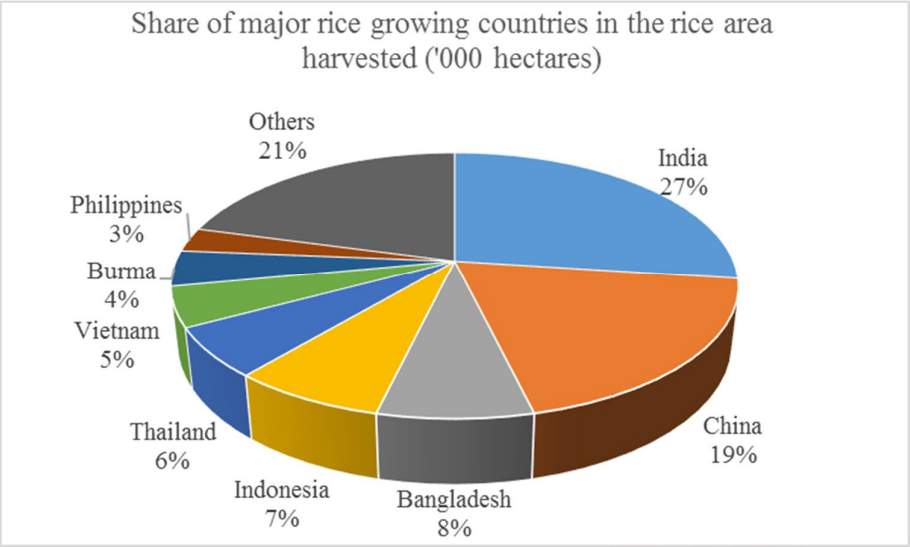
Rice is the most important staple food crop in India. It accounts for 41 per cent of the food grain production, 48 per cent of the food grain consumption, and 35 per cent of the area under food grain crops in the country (Ministry of Agriculture, 2014). Increasing rice production is very important for food security in India. However, producing enough rice to feed Indiaôs large and growing population is a major challenge as raising production through conventional means such as increasing area, irrigation and fertilizer use is facing limitations. There is a need to shift to a new and higher production frontier. In this context, hybrid rice technology offers a significant promise and has been shown to be very effective in countries such as China, Philippines, Indonesia and Bangladesh.

However, so far the diffusion of hybrid rice in India is proving to be very difficult, and its use has not taken off despite higher yield and advantages such as pest and disease resistance. Adoption of hybrid rice is a challenge for food security and food policy in India. The researchers and policy makers involved in the development of hybrid rice in the public and the private sector are still trying to explain the reasons behind this.

1.1. Rice production in India

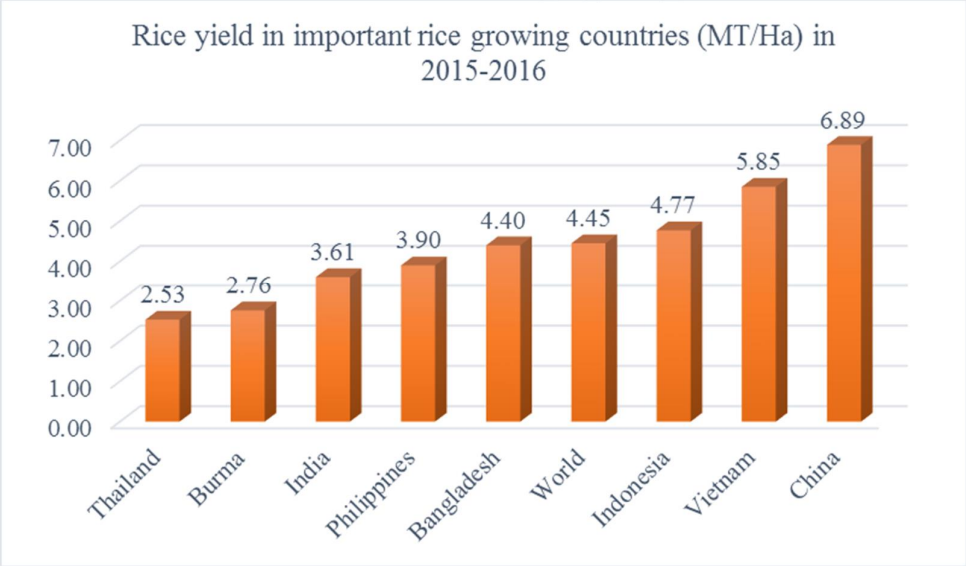
India has the largest area under rice cultivation in the world (27%) (Figure 1), but the country ranks second in terms of rice rice yields continue to lag behind most of the important rice growing countries (Figure 2). Although the productivity of rice in the country has increased over last 50 years, it is still lower than most of the rice growing countries.

Figure 1



Data source: USDA, PSD Online. May, 2016

Figure 2

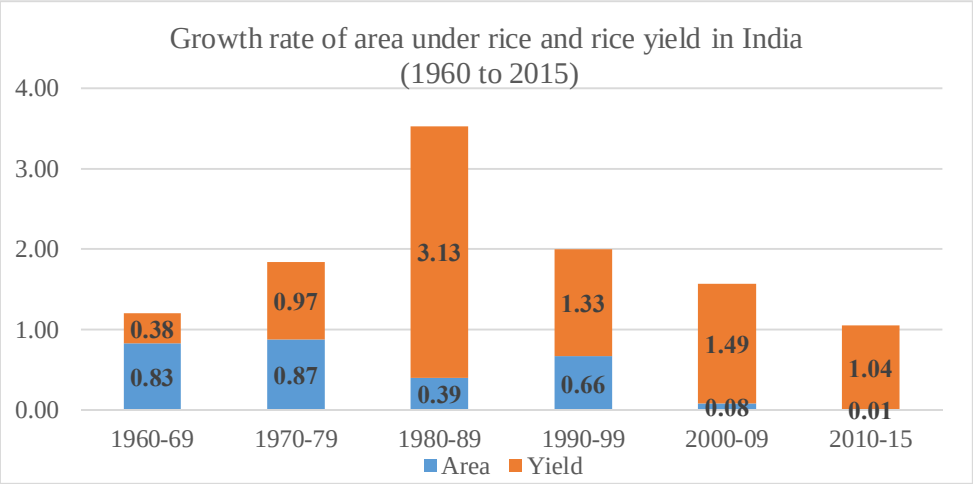


Data source: USDA, PSD Online. May, 2016

The post-independence era, after the food crisis, witnessed unparalleled developments in the form of the Green Revolution. However, the achievements of Green Revolution have started tapering off in the recent decades (Figure 3). While the growth in production of rice in the country was driven mostly by the increase in the area till 1960s, majority of the increase in production of rice in the past few decades has come from increase in yield. Due to limitations

of horizontal expansion, it is expected that majority of the future increase in production will have to come from increase in the yield (Alexandratos & Bruinsma, 2012).

Figure 3



Data source: USDA, PSD Online. May, 2016

1.2. Need for a new technology

According to FAO and IRRI, the demand for rice in the world is expected to increase by nearly 30% in next 20 years and majority of this gap will have to be filled by the rice growing Asian countries. The demand for food grains including rice in India is also expected to increase in the future primarily driven by increase in population - both within the country and outside, derived demand for feed, export and indirect use in the industry (Mittal, 2008; Ganesh-Kumar et al., 2012). Therefore, in order to ensure continuous supply of rice, it is important to push the yield barriers further and enhance the productivity levels especially in the states with poor yield levels.

Hybrid rice technology is seen as one of the most important tools in fulfilling the rice demand of the world. A study by Durand-Morat et al. (2011) noted that hybrid rice has made significant contributions towards aggregate supply of rice in spite of the low adoption rates in several Asian countries. Hybrid rice accounts for 60% of the total rice production in China and helped produce 20 million tonnes of additional rice every year, thus saving more than 2 million hectares of agricultural land for other uses (Julfiquar et al., 2003). Similarly, hybrid rice is also being grown in other countries such as Vietnam (10%), Bangladesh (6.8%), Indonesia (4.9%) and Philippines (4.6%)

Table 1. Area under hybrid rice as a percent of rice area in selected countries (1994ï 2010)

Year	China	Bangladesh	India	Vietnam
1995	43.3	0.0	0.1	1.1
1996	46.1	0.0	0.2	1.8
1997	47.7	0.0	0.3	2.6
1998	47.4	0.0	0.4	2.7
1999	44.0	0.0	0.4	3.0
2000	45.2	0.0	0.4	5.7
2001	49.6	0.0	0.4	6.4
2002	50.2	0.2	0.5	6.7
2003	49.4	0.3	0.7	8.1
2004	51.2	0.8	1.4	7.7
2005	51.4	1.9	1.8	9.0
2006	52.1	3.7	2.3	8.0
2007	50.3	9.5	2.5	8.5
2008	54.1	8.9	3.2	8.8
2009	52.1	7.5	3.7	9.4
2010	51.8	6.8	4.6	10.0

Source: Spielman, Kolady, Ward, Rashid, & Gulati (2012)

1.3. Hybrid rice in India

Realising the importance of hybrid rice technology, concentrated research efforts to develop and use it in India were initiated since 1989 and the first four rice hybrids were released in the country during 1994. Since then 59 varieties, both from the public and private sector have been released for cultivation till 2012. The initial emphasis of technology development in case of hybrid rice was mostly on increasing the yield. Over time, other traits such as disease resistance, grain quality were added as technology goals in the development of hybrid rice. Despite all this, the acceptance of hybrid rice has remained poor.

In 1996, only 0.12% of the total rice area was under hybrid rice cultivation. Over the years, the area under hybrid rice increased slightly from 0.5 million ha (1996) to 1.1million ha (2007). It was expected to touch 3 million ha in 2010 and increase up to 6 million ha by 2020 (Nirmala et al., 2009). According to recent estimates by Spielman et al. (2012), the coverage of hybrid rice in India was 4.6% in 2010.

Table 2. Area planted to hybrid rice cultivation in India, 1995-2011			
Year	Gross Rice Area (mn ha)	Area planted to hybrid rice	
		'000 ha	% of gross rice area
1995	42.84	**10**	0.02
1996	43.43	60	0.14
1997	43.45	90	0.21
1998	44.8	110	0.25
1999	45.16	125	0.28
2000	44.71	150	0.34
2001	44.9	180	0.40
2002	41.18	200	0.49
2003	42.59	1000	2.35
2004	41.91	1100	2.62
2005	43.66	750	1.72
2006	43.81	1000	2.28
2007	43.91	1100	2.51
2008	45.54	1400	3.07
2009	41.92	1300	3.10
2010	42.86	1300	3.03
2011	43.97	2000	4.55

Source: Collated from different sources

Government of India has plans to increase the cultivation of hybrid rice to 25% of the total rice growing area by 2015. However, the target seems difficult to achieve given the slow adoption rate. The sluggish pace of adoption remains an issue for both the public and the private sector entities which have made significant investments in the research and development of technology as well as in production and distribution.

According to an estimate, during kharif 2011, nearly 39% of the total area under hybrid rice area was in Uttar Pradesh followed be Bihar (16.6%), Chhattisgarh (10.5%) and Jharkhand (10.2%) (Table 4). Rest of the states such as Haryana (5%), Madhya Pradesh (4.19%), Gujarat (4.04%) and Odisha (2.67%) also have some area under cultivation of hybrid rice.

Table 3. State wise area under hybrid rice - Kharif 2011			
States	Area under hybrid rice* (ô000 hectares)	% of the total rice area in the state #	% of the total area under hybrid rice in the country
Uttar Pradesh	770	12.9	38.88
Bihar	328	9.9	16.56
Chhattisgarh	207	5.5	10.45
Jharkhand	202	13.8	10.20
Haryana	99	8.0	5.00
Madhya Pradesh	83	5.0	4.19
Gujarat	80	9.6	4.04
Odisha	53	1.3	2.67
Others	158		7.98
Total	1980		

Source: Siddiq (2012) *Based on the F1 seeds sold # calculated based on data from MoA, GoI

At the time of introduction of hybrid rice, states such as Punjab, Haryana, Tamil Nadu, Karnataka and Andhra Pradesh where the rice is ófertilized, irrigated and transplantedô, were expected to be the early adopters. However, contrary to the expectations, rainfed regions like Jharkhand, Chattisgarh, UP and Bihar, emerged as the faster adopters of this technology. Eastern regions comprising of UP, Bihar, Chhattisgarh and Jharkhand account for nearly 80% of the total hybrid rice market (Virakthmath, 2010).

Table 4. Region-wise cultivation of hybrid rice (2009)		
Eastern India	UP, Bihar, Chhattisgarh, Jharkhand etc.	80%
North-western India	Punjab, Haryana, Gujarat, Maharashtra	15%
Southern India	Karnataka, Andhra Pradesh, Tamil Nadu	5%

Source: Virakthamath (2010)

The increase in area under hybrid rice in India has been very slow as compared to some other crop technologies such as Bt cotton which rapidly spread to more than 90 per cent of area under cotton cultivation within 8-9 years of its introduction. With this background of the importance of rice in India and the need for hybrid rice technology, we now examine the literature on the adoption of agricultural technologies including hybrid rice to identify the research gaps.

2. Literature review

Adoption of a new technology is a hierarchical process (Rogers, 1962; Aker et al. 2005). The potential adopters go through the process of awareness, interest, evaluation, trial and adoption. At the end of these stages, an individual might chose to adopt the technology either partially or

completely. A large part of literature on adoption of agricultural technologies focuses on understanding the factors which lead to adoption of technologies.

The existing literature on hybrid rice, especially in the Indian context, revolves around identifying the factors associated with adoption of the technology. Low and marginal yields of hybrid rice (Spielman et al., 2012; Ahmed, Meera, & Viraktamath, 2008; Janaiah, 2003; Ramasamy et al., 2003), poor resistance towards biotic and abiotic stresses (Pandey & Bhandari, 2009; Ahmed, Meera, & Viraktamath, 2008) and poor quality of the rice grain (Sobha Rani et al., 2012; Spielman et al., 2012; Ahmed, Meera & Viraktamath, 2008; Virmani et al., 2003) have been identified as some of the reasons for slow adoption of hybrid rice in India. As far as economics is concerned, hybrid rice was found to be giving low returns in India due to higher input cost and poor market price of the output (Nirmala B., 2012; Pandey & Bhandari, 2009; Chengappa et al., 2003; Janaiah, 2003; Ramasamy et al., 2003). Farmersô preference for cheap seeds (Ward et al., 2013), higher cost of hybrid rice seed (Spielman et al., 2012; Pandey & Bhandari, 2009; Ahmed, Meera & Viraktamath , 2008), supply of hybrid rice seeds (Singh et al., 2013) and quality (Pandey & Bhandari, 2009; Xie and Hardy in Spielman et al., 2012; Spielman et al, 2012) have also been found to be important for the technology to succeed. Studies have arrived at different conclusions regarding the impact of landholding on adoption decision of hybrid rice. While Sarkar & Ghosh (2013) and Janaiah & Hossain (2003) found that adoption was negatively related to landholding size, Spielman et al. (2012) concluded that nearly 75% of all hybrid rice adopters were wealthy and belonged to upper-middle or middle income quintiles.

Thus, the existing literature has covered aspects ranging from the yield advantage, profitability, grain quality, seeds, and farm and farmer level factors to government policies as factors affecting the adoption of hybrid rice technology. However, none of the studies has attempted to consider the factors which determine whether the farmer is a partial adopter or complete adopter of the technology. It is important to understand distinguish between partial and complete adopters of hybrid rice technology as well as identify the factors which are important regarding a farmerôs decision to switch to hybrid rice cultivation completely. Moreover, the analysis in most of the above mentioned works on hybrid rice in India is very simple and is mostly based on averages or frequencies.

Khaledi et al. (2010) used a Tobit model to identify the factors that encourage or discourage complete adoption of organic farming amongst the farmers in Canada. Thus, the study assesses what makes farmers differ in terms of the area they allocate to organic farming. Bellon and Taylor (1993) examine the effect of soil taxonomy to explain the rationale behind the partial adoption of maize varieties. In general, there have been very few studies with a focus on partial versus complete adoption. Such studies are a step ahead of the adoption studies and help to understand the reason behind the share of land allocated to hybrid rice or any other such technology by the farmers. Therefore, this piece of research attempts to determine the factors which lead to partial and complete adoption of hybrid rice by the farmers in India.

3. Methodology

3.1. Model for analysis

This study attempts to identify the factors related to farm, farmer and technology which affect the level of adoption of hybrid rice ï partial or complete, by the farmers. To be more precise, we attempt to find the factors which encourage or discourage the complete adoption of hybrid rice by the farmers and evaluate the reasons behind differences in the extent of adoption across farmers. In order to do this, we employ a Tobit model. A Tobit model is considered appropriate when the dependent variable in the study is truncated at the lower bound, upper bound or both of them (Maddala, 1992). In this study we are employing upper ï limit Tobit model to examine the probability of complete versus partial adoption as well as the extent of hybrid rice adoption by the farmers. Here, *x'* is a vector of factors which affect farmerôs decision to adoption the hybrid rice technology either partially or completely and are the coefficients to be estimated. is the error term and captures the factors which are beyond this study.

$$y^* = \beta' x + \varepsilon$$

Where, E (ε) =0

$$y = \min(y^*, 1)$$

Similar approach has been used by Akinola and Young (1985), Smith and Blundell (1986), Norris and Batie (1987), Adesina and Zinnah (1993), Oladele (2005), Akpoko (2007) and Khaledi et al. (2010). We extend the model further to calculate the impact of each of the independent variables on partial and complete adopters separately. The complete derivation of these expectations has been given in annexure.

3.2. Data

This study is based on a cross-sectional data which was collected from farmer surveys conducted from December 2012 ï February 2013. Such micro level analysis of cross-sectional data can provide us information on farmersô preferences and thus, help us understand the adoption patterns (Doss, 2006). Farm level primary data was collected in three main hybrid rice growing states - Uttar Pradesh, Chhattisgarh and Gujarat, which account for more than half of the hybrid rice area of the country.

The sampling frame for the current study consists of farmers who had grown hybrid rice in at least one of the last 4 rice growing seasons, 2009 to 2012. A multi-stage stratified sampling was used to select a total of 441 hybrid rice growing farmers. The sampling of the states and districts was based on factors such as area under rice, area under hybrid rice, productivity of rice, agro-climatic conditions, extent of dependence on rain, average landholding, presence of government policies and expert opinion. On an average, 2-3 villages were selected from each district based on the inputs from the field assistants working in those regions.

The survey tool was translated into the local language for each state. We requested that the survey instrument be completed by the person who was responsible for carrying out activities related to hybrid rice cultivation. Farmers were interviewed with a structured and pre-tested questionnaire. Interviewers had prior experience of administering such survey questionnaires in rural India. They were further trained for the data collection of the current study.

3.3. Sample profile

There are two clearly identifiable groups of hybrid rice growing farmers in the sample: those who had cultivated hybrid rice on the entire rice area that they had and others who cultivated hybrid rice only on a part of the rice area. They have been termed as complete and partial adopters respectively. Table 5 presents the descriptive statistics of the socio-economic characteristics of the partial and complete adopters in the sample.

Table 5. Socio-economic characteristics of farmers by adoption status

	All (i)	Partial adopters (ii)	Complete adopters (iii)	Difference in means (ii) ï (iii)
Mean age	43.71 (.583)	44.09 (.839)	43.26 (.819)	.828 (1.173)
Education	9.30 (.230)	9.09 (.319)	9.55 (.333)	-.463 (.461)
Family members (no.)	7.65 (.177)	8.00 (.232)	7.21 (.269)	.789* (.355)
Avg distance from city	12.60 (.527)	12.56 (.732)	12.64 (.752)	-.085 (1.050)
Rice Experience (years)	20.96 (.553)	21.24 (.756)	20.63 (.812)	.610 (1.110)
Hybrid Knowledge (years)	7.07 (.158)	6.78 (.212)	7.42 (.234)	-.646* (.316)
Hybrid Experience (years)	5.46 (.144)	5.05 (.199)	5.96 (.202)	-.917** (.284)
Cattle Ownership	.906 (.014)	.920 (.018)	.888 (.022)	.032 (.028)
Machinery Ownership	.400 (0.023)	.445 (0.032)	.345 (0.034)	.100* (.047)

Note: The figures in parenthesis are the standard errors. *, ** and *** are significance levels at 5, 1 and 0% respectively.

T-tests have been conducted to determine if there is a significant difference between the means of the two groups at a given significance level. The data shows variation between the complete and partial adopters in terms of age, education, family size, experience of rice, hybrid rice knowledge, experience of hybrid rice cultivation, ownership of cattle and machinery. On an average, complete adopters are younger and more educated than the partial adopters. Also, farmers who adopted hybrid rice completely had smaller families, lesser cattle and machinery ownership compared to partial adopters. It can also be noted that the complete adopters had the prior knowledge of the technology for a longer time and were using hybrid rice technology for longer duration than the partial adopters. However, the complete adopters had lesser experience of rice cultivation compared to partial adopters. To check whether the means for the two groups are significantly different from each other, we conducted t-tests. The test results indicate that the partial and complete adopters differ significantly from each other in terms of family size, the duration for which famers have known about hybrid rice and the experience of hybrid rice cultivation. Other differences, although exist, are not statistically significant.

3.4. Land allocation and production systems

Table 6 presents the landholding and allocation pattern amongst the farmers categorised by their adoption status. The average landholding size and average rice area is higher for the partial adopters as compared to the complete adopters. Similarly, the percentage of landholding allocated to rice is higher for partial adopters compared to complete adopters.

Table 6. Land holding and allocation pattern

	All (i)	Partial adopters (ii)	Complete adopters (iii)	Difference in means (ii) ï (iii)
Average landholding (ha)	2.61 (0.161)	3.28 (0.265)	1.79 (.132)	1.491*** (.296)
Average rice area (ha)	2.31 (0.139)	3.04 (0.228)	1.43 (0.106)	1.608*** (.252)
% of area cultivated to rice	77.24% (1.185)	81.82% (1.518)	71.69% (1.795)	10.124*** (2.351)
% of rice area cultivated to hybrid rice	74.76% (1.321)	53.87% (1.332)	100.0% (0.00)	-46.126*** (1.332)

Note: The figures in parenthesis are the standard errors. *, ** and *** are significance levels at 5, 1 and 0% respectively.

The test for difference of means indicates that the partial adopters of hybrid rice have significantly higher average landholding, average area under rice and percentage of area under rice. However, by definition, the percentage of rice area under hybrid rice for complete adopters is 100 % and is higher than the partial adopters. All these differences are statistically significant. These patterns indicate that there is probably an inherent difference between the complete and partial adopters in terms of their resource endowments and this might be reason behind the extent of technology adoption by them. We explore more of this in the next few segments. The descriptive statistics of some other important variables and the results of difference of means tests are presented in Table 7.

Table 7. Descriptive statistics of other important variables

	All (i)	Partial adopters (ii)	Complete adopters (iii)	Difference in means (ii) ï (iii)
Information	3.470	3.404	3.551	-.147***
	(.021)	(.028)	(.032)	(.042)
Adequate irrigation	4.046	4.164	3.903	.2610*
	(.051)	(.069)	(.075)	(.102)
Better yield	4.324	4.291	4.365	-.074
	(.033)	(.046)	(.048)	(.067)
Good demand	3.515	3.253	3.831	-.578***
	(.053)	(.072)	(.072)	(.102)
Good price	3.018	2.941	3.112	-.172
	(.047)	(.060)	(.075)	(.096)
Government procurement	2.916	3.128	2.663	.465**
	(.074)	(.103)	(.106)	(.147)
Seed subsidy	1.658	1.545	1.797	-.252*
	(.048)	(.061)	(.076)	(.098)
Risk taking ability	3.716	3.734	3.695	.039
	(.048)	(.067)	(.070)	(.096)
Package awareness	3.926	3.966	3.877	.089
	(.038)	(.053)	(.056)	(.077)
Ease of availability	4.600	4.629	4.566	.062
	(.028)	(.038)	(.043)	(.057)
Government outlets	1.715	1.699	1.736	-.037
	(.050)	(.070)	(.071)	(.100)
Reasonable price of seeds	3.921	3.915	3.929	-.014
	(.051)	(.071)	(.073)	(.102)
Good quality seeds	3.935	3.873	4.010	-.137
	(.038)	(.052)	(.054)	(.075)
Credit from dealer	2.937	2.781	3.123	-.342**
	(.064)	(.088)	(.091)	(.126)

Note: The figures in parenthesis are the standard errors. *, ** and *** are significance levels at 5, 1 and 0% respectively.

It is interesting to note that the average information available to partial adopters is significantly lower than the complete adopters. At the same time, they perceive the market demand of the

hybrid rice output, availability of seed subsidy and availability of credit facility from the dealers to be significantly lower than the complete adopters. On the other hand, complete adopters report significantly lesser availability of water and poor government procurement of the hybrid rice output compared to partial adopters. There are differences in perception of the two categories of farmers regarding several other aspects of hybrid rice cultivation but they are not statistically significant.

4. Results and discussion

We use Tobit analysis in order to understand the factors that make a farmer adopt the technology completely vis-à-vis partially. The dependent variable is ñextent of adoptionò and is defined as the proportion of total rice area under hybrid rice cultivation. The dependent variable ranges from 0 to 1 where 1 represents complete adoption. In the upper bound TOBIT model, the proportion of land under hybrid rice cultivation was regressed against various factors hypothesized to influence the adoption decision. The list of independent variables used in the analysis is given in Table 8. The independent variables used in the model can be broadly divided into three categories (i) farm and farmer related variables (ii) farmerôs perception of technology and (iii) dummy variables. The descriptive statistics of these variables has already been presented in the previous sections.

Table 8. Description of variables included in the model

Variable	Description of the variable
Experience	Farmerôs experience of hybrid rice cultivation in years
Education	Number of years of education
Age	Age in years
Family size	Number of members in the family of the farmer
City distance	Distance from the city in kilometres
Landholding	Total land owned by the farmer in hectares
Information	Quality of information available (5 to1)
Adequate irrigation	Availability of sufficient water for irrigation (5 to 1)
Better yield	Hybrid rice yields better than OPVs (5 to 1)
Good demand	Hybrid rice has good market demand (5 to 1)
Good price	Good market price of hybrid rice output (5 to 1)

Government procurement	Government procurement of hybrid rice output (5 to 1)
Seed subsidy	Availability of subsidy on hybrid rice seed (5 to 1)
Risk taking ability	Willingness to try new technology (5 to 1)
Package awareness	Awareness of correct package of practices (5 to 1)
Ease of availability	Ease of availability of hybrid rice seeds (5 to 1)
Government outlets	Availability of hybrid rice seeds in govt. outlets (5 to1)
Reasonable price of seeds	Reasonable pricing of hybrid rice seeds (5 to 1)
Good quality seeds	Availability of good quality seeds (5 to 1)
Credit from dealer	Availability of credit from the seed dealer (5 to 1)
Kharif crops	Dummy: 0 = 1 crop, 1 = multiple crops
Cattle ownership	Dummy: 0 = Cattle owned , 1 =No cattle owned
Machinery ownership	Dummy: 0= Machinery owned, 1 = No machinery owned
State	Dummy: 0= GJ, 1 = UP, 2 = CG

The farm related variables include details of distance from the city, landholding, availability of adequate water for irrigation and number of kharif crops. The farmer related variables include farmerôs age, education, experience of hybrid rice cultivation, availability of information, family size, cattle and machinery ownership etc. Availability of information has been captured as an index. Farmers were asked about the various sources of information available to them and their ratings in terms of quality. We have taken weighted average to represent the extent of information available to the farmers.

Farmersô perceptions of the various aspects of hybrid rice technology and its cultivation were also captured. Variables such as better yield of hybrid rice, good demand in the market, good price available to the farmers, government procurement of hybrid rice output, availability of seed subsidy, farmerôs willingness to take risk of trying new technologies, availability of hybrid rice seeds, reasonable pricing of hybrid rice seeds, availability of good quality seeds and availability of credit for purchasing hybrid rice seeds have been used as explanatory variables. These variables were presented as statements to the farmers and responses to them were captured on a scale of 5 to 1 where 5 meant strongly agree and 1 meant strongly disagree. Apart from these, dummy variables were used for the states in the study, cattle ownership, machinery ownership and number of kharif crops (single or multiple).

The results of the TOBIT model have been shown in table 9 and 10. The results from hybrid rice share estimation include the estimates of the coefficients, standard errors, significance levels and marginal effects. The dependent variable in this estimation is the extent of adoption which varies from 0 to 1 with 0 indicating no adoption, 1 indicating complete adoption and the values in between indicating partial adoption of hybrid rice by the farmers.

Model statistics:

The measures of fit for the Tobit model have been given in Table 9. Higher likelihood of full model compared to null or intercept only model as well as the LR value and its probability indicate that the specified model is significant. The table also reports R-square values for the model. However, we are not interpreting it as it is not equivalent to the R-square of OLS regression. The sigma which is the estimated standard error is 0.3629.

Table 9. Measures of Fit for Tobit model	
Log-Lik Intercept Only: -246.618	Log-Lik Full Model: -187.776
Prob > LR: 0.000	LR(25): 117.684
McFadden's R^2: 0.239	McFadden's Adj R^2: 0.129
ML (Cox-Snell) R^2: 0.281	Cragg-Uhler (Nagelkerke) R^2: 0.375
Sigma (ů) : .3629	Standard Error of sigma : .0199

The assumption of normality of errors was also tested for the given model. The residuals were calculated and a p-p plot was made which showed that the error terms were normally distributed. This also indicates the robustness of the specified model. Overall, using the central limit theorem, the distribution of sample means can be considered to be normal as the sample size is 441 (more than 30).

Table 10 reports the results of the Tobit model. The independent variables used in the model are given in Column 1. Column 2, 3 and 4 report the Tobit coefficients, their standard errors and t-statistics with significance levels respectively. Column 5 presents the changes in the dependent variable with change in the independent variables for all the farmers, whereas Column 6 and 7 report the changes in the dependent variable with changes in the independent variables for partial and complete adopters respectively. Column 8 reports the impact of independent variables on the probability of a farmer being a partial adopter. All the marginal effects have been captured at the means of the independent variables.

Variable-wise results:

The coefficients of the independent variables used in the model have been reported in column 2 of table 10. Farmerôs experience of hybrid rice cultivation and education level of the farmer are positively and significantly related to the share allocated to hybrid rice cultivation. Thus, farmers with more experience of hybrid rice and higher education are more likely to allocate higher area under rice for hybrid rice cultivation. On the other hand, size of landholding owned by the farmer and having multiple kharif crops are negatively and significantly related to the percentage of area under hybrid rice cultivation. It shows that smaller farmers and farmers who grow multiple crops (crops other than rice) during kharif season are more likely to have higher percentage of rice area under hybrid rice cultivation. Among the variables related to the hybrid rice cultivation, perception of good demand of the hybrid rice in the market and availability of seed subsidy by the government are positively and significantly related to the share of hybrid rice cultivation in the total area under rice cultivation. The dummies for the state of Uttar Pradesh and Chhattisgarh are significant and have a negative relationship with the percentage of rice area under hybrid rice cultivation indicating lower adoption levels in these states compared to Gujarat. Coefficients of rest of the variables are not significant.

Column 5 values show the impact of change in independent variables on the dependent variable for all the observations (partial as well as complete adopters). The values show that a one-percentage-point increase in the farmerôs experience predicts an increase of 1.49% in the share of the hybrid rice area for all hybrid rice growing farmers. Similarly, a 1% increase variable such as education, good demand of hybrid rice and availability of subsidy on hybrid rice seeds leads to an increase in the share of the rice area under hybrid rice cultivation by 0.79%, 6.51% and 4.07% respectively. On the other hand, a 1% increase in variables such as landholding, good market price and availability of seeds through government outlets predict a decrease of 2.39%, 3.49% and 2.90% respectively in the share of rice area under hybrid rice cultivation. Also, if the farmer is having multiple kharif crops or belongs to the state of Uttar Pradesh and Chhattisgarh, results predict a decrease in the share of hybrid rice area by 6.67%, 10.19% and 8.41% respectively.

Column 6 presents effect on the adoption of hybrid rice by the farmers as the independent variables change for the farmers who had adopted hybrid rice partially during the time of the survey. Thus, the column shows that the predicted effect of a 1% increase in the experience

level of the farmer, education, good demand, and seed subsidy is 1.05%, 0.5%, 4.57% and 2.85% increase in the proportion of hybrid rice cultivation for the partial adopters. Also, a 1% increase in variables such as landholding, farmer growing multiple kharif crops, being from Uttar Pradesh or Chhattisgarh predicts a decrease in the proportion of hybrid rice by 1.67%, 6.67%, 7.14% and 5.89% respectively for the partial adopters.

Column 7 presents the effect of changes in the independent variables on adoption for farmers who were complete adopters at the time of the survey. The values in the column show that the predicted effect of a 1% increase in the experience of hybrid rice cultivation, education, good demand and seed subsidy is 0.44%, 0.23%, 1.95% and 1.22% increase in the proportion of hybrid rice cultivation for the current complete adopters of the technology. Also, a 1% increase in landholding leads to a decline of 0.71% in the proportion of area under hybrid rice cultivation for the complete adopters. In case a farmer cultivates multiple kharif crops, is from Uttar Pradesh or from Chhattisgarh, the decline in the proportion of area under hybrid rice cultivation for the complete adopters is 2.84%, 3.05% and 2.51% respectively.

Column 8 reports the effect of the change in each one of the independent variable on the probability of a farmer of having less than the maximum area under organic practice. That is, it shows the impact of the independent variables on the likelihood of a farmer of being a partial adopter of hybrid rice rather than a complete adopter. . Thus, a 1% increase in the experience and education level of the farmer decreases the probability of a farmer being a partial adopter of hybrid rice by 2.40% and 1.27% respectively. Similarly, if the landholding of the farmer increases by 1 %, the probability of him being a partial adopter increases by 3.84%. Also, if the perception of the farmer regarding good demand of hybrid rice and availability of seed subsidy increases by 1%, the probability of being a partial adopter decreases by 10.46% and 6.53% respectively. At the same time, if a farmer shifts from single kharif crops to multiple kharif crops i.e. rice, there is 15.26% higher probability of him being a partial adopter. Similarly, the probability of a farmer bring a partial adopter is higher by 16.35% and 13.50% if he belongs to Uttar Pradesh and Chhattisgarh respectively.

Table 10. Results of TOBIT analysis

1	2	3	4	5	6	7	8
Independent Variables	Tobit coefficient	Standard Error	t-statistic	Effect on dependent variable for all observations (adopters)	Effect on dependent variable for observations below the limit (partial adopters)	Effect on dependent variable for observations at the limit (complete adopters)	Effect on probability of being below the limit (probability of being partial adopters)
Experience	0.023	0.008	2.91**	0.0149	0.0105	0.0044	-0.0240
Education	0.012	0.005	2.29*	0.0079	0.0056	0.0023	-0.0127
Age	-0.002	0.002	-1.28	-0.0015	-0.0010	-0.0005	0.0024
Family size	-0.005	0.006	-0.77	-0.0031	-0.0022	-0.0009	0.0050
City distance	-0.002	0.002	-1.01	-0.0014	-0.0010	-0.0004	0.0022
Landholding	-0.037	0.009	-4.14***	-0.0239	-0.0168	-0.0071	0.0384
Information	0.022	0.051	0.43	0.0139	0.0098	0.0041	-0.0223
Adequate irrigation	-0.029	0.023	-1.28	-0.0186	-0.0131	-0.0055	0.0299
Better yield	0.021	0.033	0.66	0.0137	0.0096	0.0041	-0.0220
Good demand	0.102	0.025	4.06***	0.0652	0.0457	0.0195	-0.1046
Good price	-0.054	0.030	-1.8	-0.0349	-0.0245	-0.0104	0.0561
Government procurement	-0.026	0.018	-1.46	-0.0168	-0.0118	-0.005	0.0270
Seed subsidy	0.063	0.028	2.28*	0.0407	0.0285	0.0122	-0.0653
Risk taking ability	-0.012	0.022	-0.52	-0.0074	-0.0052	-0.0022	0.0120
Package awareness	-0.048	0.029	-1.63	-0.0305	-0.0214	-0.0091	0.0489
Easy availability	0.037	0.041	0.91	0.0239	0.0168	0.0071	-0.0384
Government outlets	-0.045	0.024	-1.87	-0.0290	-0.0203	-0.0087	0.0466
Reasonably priced seeds	0.023	0.022	1.04	0.0149	0.0104	0.0045	-0.0238
Good quality seeds	0.030	0.030	1.00	0.0193	0.0136	0.0057	-0.0310
Credit from dealer	0.026	0.016	1.59	0.0168	0.0118	0.005	-0.0270
Kharif_dummy	-0.148	0.050	-2.98**	-0.0951	-0.0667	-0.0284	0.1526
Cattle_dummy	0.120	0.081	1.49	0.0772	0.0541	0.0231	-0.1238
Machinery_dummy	0.006	0.052	0.12	0.0042	0.0029	0.0013	-0.0067

State_dummy_1	-0.159	0.079	-2.02*	-0.1019	-0.0714	-0.0305	0.1635
State_dummy_2	-0.131	0.066	-1.99*	-0.0841	-0.0590	-0.0251	0.1350
Constant	0.635	0.346	1.84				

Note: The figures in parenthesis are the standard errors. *, ** and *** are significance levels at 5, 1 and 0% respectively.

Overall, the results indicate a positive relation between share of hybrid rice cultivation and experience of farmer with hybrid rice cultivation, number of years of education, good demand of hybrid rice and availability of seed subsidy. On the other hand, landholding of the farmer, multiple kharif crops and the dummies for the state of Uttar Pradesh and Chhattisgarh are negatively related to the share of hybrid rice. This indicates that the farmers who are educated, experienced, have smaller landholdings and grow single kharif crop are more likely to have higher area under hybrid rice cultivation. Farmers are more likely to be complete adopters if they perceive that hybrid rice has good demand in the market and subsidy is available on the purchase of seeds. These are mostly the small and marginal farmers who sell the hybrid rice output in the market and depend upon government subsidies for the adoption of new technologies. Although they have smaller landholdings, they usually allocate complete rice area for hybrid rice cultivation.

Thus, the results indicate the small and marginal farmers are the ones who are complete adopters of hybrid rice. For them, demand of output in the market and subsidy on seeds is of importance. Large farmers, however, are the partial adopters. They have more landholding but allocate relatively lesser area to hybrid rice cultivation. The inputs from the field visits indicate that these farmers prefer to grow the traditional rice varieties due to better taste. These farmers have access to government outlets and manage to get good price of the output in the market. The results point towards the inefficiencies existing in the system. Access to market, availability of good output prices and availability of seeds through government outlets seem to be an issue for the small and marginal farmers, who are the complete adopters of the technology. Also, the coefficients of state dummies show that farmers in Uttar Pradesh and Chhattisgarh have lesser percentage of their rice area under hybrid rice cultivation.

5. Conclusion and policy implications

Rice is the staple food of India and the demand for it is growing consistently. However, increasing the production of rice remains a challenge due to constraints on the horizontal expansion. Technologies such as hybrid rice seem to have huge promise as it has the potential

to increase the production by 15-20% without increasing the area under cultivation. However, the poor rate of adoption of hybrid rice by the Indian farmers has been a reason of concern for the policy makers and the private sector involved in the production and distribution of hybrid rice seeds.

The results from this study can be of help in policy making aimed at encouraging the adoption of hybrid rice technology or other similar agricultural technologies in India or other developing economies. Overall, factors related to the farmer, the farm as well as the perception of the technology is seen to be related to the share of rice area under hybrid rice cultivation. The results indicate that education, experience, landholding, demand, price, subsidy, seed availability and cropping pattern are of importance in determining the status of adoption of hybrid rice by the farmers. Therefore, it may be possible to encourage hybrid rice adoption by the farmers in India by:

- Targeting the educated but small and marginal farmers
- Target regions where multiple kharif crops are being grown.
- Ensuring the availability of good output price
- Making hybrid rice seeds available through government outlet to all.
- Facilitating the marketing of the hybrid rice output so as to ensure good demand.

Adoption is found to be negatively related to the extent of land owned by the farmer. This indicates that farmers with smaller landholdings are more likely to adopt the technology completely. Therefore, the focus of initiatives to encourage the adoption of new agricultural technologies should be the small and marginal farmers. Contrary to the expectations, factors such as family size, age of the farmer, distance from the city, mechanization, better yield, awareness level of the farmer, price of the hybrid rice seeds, quality of seeds etc. were not found to be significant determinants of the extent of adoption of hybrid rice by the farmers.

The evaluation of hybrid rice cultivation with censored data indicates that the partial and complete adopters of the technology differ from each other with respect to their intensity of response towards certain perceptions related to hybrid rice cultivation. The calculation of separate effects for partial and complete adopters using the upper bound Tobit model allows us to identify the factors that affect partial and complete adopters differently along with how the different technology, farm and farmer related factors can potentially affect the degree of adoption, that is, the share of hybrid rice cultivation out of total rice cultivated by the farmer.

Insight into these effects can be very helpful in designing policies for encouraging the adoption of hybrid rice technology in the country.

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- Prof. Varsha Khandker joined the institute in 2014 after completing her Fellow Programme in Management (Ph.D) from IIM Ahmedabad. She is a certified instructor for marketing simulations ï MarkStrat and BrandPro. She is a faculty mentor for BrandScan ï a students led market research fair.
- She is also a visiting faculty at National Institute of Agricultural Marketing (NIAM), Jaipur and has taught Rural Marketing to PGDM students and Agricultural Input Marketing to Agricultural Practitioners from Kenya and Libya as a part of US-India-Africa Triangular International Program on óAgricultural Marketing Managementô.

Teaching

Marketing Management, Marketing Research, Managerial Analysis for Decision, Marketing Strategy, Rural Marketing.

Research

Emerging issues in agribusiness and food industry, technology adoption, consumption patterns, education.

Publications

- Gandhi, V. P., & Khandker, V. (2012). Frontier technologies in agriculture biotechnology: The promise and performance of BT cotton in India. *Indian Journal of Agricultural Economics*, 67(3).
- Pal, D., & Khandker, V. (2010). Does Land Reform Matter? An Empirical Analysis of Indian States, *IIM Ahmedabad Working Paper Series*, W.P. No. 2010-12-01, IIM Ahmedabad

Conferences and Workshops

- Attended 3-day certification workshop organized by StratX Simulations on marketing simulations ï MarkStrat and BrandPro in Paris. (April, 2016)
- Attended 2015 Asia Pacific Annual Conference of AACSB International in Xiôan,China. (October, 2015)
- Attended Faculty Development Program on óDrivers of Learningô at Indian School of Business (ISB) Hyderabad. (August, 2015)
- Attended 6th Indian Management Conclave at Indian School of Business (ISB) Hyderabad. (August, 2015)
- Poster titled ñDeterminants of Satisfaction with Hybrid Rice Technology amongst the Indian Farmersò (with Prof. Vasant P. Gandhi) accepted for presentation at 4th International Rice Congress, Thailand. (October 2014)
- Attended Indian Seed Congress organized by the National Seed Association of India in Gandhinagar, Ahmedabad. (February 2014)
- Presented poster titled ñChallenges in the Adoption of Hybrid Rice in India: A Conceptual and Empirical Study of the Farmer and Market Response Behaviorò (with Prof. Vasant P. Gandhi), 6th International Hybrid Rice Symposium, Hyderabad, India. (September, 2012)
- Presented paper titled ñIntroduction of New Technologies in Agriculture: A Study of the Challenges in the Adoption of Hybrid Rice in Indiaò (with Prof. Vasant Gandhi), 56th Annual Conference of Australian Agriculture and Resource Economics Society, Fremantle, Australia. (February, 2012)
- Attended the workshop and field visits of the Australian Centre for International Agricultural Research (ACIAR) project on ñEnhancing Institutional Performance in Watershed Management: A Study of the Nature and Performance of Watershed Development in Indiaò in Perth, Australia. (February 2012)
- Presented paper titled ñIntroduction of New Technologies in Agriculture: A Study of the Challenges in the Adoption of Hybrid Rice in Indiaò (with Prof. Vasant Gandhi), 5th Doctoral Colloquium, Indian Institute of Management, Ahmedabad. (January, 2012)
- Attended the workshop and field visits of the Australian Centre for International Agricultural Research (ACIAR) project on ñEnhancing Institutional Performance in Watershed Management: A Study of the Nature and Performance of Watershed Development in Indiaò in Hyderabad, India. (November 2010)
- Attended the workshop and panel discussion on the ñPre-budget Consultationò organized by Centre for Management in Agriculture (CMA) at Indian Institute of Management, Ahmedabad. (January, 2010)

Awards

- Best project certificate from the District Commissioner of Udupi for the group project titled ñ*A retrospective view of SAKALA Implementation in Udupi district".* (June, 2016)
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