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RICE ECOSYSTEMS AND ADOPTION OF MODERN RICE VARIETIES IN ODISHA, EAST INDIA: INTENSITY, DETERMINANTS AND POLICY IMPLICATIONS

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ABSTRACT

Odisha is one of the major rice producing states of the eastern region of India. But, the adoption of modern agricultural technologies like modern varieties (MVs) of paddy is still low and skewed across regions and farmer groups in the state even after five decades of inception of green revolution in India. The state has two distinct ecosystems because out of 6.5 million hectares of gross cropped area of the state, 49% is still rainfed and 51% is irrigated. The patterns of adoption of MVs of rice and constraints in adoption process differ in both ecosystems. On this background, the present paper tries to analyze the intensity of adoption of MVs of rice and its determinants in irrigated and rainfed rice ecosystems of the state. The study is based on the primary data at the household level collected by a multistage purposive sampling method. The sample included 300 farm households from six villages of two districts, i.e., Cuttack and Khordha. These two districts represent the irrigated ecosystem and rainfed ecosystem, respectively. The study found that the total study region shows an increasing trend in the adoption intensity with the rise in the size of operational landholding even though the absolute area for large farmer group is the lowest. This positive association is higher in the irrigated region than in the rainfed ecosystem. There is no huge difference in adoption intensity of MVs across the farmer groups in the irrigated region as compared to their counterparts in the rainfed ecosystem. From the tobit model regression results, the study has found a glaring difference between the specific factors influencing the adoption intensity in both ecosystems. Factors like education, farm size, land position, extension visits, credit accessibility, local market, seed availability, perception about taste of MVs and shorter maturity of MVs were significantly influencing the adoption intensity in irrigated ecosystem. But, in the rainfed ecosystem, variables like non-farm activities, soil quality, land position, seed availability, perception on shorter maturity and higher yield of MVs were the significant determinants of adoption intensity. The pooled sample regression results reveal that the ecosystem dummy variable plays a significant role in the adoption decision. Therefore, the study pitches for the development of irrigation facilities along with rigorous implementation of farmer field school program and strengthening of agricultural extension networks.

JEL Classifications: Q12, Q16, C01, C21
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INTRODUCTION

Adoption of modern technology in backward agriculture has been drawing the attention of development economists and planners since long, as adoption offers an opportunity to increase output and income substantially (Sarap and Vashist 1994). Moreover, technology driven farm production has a direct impact on poverty and employment in backward economy through augmentation in productivity, profitability and sustainability of farming of smallholders (WDR 2008; Asfaw et al. 2012). Of course, the green revolution technologies introduced in the form of a package of high yielding varieties (HYVs) of seeds, fertilizers and pesticides during the 1960s in Indian agriculture increased the production substantially (FAO 2004; Pingali 2012)[1]. But, the success stories prevailed more markedly in irrigated ecosystems and largely bypassed the rainfed ecosystems where abiotic stresses like droughts of various types at different stages of crop growth occur regularly (Khush 1990; Evenson and Gollin 2003). Therefore, the slow technological transfer and diffusion rate of modern varieties (MVs) of rice in unfavorable rainfed farm ecosystems need to be studied properly along with other ecosystems.

Situated in the eastern part of India, Odisha is one of the major rice producing states. Out of total 6.5 million hectares (ha) of cultivable areas in Odisha, 49% is still rainfed. The cropping pattern is dominated by rice which accounts for more than 75% of gross cropped area under cereals and more than 45% of total cropped area in the state (Odisha Agriculture Statistics, 2015-16). But, out of total area under MVs of rice[2] (4180 thousand ha), only 36% is irrigated and the rest is rainfed. The overall performance of agricultural sector is dismal and it lags behind many states of India (Paltasingh and Goyari 2013). It is true that the state level macro data may ignore many farm level characteristics. Again, the specific factors influencing the adoption intensity may not be the same in both the ecosystems. Therefore, it is necessary to have a micro level analysis by taking the farmers into account for a better understanding of the problem. In view of these arguments, this study attempts (i) to analyze the adoption intensity of MVs of rice in two ecosystems across the farming groups in the study area of Odisha and (ii) to examine the specific factors influencing the adoption intensity in both the ecosystems. The study also examines the decomposition of the total elasticity of adoption into two parts of change in probability of adoption and intensity of adoption.

The paper is organized in the following manner: after a brief introduction, the second section talks about the empirical strategies and data collection from the study area. The third section discusses the estimated results. Finally, the paper concludes with some policy implications.

MATERIALS AND METHODS

Empirical Strategies

The present study follows the frameworks of Mazvimavi and Twomlow (2009), Abdulai et al. (2011) and Asfaw et al. (2012) which assume that the decision to adopt modern technology is based upon the theory of utility maximization. The farmer initially has two options, either to adopt modern technology (modern variety) or traditional technology (traditional variety). Now, let j represents his technology choice where $j = 1$ for modern technology and $j = 2$ for traditional technology. The unobservable utility function that ranks ith farmer's preference is given by the equation (1).

$$U(M_{ji}, C_{ji}, A_{ji}) \tag{1}$$

where, M_{ji} is vector of farmer's specific characteristics, C_{ji} is vector of socioeconomic factors and A_{ji} is vector of institutional and other factors. The underlying utility function for the farmer can then be represented as equation (2).

$$U_{ji} = \alpha_j F_i(M_{ji}, C_{ji}, A_{ji}) + e_{ji}; j = 1,2 \text{ and } i = 1,2 \ldots\ldots n \tag{2}$$

Because of the random nature of utilities, the ith farmer will select the alternative j = 1, if $U_{1i} > U_{2i}$ or the unobservable (latent) random variable $Y_i = U_{1i} - U_{2i} > 0$. Now the probability of adoption of modern technology can be expressed as below:

$$\begin{aligned} P_i &= Pr(Y_i = 1) = Pr(U_{1i} > U_{2i}) \\ &= Pr[\alpha_1 F_i(M_{1i}, C_{1i}, A_{1i}) + e_{1i} > \alpha_2 F_i(M_{2i}, C_{2i}, A_{2i}) + e_{2i}] \\ &= Pr(e_{1i} - e_{2i}) > F_i(M_i, C_i, A_i)(\alpha_2 - \alpha_1) \\ &= Pr(\mu_i) > -F_i(M_i, C_i, A_i, \beta) \\ &= F_i(X_i\beta) \end{aligned} \tag{3}$$

where X is the n × k matrix of explanatory variables and, β is a k×1 vector of parameters to be estimated, $Pr(.)$ is a probability function, μ_i is random error term and $F(X_i\beta)$ is the cumulative distribution function for μ_i evaluated at $X_i\beta$. The probability that a farmer will adopt modern technology is a function of the vector of explanatory variables, unknown parameters and the error term. The estimation of equation (3) depends on the distribution of F (.) which is ultimately decided by the error term μ_i. If μ_i is normally distributed with zero mean and constant variance σ^2, then F (.) will be a cumulative distribution with the functional form being specified as a probit/tobit model (Mazvimavi and Twomlow 2009; Akinola et al. 2010). Here, the present study uses the tobit model for analyzing adoption behavior since the use of binary choice models (logit/probit) may not capture the adoption intensity (Mazvimavi and Twomlow 2009). The major issue related to technology adoption is to measure the extent and intensity of use at the individual farm level rather than the initial decision to adopt a new practice (Rajasekharan and Veeraputharan 2002). Thus, tobit model can be used to analyze such a decision. The tobit model coefficients can be further disaggregated to find the probability of change in adoption and expected use intensity of practice due to change in any of the explanatory variables (McDonald and Moffitt 1980; Alene et al. 2000; Akinola et al. 2010). Details of this decomposition of the total elasticity/change in adoption are given in Appendix-B.

Now the unobserved latent variable (index) can be expressed as

$$\begin{aligned} I_i^* &= \beta^T X_i + \mu_i \\ \text{and } Y_i &= g(I_i^*) \end{aligned} \tag{4}$$

The adoption behavior can be explained as:

$$Y_i = \begin{cases} \beta^T X_i + \mu_i & \text{if} \quad I_i^* = \beta^T X_i + \mu_i > T \text{ (for adoption)} \\ 0 \quad \text{if} \quad I_i^* = \beta^T X_i + \mu_i \le T \text{ (for non} - \text{adoption)} \end{cases} \tag{5}$$

The equation (5) represents a censored distribution of intensity of use of a technology where Y_i is probability of adopting and intensity of use of the innovation by the i^{th} farmer. Here, I_i^* is the non-observed latent variable (index) reflecting the combined effect of all the factors *Xs* that have influenced technology adoption and T is unobserved threshold level. β^T is vector of tobit maximum likelihood coefficients. If the non-observed value of I_i^* is greater than *T*, the observed variable Y_i becomes a continuous function of the independent variables, and 0 otherwise.

Study Area and Data

The study is based on primary data collected from Cuttack and Khordha districts of Odisha during the kharif season[3] of the year 2012-13. With 58% of its cultivated area under irrigation, Cuttack is an irrigated district but Khordha is regarded as a rainfed district because only 37% of its cultivable area is under irrigation. The multistage purposive sampling method was followed where one block was selected purposively from each of both districts and then three villages were selected from each block. All three villages are clustered together in each block. Finally, the farmers from all six villages were selected randomly. The villagers in Cuttack are well facilitated with assured canal irrigation while the villagers from Khordha are rainfed in nature and the farming takes place once in a year after receiving the monsoon rainfall during June-July. Rice is the major crop grown in both study regions. The sample of 300 farming households was interviewed with the help of a survey schedule. Descriptions and definitions of study variables used in the tobit regression model along with their descriptive statistics are presented in Table 1. The dependent variable (ADOPTION) is defined as the proportion of total operational landholding devoted to MVs of rice cultivation. Farming experience (FMEX) is counted in terms of number of years that a farmer is in farming. The average year of experience for the entire sample area is 22 years. Usually, the experienced farmers are supposed to adopt a modern technology more than less experienced farmers. But, at the same time, younger farmers are also more likely to adopt a modern technology than older farmers (Sidibe 2005). So, theoretical relation is not clear. However, we hypothesize a positive relation between the two variables in the null hypothesis. Farmer's education level influences the farmer's adoption behavior positively. It helps a farmer in decoding the information and using the available information efficiently (Alene et al. 2000; Mzoughi 2011). Some studies argued that education defined as the years of schooling does not reveal any significant impact on adoption as it has a threshold effect (Phillips 1994; Alene and Manyong 2007; Paltasingh 2016). We use the dummy variable (EDUDM) in the regression, where it takes the value of one if formal schooling is of 6 years or more, and zero if the farmer is having less than 6 years of schooling[4]. Household size (HSIZE) is measured as the number of members in a farm household. Some studies found a positive relationship between these two variables and argued that large HSIZE means high demand for food which ultimately leads to higher adoption of modern technologies (Abdulai et al. 2011). So, we hypothesize a positive impact of household size on the MV adoption. Number of nonfarm activities (NFAC) is a farmer specific characteristic which is hypothesized to have positive impact on adoption (Alene and Manyong 2007). It is measured as the number of non-farm activities of the household head.

TABLE 1. DESCRPITIVE STATISTICS OF STUDY VARIABLES

Variable	Description	Mean	Std. Dev.
Dependent Variable			
ADOPTION	Share of area under MVs of rice in total operational landholding	0.63	0.87
Independent Variables			
FMEX	Farming experience of farmer in years	22	8.15
EDU	Education of farmer (years of schooling)	5.89	3.21
EDUDM	Head's education dummy (1-if 6 years or more of schooling, 0-otherwise)	0.65	0.48
HSIZE	Household size in number of persons	6.56	1.82
NFAC	Number of non-farm activities of the head	1.89	0.87
FSIZE	Farm size (ha)	1.19	0.76
TOPC	Total operational cost (INR/ha)	15,744	17,200
SOILQ	Soil quality on the basis of farmer's own assessment (1-if fertile, 0-otherwise)	0.52	0.50
LANDP	Land position (share of medium land to the total operated landholding)	0.38	0.63
ECDMY	Ecosystem dummy (1-if irrigated ecosystem, 0- rainfed ecosystem)	0.49	0.51
EXTN	Contact with extension service (1-if yes, 0-no)	0.28	0.45
TNCY	Tenancy structure (share of leased-in area to total operated landholding)	0.05	0.09
SEED	Availability of MV seeds to farmer through barter exchange (1- if exchanged, 0-otherwise)	0.48	0.50
CRDIT	Access to credit (1- if accessed, 0-no)	0.82	0.72
SOC	Social capital in the form of developmental group membership (1-if member of a group, 0-no)	0.40	0.49
MKTD	Distance to local market (kilometers)	2.42	1.13
MEDIA	Access to media (1-if he owns television, radio etc., 0-otherwise)	0.64	0.48
LIVSTK	Livestock ownership (no. of livestock adult equivalent)	4.94	4.05
SMC	Farmer's perception on early maturity property of MVs (1-if yes, 0-no)	0.61	0.49
YLDC	Farmer's perception on higher yield characteristic of MVs (1-if yes, 0-no)	0.35	0.47
TAST	Farmer's perception on good taste characteristic (1-if yes, 0-no)	0.55	0.48
FMSUIT	Farmer's perception about suitability of MVs to a particular farm ecosystem (1-if yes, 0- no)	0.41	0.49

Source: Authors' field survey, 2012-13.

Total farm size (FSIZE), which is measured in hectares of operated landholding, is hypothesized to influence adoption behavior positively (Feder et al. 1985; Akinola et al. 2010; Thuo et al. 2014). The average farm size of 1.19 hectares in the total sample indicates that most of the sample farmers are small farmers. Land position (LANDP) is measured as the ratio of amount of medium-land area to the total operated landholding for the reason that, in general, the medium-land makes farm environment conducive for growing MVs of rice. Farmers usually possess several plots of land at different locations with different positions. Following Samal et al. (2011), the position of land on the basis of water regimes is classified as upland (no standing water), medium-land (water depth ≤ 30 cm) and lowland (water depth > 30 cm). If one farmer is having large amount of medium-land areas, then he is more likely to adopt MVs of rice. Another farm specific characteristic is soil quality (SOILQ) which is defined as a dummy variable that takes the value of one if it is good quality soil and zero otherwise. Farmer's own knowledge and assessment about soil fertility of a plot is used here based on different criteria as discussed in Corbeels et al. (2000) and Lima et al (2011). Fertile soil induces a higher rate of adoption as it ensures higher crop yields (Wubeneh and Sanders 2006; Koundouri et al. 2006). So, it is hypothesized that both variables will have the positive influence on MVs adoption. Total operation cost (TOPC) in rice cultivation is another economic factor which is measured in Indian rupees per hectare. It includes cost in ploughing, soil preparation, planting, harvesting etc. Credit (CRDIT) variable is measured as a dichotomous variable that takes the value of one if farmer gets access to credit and zero otherwise. When a significant cash investment is required for the use of a new technology, then credit plays an important role in its adoption, particularly for small farmers without readily available cash (Feder et al. 1985; Sarap and Vashit 1994). So, in general, a positive relation between credit availability and MVs adoption behavior can be expected.

Contact with agricultural extension services (EXTN) is another institutional factor which is defined as a dichotomous variable – taking the value of one if the farmer has any contact with the agricultural extension services and zero otherwise. Farmers who visit or are visited by extension officers are generally progressive farmers and more likely to adopt modern technology (Adesina and Chianu 2002; Alene and Manyong 2007) and hence a positive relationship can be expected. Tenancy structure (TNCY), an institutional factor, is defined here as the proportion of leased-in area to total operated land area. So, its value ranges from 0 to 1 indicating a farmer to be a complete owner cultivator to a tenant, respectively. The mean value is 0.049 which indicates that most of the farmers are owner operators. If the operator is a land owner having a secured land right, then he is more likely to modern technology. It is hypothesized that a tenancy structure is positively related to technology adoption (Adesina et al. 2000). Social capital (SOC) is defined as a dummy variable which takes the value of one if a farmer is a member of any developmental group such as cooperative societies, or zero otherwise. This variable has been found to enhance the interaction and cross-fertilization of ideas among farmers (Alene and Manyong 2007; Akinola et al. 2010). So, a positive relation can be expected. Existence of local market (MKTD) is one of the institutional factors which is measured here as the distance of the study village to local market in kilometers. Besides providing necessary facility for exchange of inputs and outputs, a local market can strengthen the coping strategies against all odds that ultimately can enlarge the scope of technology adoption (Feder et al. 1985; Adesina and Chianu 2002). The media accessibility (MEDIA) variable is defined as a dichotomous variable. Accessibility to media helps in diffusion of information that brings the farming community the required knowledge about the modern agricultural technologies. Thus, it augments the probability of adoption (Alene and Manyong 2007). The mean score is 0.64 indicating that majority of farmers own media equipments like radio, television, internet etc. Ownership of livestock (LIVSTK) plays a crucial role in adoption decision. It is an asset which one can use either in the production process directly or can be exchanged for cash and other productive assets (Akinola et al. 2010). It is expected to influence the adoption of MVs positively. The exchange of new seeds (SEED) among the farmers also plays a pivotal role in MVs adoption. We define this variable as a dummy variable which takes the value of one if seeds of MVs are obtained through farmer-to-farmer exchange and zero otherwise. The intensity of adoption of MVs is boosted if farmer-to-farmer diffusion takes place to a large extent. It helps the farmer to understand and evaluate the nature of technology fully in a friendly manner (Alene and Manyong 2007). Purchasing the seeds from the outside market is an economic constraint which is unaffordable for many poor farmers. So, this variable is expected to a have positive impact on the adoption of MVs.

We also define four dummy variables (1-if perception is yes, 0-otherwise) on farmers' perceptions about four characteristics of MVs of rice - higher yield (YLDC), shorter maturity duration (SMC), good taste (TAST) and farm ecosystem suitability (FMSUIT). Sample farmers were asked to evaluate and report during field surveys. All these variables are hypothesized to influence the adoption of MVs positively (Adesina and Zinnah 1993; Alene and Manyong 2007).

TABLE 2. INTENSITY OF MVs ADOPTION IN STUDY REGION (Area in ha)

Farm ecosystems/ Farmer groups	Total area under MVs	Total area under TVs	Total area under rice	% of area under MVs	% of area under TVs
Irrigated ecosystem					
Marginal	19.68	02.53	22.21	88.59	11.41
Small	46.15	09.13	55.27	83.49	16.51
Medium	25.65	02.79	28.44	90.21	09.79
Large	04.24	00.21	04.45	95.27	04.73
Rainfed ecosystem					
Marginal	3.68	19.7	23.38	15.72	84.28
Small	49.09	46.69	95.78	51.25	48.75
Medium	38.56	23.58	62.14	62.06	37.94
Large	02.27	01.78	04.05	56.00	44.00
Total study region					
Marginal	23.36	22.24	45.6	51.23	48.77
Small	95.23	55.82	151.05	63.05	36.95
Medium	64.21	26.36	90.58	70.89	29.11
Large	06.51	01.99	08.50	76.57	23.43

Note: MVs and TVs indicate 'modern varieties' and 'traditional varieties' of rice, respectively.
Source: Authors' field survey, 2012-13.

RESULTS AND DISCUSSION

Intensity of Adoption of MVs of Rice

The intensity of adoption of a crop, in general, is defined as the share of land devoted to the cultivation of that crop. Table 2 shows the intensity of adoption of MVs of rice across farming groups[5] of the sample. Three important points are observed here. First, in both ecosystems, the intensity increases with the increase in the size of operated landholding even though the absolute area for large farmer group is the lowest. Second, in irrigated ecosystem, farmers have greater adoption intensities as compared to the rainfed ecosystem. In the irrigated ecosystem, the positive association between them is quite clear as the marginal farmers devoted 89% of their operated land to MVs, followed by 84% by small, 90% by medium and 95% by large farmers. In the rainfed ecosystem, the medium farmers devoted the largest share of land to MVs followed by large and small farmers. Third, the intra-ecosystem comparison shows that in irrigated ecosystem, there is not much difference in adoption intensity across the farming groups and they are devoting a major portion of their operational holding to MVs. But, in the rainfed ecosystem, except medium farmers (62%), the amount of land devoted to MVs is low by other groups in comparison to their counterparts in the irrigated ecosystem. One of the main reasons for the huge difference in adoption intensities in-between two ecosystems can be due to the subjective and objective risks attached with the farming conditions in rainfed ecosystem in general and growing MVs in particular. Rainfed ecosystem is not conducive for growing MVs due to water intensive nature. Moreover, marginal farmers are mostly tenants who lease-in land and many of them usually prefer to cultivate TVs rather than taking risk of growing MVs. Overall trend for the total study region also shows an increasing trend in adoption intensity with the rise in the size of operational landholding. This result is similar to Feder et al. (1985), Swain (2002) and Akudugu et al. (2012). They concluded that fixed adoption costs, risks perception and human costs matter a lot in adoption pattern. The difference in ecosystems causes different factors to have different impacts on the adoption intensity.

Determinants of Adoption of MVs of Rice

This section provides a comparative analysis of determinants of adoption of MVs of rice in two ecosystems of the sample. Table 3 presents the maximum likelihood results of tobit regression model for the factors affecting the adoption behavior in the irrigated ecosystem[6]. Estimated results show that education and farm size are highly significant and retain their theoretical positive signs. It indicates that educated large farmers are more likely to adopt MVs. This finding is similar to Feder et al. 1985; Kassie et al. 2011; Mariano et al. 2012 and Ghimire et al. 2015. Schultz (1975) argued that impact of formal education is effective in creating conducive farm environment as it helps farmers to adopt modern technology. In addition, it is observed that education has a threshold effect on adoption. It means farmers having a minimum of six years of schooling are influenced to adopt the modern agricultural technology. The result is in line with studies like Phillips (1994), Alene and Manyong (2007), Mazvimavi and Twomlow (2009), Nyariki (2011) and Mzoughi (2011). Farming experience is not coming as a significant influencing factor for adoption behavior which is similar to the result of Mazvimavi and Twomlow (2009). Household size, though insignificant, retains its theoretical positive sign. So, it supports the finding of Abdulai et al. (2011). Land position variable is found to be affecting the adoption of MVs significantly in irrigated ecosystem. The significance of land position indicates that endowment of medium land plots is a major factor that encourages farmers to adopt MVs (Ghimire et al. 2015). Extension visit is observed to be a significant factor affecting adoption practice positively which is supported by many studies like Abdulai et al. (2011), Asfaw et al. (2012) and Mariano et al. (2012). Credit accessibility is found to be significantly and positively influencing the adoption. Sarap and Vashist (1994) and Asfaw et al. (2012) also found the similar result. The MKTD variable has significantly negative coefficient which implies that large distance of a sample village from a local market reduces adoption. This finding is similar to the argument of Adesina and Chianu (2002).

TABLE 3. TOBIT MODEL ESTIMATES FOR DETERMINANTS OF ADOPTION OF MVs OF RICE IN IRRIGATED ECOSYSTEM

Variable	Coefficient	Std. error	z-Statistic
Constant	-0.198	0.14	-1.4
FMEX	-0.001	0.01	-0.22
EDUDM	0.022**	0.06	2.38
HSIZE	0.005	0.01	0.39
FSIZE	0.039**	0.03	2.22
SOILQ	0.011	0.05	0.21
LANDP	0.043**	0.04	2.18
EXTN	0.023*	0.05	1.79
TOPC	0.002	0.01	4.19
CRDIT	0.043*	0.05	1.87
MKTD	-0.026*	0.02	-1.71
MEDIA	0.004	0.04	0.09
LIVSTK	-0.002	0.01	-0.36
SEED	0.06*	0.04	1.69
SOC	0.061	0.11	0.58
TAST	-0.129**	0.06	-2.16
YLDC	-0.04	0.05	-0.84
SMC	0.131**	0.06	2.02
FMSUIT	-0.032	0.1	-0.31
Log-likelihood	-71.11		
LR Chi^2 (18)	338.24		
Prob. > Chi^2	0.000		
Pseudo R-squared	0.21		

*Note: ***, ** and * refer to the statistical significance at 1%, 5% and 10% levels, respectively.*
Source: Authors' field survey, 2012-13.

Both MEDIA and LIVSTK variables are found to be having insignificant influences on adoption even though the former has retained its theoretical positive sign. Estimated results have shown that the SEED variable has a significant impact on the adoption decision which was also observed by Ghimire et al. (2015). Thus, the farmer-to-farmer exchange system of seeds is a significant diffusion mechanism. Social capital is not found to be significant factor even though the coefficient is positive. Out of four perception variables about technology characteristics, only farmers' perception about taste of MVs and early maturity period were found to have significant impact in influencing the adoption behaviour in irrigated rice ecosystem. While the SMC variable has the positive influence, the good taste (TAST) variable has negative influence on the adoption behaviour. In fact, the local varieties are preferred to MVs as far as taste is concerned. Even in many special occasions relating to socio-cultural rituals, only local varieties are cooked and served in many villages till now. Sall et al. (2000) argued that farmers' perceptions about length of crop maturity, taste, and cooking quality significantly influence the adoption pattern of the MVs of rice.

TABLE 4. TOBIT MODEL ESTIMATES FOR DETERMINANTS OF ADOPTION OF MVs OF RICE IN RAINFED ECOSYSTEM

Variable	Coefficient	Std. error	z-Statistic
Constant	1.008**	0.429	2.347
FMEX	-0.002	0.006	-0.366
EDUDM	0.002	0.032	0.062
FSIZE	0.003	0.070	0.040
SOILQ	0.109**	0.114	2.196
LANDP	0.075***	0.100	7.460
EXTN	0.072	0.116	0.619
NFAC	0.187***	0.061	3.394
CRDIT	-0.002	0.045	-0.038
MKTD	-0.035	0.071	-0.488
LIVSTK	0.034	0.030	1.160
SEED	0.293*	0.157	1.865
TAST	0.050	0.129	0.387
YLDC	0.257**	0.108	2.386
SMC	0.171**	0.132	2.294
FMSUIT	0.142	0.179	0.791
Log-likelihood	-61.94		
LR Chi^2 (15)	235.21		
Prob. > Chi^2	0.000		
Pseudo R-squared	0.24		

*Note: ***, ** and * refer to the statistical significance at 1%, 5% and 10% levels, respectively.*
Source: Authors' field survey, 2012-13.

Table 4 presents the tobit model results for the factors affecting adoption of MVs of rice in the rainfed ecosystem of the sample. Coefficients of study variables like farm size, education and extension contacts are found to be positive but insignificant. This implies that these variables do not play a significant role in adoption behavior of MVs in unfavorable farm ecosystem of rainfed compared to irrigated ecosystem. But, variables like land position and soil quality are found to be important determining factors of MVs adoption in rainfed region in the absence of assured irrigation. Both factors are statistically significant and retain their expected positive signs. The credit accessibility variable is observed to be not significantly influencing adoption in rainfed compared to irrigated ecosystem. Variables like MKTD and LIVST are also not significant but retain their theoretical expected signs. The NFAC variable is observed to be significant in influencing adoption which implies that farmers having other non-farm occupations are also adopters of MVs. This result contradicts the hypothesis that farmers engaged in non-farm activities usually do not put much emphasis on agricultural development. In general, farmers in rainfed region cannot depend exclusively on crop cultivation but they take up other occupations also to earn additional incomes. Hence, farmers having other sources of income can afford to take the risk of growing MVs in rainfed region. Similar to the irrigated ecosystem, the variable SEED has a positive and significant influence on adoption of MVs in rainfed ecosystem also.

Thus, factors influencing adoption of MVs of rice are not exactly similar in two rice ecosystems of the sample. In the irrigated ecosystem, the factors like education, FSIZE, LANDP, EXTN, CRDIT, MKTD, SEED, TAST and SMC are significantly important influencing factors on adoption. However, in the rainfed ecosystem, the adoption of MVs is determined significantly by the factors like SOILQ, LANDP, NFAC, SEED, YLDC and SMC. Thus, more economic factors are significant in irrigated ecosystem than in rainfed ecosystem where more significant factors are farm-specific. Besides EXTN and SEED, SMC has significant influence on the adoption of MVs in both ecosystems. Now, to establish the importance of the differences in ecosystems on adoption intensity, we estimate the tobit regression model for the total sample after incorporating a dummy variable that takes the value of one if it is irrigated ecosystem and zero for rainfed ecosystem. The results are reported in Appendix-A. It is observed that the ecosystem dummy is highly significant and positive in sign indicating that assured irrigation stimulates a higher rate of adoption of MVs. Other factors which are significantly influencing adoption in the entire study region are mostly those factors which were significant either in the case of irrigated or rainfed farm ecosystem.

Elasticity of Adoption of MVs of Rice

Table 5 shows the decomposition of total change in adoption, i.e., the total elasticity of adoption due to a unit change in independent variables which are significantly influencing the adoption decision in both ecosystems. The total change is decomposed into two parts - the change in probability of adoption and the expected change in intensity of adoption, i.e., the potential change in adoption once decision to adopt is taken due to change in the values of independent variables. The results are interpreted as follows: the total elasticity value for farm size is 0.039, meaning that a 10% increase in farm size would induce a 3.9% increase in adoption, given the impact of farm size on adoption. That 3.9% increase in adoption is due to 0.12% increase in probability of adoption and 3.78% increase in intensity of adoption. The results for other variables can be interpreted in this manner. Our results show that the change in probability of adoption is comparatively weaker than the change in intensity of adoption for all variables in both ecosystems. Among variables in the irrigated ecosystem, SMC, SEED, FSIZE and LANDP are having relatively greater total elasticities in adoption through the higher intensity of adoption change. In the rainfed ecosystem, SEED, SMC, YLDC, NFAC and LANDP variables have relatively higher total elasticities due to higher contribution from the change in intensity of adoption. This analysis shows that a higher intensity of adoption of MVs can be brought by multiplicity of significant variables but their elasticity degrees are different.

TABLE 5. DECOMPOSITION OF TOTAL ELASTICITY OF MVs ADOPTION

Variable	Change in probability of adoption	Change in intensity of adoption	Total elasticity of adoption
Irrigated Ecosystem			
EDUDM	0.0068	0.0208	0.0276
FSIZE	0.0012	0.0378	0.0390
LANDP	0.0014	0.0418	0.0432
EXTN	0.0072	0.0219	0.0291
CRDIT	0.0014	0.0411	0.0425
MKTD	-0.0008	-0.0253	-0.0261
SEED	0.0019	0.0575	0.0594
TAST	-0.0041	-0.1245	-0.1286
SMC	0.0042	0.1265	0.1306
Rainfed Ecosystem			
SOILQ	0.0018	0.1082	0.1100
LANDP	0.0030	0.1744	0.1774
NFAC	0.0031	0.1869	0.1899
SEED	0.0005	0.2923	0.2928
YLDC	0.0042	0.2565	0.2607
SMC	0.0028	0.1706	0.1734

Note: These results are derived from those in Table 3 and 4.

CONCLUSIONS AND POLICY IMPLICATIONS

The paper analyzed the intensity of adoption pattern of MVs of rice in both rice ecosystems in Odisha and has found that intensity was higher in the irrigated than the rainfed ecosystem. One of the reasons for this mismatch was due to the presence of assured irrigation in the irrigated ecosystem. Sample farmers in the rainfed ecosystem are heavily dependent on monsoon rainfall which is not regular. The specific factors influencing the adoption behavior of MVs in irrigated ecosystem were different from those in the rainfed ecosystem. In the irrigated ecosystem, education, farm size, land position, extension visits, credit accessibility, local market, seed availability, perception about taste of MVs and shorter maturity duration of MVs were significantly influencing the adoption behavior. But, in the rainfed ecosystem, variables like number of nonfarm activities, soil quality, land position, seed availability, perception about shorter maturity of and higher yield of MVs were the significant determinants of adoption intensity of MVs. An ecosystem dummy variable was introduced in the total sample regression model. This variable was found highly significant and positive, indicating the importance of assured irrigation in creating a favorable farm environment for adoption of modern agricultural technologies.

The study suggests a few policies for agricultural development in Odisha. Empirical analysis revealed that the adoption pattern of MVs of rice was not uniform in both the ecosystems. Irrigated ecosystem experienced a better rate of adoption as compared to the rainfed ecosystem. Assured irrigation plays a major role in the adoption of MVs as it creates a conducive environment and then the other factors contribute to adoption. But heavy dependence on monsoon rainfall in rainfed ecosystem makes the farmers vulnerable to aberrant climatic condition. Again, the statistics at aggregate level show that 49% of the cultivable land in the state is still rainfed that can be brought under irrigation. Thus, it pitches for the development of irrigation sector. In fact, it is the key to bring sustainable agricultural development in the state. Along with education, a strong and effective agricultural extension network is the need of the hour to link farmers on the field to the scientific research and development activities. The information about recent development of new stress-tolerant rice varieties like Swarna-Sub1, Samba Mahsuri-Sub1, and IR64-Sub1 for submergence and Sahbaghi dhan for drought areas in India has to be disseminated widely. A farmer's centre for providing all the necessary information can be set up at the village level which will eliminate the information asymmetry and it will help in faster diffusion of improved technology among farmers.

APPENDIX A. TOBIT MODEL ESTIMATES FOR DETERMINANTS OF ADOPTION OF MVs OF RICE IN TOTAL SAMPLE

Variable	Coefficient	Std. error	z-Statistic
Constant	0.566**	0.235	2.405
FMEX	-0.002	0.004	-0.614
EDUDM	0.075*	0.089	1.835
FSIZE	0.014	0.046	0.312
ECDMY	0.027***	0.100	3.684
SOILQ	0.179**	0.073	2.433
LANDP	-0.353***	0.055	-6.434
EXTN	-0.032	0.076	-0.419
NFAC	0.032	0.040	0.792
CRDIT	0.020	0.043	0.002
MKTD	-0.058*	0.033	-1.778
LIVSTK	0.001	0.011	0.097
SEED	0.429***	0.080	5.357
TAST	-0.017	0.089	-0.190
YLDC	0.217**	0.074	2.947
SMC	0.288**	0.094	3.059
FMSUIT	0.223**	0.084	2.652
Log-likelihood	-194.47		
LR Ch^2 (16)	354.32		
Prob. > Chi^2	0.000		
Pseudo R-squared	0.24		

*Note: ***, ** and * refer to the statistical significance at 1%, 5% and 10% levels, respectively*

APPENDIX-B

Decomposition of the total effect on adoption of MVs due to a unit change in explanatory variable

Some information relating to decomposition of the adoption behavior can be deduced from the regression models. Following Tobin (1958), and McDonald and Moffitt (1980), the expected intensity of adoption of a given technology $E(Y)$ is expressed as:

$$E(Y) = X\beta\, F(z) + \sigma f(z) \tag{B1}$$

where $z = (X\beta)/\sigma$ and it is the Z score for the area under normal curve and β is a vector of maximum likelihood coefficients and σ is standard error of regression, $F(z)$ is cumulative normal distribution of z and $f(z)$ is normal density function at z. The z is computed at mean values of all variables. Furthermore, the expected value of Y for observation above the limit, i.e., E(Y*) is $X\beta$ plus the expected value of the truncated normal error term (Amemiya, 1984):

$$\begin{aligned} \mathrm{E}(Y^*) &= E(Y|Y > 0) \\ &= E(Y \,|\, \mu > -X\beta) \\ &= X\beta + \sigma \left[\frac{f(z)}{F(z)}\right] \end{aligned} \tag{B2}$$

Therefore, the basic relationship between the expected value of all observations, $E(Y)$, and the value conditional upon being above the limit, E(Y*) , and the probability of being above the limit, $F(z)$ is expressed as follows:

$$E(Y) = F(z)E(Y^*) \tag{B3}$$

Following McDonald and Moffitt (1980), the equation (B3) can be decomposed into two parts to have the total change in E(Y) due to a change in X_i as:

$$\frac{\partial E(Y)}{\partial X_i} = F(z)\left[\frac{\partial E(Y^*)}{\partial X_i}\right] + E(Y^*)\left[\frac{\partial F(z)}{\partial X_i}\right] \tag{B4}$$

Thus, the total change in Y is decomposed into two parts as (i) the change in Y of those above the limit weighted by probability of being above the limit, and (ii) the change in probability of being above the limit, weighted by the expected value of Y if above the limit. However, the total change in Y due to change in X_i or the marginal effect of an explanatory variable on the expected value of the dependent variable can be expressed as:

$$\frac{\delta E(Y)}{\delta X_i} = F(z)\beta_i \tag{B5}$$

Again, the second partial derivative showing the change in probability of adopting a technology due to change in an independent variable X_i can be expressed as:

$$\frac{\delta F(z)}{\delta X_i} = \frac{f(z)\beta_i}{\sigma} \tag{B6}$$

Similarly, the first partial derivative tells the change in intensity of adoption with respect to a change in an explanatory variable among adopters and it can be expressed as:

$$\frac{\delta E\,(Y^*)}{\delta X_i} = \beta_i\left[1 - \frac{zf(z)}{F(z)} - \frac{f(z)^2}{F(z)^2}\right] \tag{B7}$$

The Tobit coefficients do not directly give the marginal effects of the associated independent variables on the dependent variable. But, their signs show the direction of change in probability of adoption and marginal intensity of adoption as respective explanatory variable changes (Maddala, 1983).

ENDNOTES

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1. A detailed account of the impact of green revolution technology on production can be found in Pingali (2012). He indicated that the developing countries in Southeast Asia and India were the first countries to show the impact of the green revolution varieties on rice yields, with China and other Asian regions experiencing stronger yield growth in the subsequent decades.
2. Modern varieties of rice include seeds of HYV, hybrid and stress tolerant varieties.
3. Rice is grown mainly in two cropping seasons in Odisha – kharif (June-November) and rabi (December-May), which are also known as the winter and summer seasons, respectively, as per the harvesting time.
4. Six years of schooling can be regarded as the minimum level in the basic education cycle in India as it completes the primary level of education.
5. On the basis of landholding, sample farmers have been classified as: marginal (< 1.0 ha), small (1.0-2.0 ha), medium (2.0-5.0 ha) and large farmers (> 5.0 ha).
6. Some study variables like NFAC, HSIZE, SOC and TOPC do not appear in all estimated data Tables because these were removed in the final regressions due to high p-values and theoretically contradictory results.

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