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Intensity of input adoption among smallholder farmers in Tamil Nadu: A fractional logit approach

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Abstract:
Announcement of the doubling farmers' income has invoked great interest among the researchers regarding the feasibility of achievement of this goal with majority of Indian farmers being smallholders. Research on strategies to improve the income of the smallholder farmers is although extensive, however, the nature and extent of the issues faced by these farmers vary across regions and needs to be addressed accordingly. Primary data were generated using a field survey from the farmers operating in small landholdings to evaluate the intensity of input adoption among them using a "fractional logit model". Average area under input adoption was found to be 0.913 acres in the study area. The econometric results suggest that participation in the Farmer Producer Organization increased the intensity of input adoption by 3.79 percent. Qualification and Non-Farm Income were found to increase intensity of input adoption by 0.125 and 1.309 percent respectively. Livestock and Farm size were also statistically significant in affecting the intensity of input adoption among the sampled cultivators. Participation in FPOs reduce the cost of inputs for the farmers and thereby enhances their intensity of input adoption and thus ensuring higher participation of smallholder farmers can be instrumental in enhancing their input adoption.
Keywords: Input Adoption, FPO, Fractional Response Model, QMLE, Smallholder Farmers

Introduction:

Extensive agricultural farming has characterised the nature of agriculture in India during the pre-green revolution era (1965), and intensive farming practices in the period after green revolution. Use of modern inputs has increased significantly after the green revolution. Adoption of improved varieties and advanced technologies by farmers operating in small landholding is critical to improve the productivity and profitability of farmers. "Improved agricultural techniques and inputs, such as improved seeds that produce higher yields or fertilizers, are vital to increasing agricultural productivity, especially among subsistence

farmers" (Fan and Hazel, 1999). Advancement in agricultural technologies and transfer of these technologies to farmers operating in small landholding is critical to enhancing the production and profitability of farmers, and ultimately can contribute to reduction in poverty (Woosen et al., 2017). Use of modern technological inputs can enhance the welfare of households engaged in agricultural activities (Mendola, 2007; Ayenew et al., 2020). Adoption of productivity enhancing inputs like HYV seeds, fertilizer, plant protection techniques, machines etc. has contributed significantly in increasing production levels of the farmers and thereby increasing their market participation through increased marketable surplus (Sharma and Wardhan 2017). However, (Yigezu et al., 2018) has argued that the intensity of adoption of technologies among the farmers can be increased through greater exposure to innovative and modern technologies and their positive impact on productivity gains.

Yet, the rate of adoption of improved and advanced technological inputs in agriculture by farmers has been slow. 86 percent of total farmers in India account for small and marginal farmers but they are operating only about 47 percent of total cropping area (Agricultural census, 2015-16), while small and marginal farmers account for 93% of total farmers operating 62% of total cultivable land (GoTN 2022) which reveals the significant disparities that exist in agriculture sector. Small and marginal land sizes can generate smaller surplus output and their access to agricultural inputs and market is limited. "Farmers operating in small landholdings are often faced with lower production, and limited access to inputs, farm training, credit access and output markets, lower rates of technology adoption and market efficiency, which in turn result in lower profitability" (Kumar et al., 2020).

With this context, the paper with its focus on Tamil Nadu examines the input adoption among the smallholder farmers and the factors affecting intensity of input adoption. The study has used the data generated through a primary survey in the Tiruvannamalai district of Tamil Nadu. While analysing the intensity of input adoption among the smallholders, the study has distinguished the farmers into two categories, one participating in the Farmers Producers Organisation (FPO). It is necessary to understand that being a member of the FPO allows the smallholders easy access to inputs required for agricultural production. The smallholder farmers not participating in the FPO faced with higher input costs and thereby lower input adoption rate. Thus, understanding the implication of FPOs on input adoption among the smallholders is important. Thus, the present study is an important addition to the existing literature as it specifically deals with the issue of input adoption among the smallholder farmers.

Methodology

The rate of input adoption among the surveyed farmers in Tamil Nadu has been calculated using primary data. For these two sets of sampled farmers, one participating in FPO and other not participating in FPO and the differences in the rate of input adoption among these two sets of farmers have been examined.

Survey of the existing literature suggests use of Logit, Probit, Censored Regressions, Truncated Regressions for modelling the determinants of input adoption. However, these binary choice models (Probit and Tobit) are useful when the explanatory variable is binary (Greene, 2003). Again, when the the variable is continuous and is proportional in nature censored or Tobit regressions are used (Papke and Woolridge, 1996). The Fractional Response Models are feasible in addressing several econometric issues faced by these methodologies and in modelling continuous dependent variable within upper and lower limit. (Papke and Woolridge, 1996). The Fractional Response Model gives higher fit of the model as it is superior to other linear estimated models where dependent variable is limited between upper and lower values and can also captures the non-linearity of the data. Furthermore, use of FRM does not require special data transformations (Woolridge, 2012)

To examine the input intensity among the farm households operating in land holdings of small size in the study area, a fractional logit model (FLM) has been employed. The intensity of input adoption has been defined as the area of paddy under fertilizer, herbicide, pesticide and machinery per farmer divided by the total area under paddy, which lies between 0 and 1. From (Papke and Woolridge, 1996), a functional form specifying the expectation of input intensity of the ith farmer conditional on a vector of independent variables (Xi) is formulated as:

$$E(Y|X_i) = Z(\beta X_i) \quad (1)$$

Where, Yi denotes the intensity of input adoption and Xi is a vector of demographic and other attributes affecting intensity of input adoption and β is a vector of unknown parameters to be estimated. Z(.) is a cumulative distribution function which follows a logistic distribution function and represents a nonlinear link function satisfying 0 less than equal to Z(.) less than equal to 1, ensuring that the estimated values lie between 0 and 1 and E is the expectations operator.

Equation 1 is formulated following a “quasi-maximum likelihood estimation” technique where the probability for an observation is specified as the Bernoulli likelihood:

$$Li = [F(\beta X_i)]^{Yi}[1 - F(\beta X_i)]^{1-Yi} \quad (2)$$

The estimated β values of "QMLE" are consistent and it is advantageous to construct a "Fractional Logit Model using logistical conditional mean function and quasi-likelihood method" (Misango et al., 2022).

Data Source and Sampling Techniques

The technique of multi stage sampling is used for collecting the primary data. In the first stage, the state Tamil Nadu has been selected. In the next stage, Tiruvannamalai district has been selected because it is the highest paddy producing district in Tamil Nadu with the share of 10.38% (714279 MT) according to (Ministry of Statistics and Implementation, 2024). In the next stage, 5 taluks from the district based on number of small and marginal operational holdings have been selected with high concentration of smallholder farmers in the taluks. At the final stage respondents are selected from the villages of each taluk.

Selection of samples are based on the government data provided by statistics and agriculture office of the study area. The following formula has been used for calculating the number of farmers to be sampled for the study.

By using the sample size determination equation

$$\text{Sample size} = N/1+Ne^2$$

Where, N=Total Population size

e= margin of error

By employing the formula, it gives a total sample size of 398.75 which can be rounded off to 399. Now the following table gives the distribution of the total sample size across the selected taluks based on their relative share in operational land holdings.

Measurement of the variables:

Table 1 depicts the summary and measurement of the dependent and independent variables used for the purpose of analysis. The dependent variable is intensity of input adoption by paddy cultivating smallholder farmers in the study area. It is obtained by dividing the acres of paddy under inputs by total acres under paddy operated by a farmer. The nature of the variable is fractional variable as it lies between 0 and 1.

FPO membership was used as a proxy for easy accessibility for procuring inputs and marketing output. Participation in the FPOs allows farmers to buy inputs at a lower cost as compared to

private markets and hence enhances their input adoption. Income from non-farm sources plays a key role in aiding financial status of the farmers for purchasing inputs and is used as a dummy variable, that is, farmers having access to non-farm income as 1 and 0 otherwise.

Table 1: Variables Description		
Name of Variables	Description of variables	Measurement (in units)
Explained Variable		
Input Intensity	Acres of Paddy under inputs divided by total acres under Paddy	Proportion
Independent Variables		
FPO membership	Membership in Farmer Producer Organization	Dummy (1=Yes, 0=No)
Age	Farmer's age	Years
Gender	Farmer's gender	Dummy (1=Yes, 0=No)
Qualification	Qualification of the farmer	Categorical
Non-farm income	Income of the farmer from non-farm enterprise	Dummy (1=Yes, 0=No)
Family Size	Number of persons living in the household	Continuous
Livestock	Livestock Ownership	Dummy (1=Yes, 0=No)
Farm Size	Acres under Paddy	Dummy (1=Marginal, 2=Small)

Farm size was used to identify the differences in input adoption within the smallholders, it is generally expected that a farmer with a large farm size will have higher input adoption.

Gender, age, qualification, household size, livestock ownership are also used as control variables in the model. The effect of gender of the farmer on input adoption is mixed, however, in a patriarchal society it is convenient for men to access the markets and gather information regarding inputs. Age variable is considered to measure the farmers' experience in farming. Qualification was used to measure the knowledge level of the farmer and his attitude towards input adoption. Livestock ownership indicates the level wealth status of the family. For measuring available family labour household size was used.

Results and Discussion

Results of descriptive statistics

Table 2 depicts the socio-economic and demographic details of paddy cultivating farmers in Thiruvanamalai district. The mean age of the farmers in the sample was found to be 50 years. In the study area the mean years of schooling was 7.65 years which is equivalent to secondary education. The average size of the farm household is 4.46 persons.

Average area under paddy was found to be 0.913 acres, where 0.605 acres were observed to be cultivated using inputs with an input intensity of 0.66, which is arrived at by dividing mean area of paddy under inputs by mean area under paddy.

Table 2: Socio-economic and demographic details of input adopting paddy farmers

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
Age	50.123	10.535	28	84
Area under Paddy	.913	.367	.2	2
Paddy under Input	.605	.511	0	2
Education	7.657	5.061	0	15
Household Size	4.461	1.295	1	8
Frequencies	**Count**	**Percent**		
Head of the household (Male %)	371	92.98		
Non-Farm Income (% accessing)	127	31.83		
FPO membership (% belonging)	192	48.12		

The percentage of male as household in the sample was found to be 92.98. Only 31.83 percent of the sampled household had access to non-farm income, revealing higher dependence on farm income for their livelihood among the sampled farmers. Furthermore, 48.12 percent of the sampled farmers belonged to FPOs through which they procure inputs at lower costs.

Results of the Econometric Analysis

Table 3 depicts the results of the QMLE (Quasi-Maximum Likelihood Estimates) of the intensity of smallholders input adoption using the fractional logit model (Misango et al., 2022). For checking multicollinearity in the model, we adopted VIF and the mean Variance Inflation

Factor (VIF) score was observed as 1.431. Again, for checking the presence of heteroskedasticity in the model we have employed the Breusch-pagan tests which failed to reject null hypothesis (Chi^2 (1) = 15.15; Prob>chi^2 = 0.0001).

Results revealed that FPO membership, Age, Qualification. Non-farm income, Livestock and Farm size were found to be statistically significant.

Being a member of FPO is having a positive impact on input intensity with 1 percent level and participation in an FPO has enhanced the input intensity by 3.79 percent. This validates that participation in FPOs enhances the accessibility to inputs by smallholder farmers.

The negative impact of farmer's age on input intensity at 1 percent level shows that age increases intensity of input adoption decreases. The negative result found can be explained as older farmers are generally reluctant in adopting new technologies and modern inputs while younger farmers have a positive attitude towards the same.

Farmer's education level is having a positive impact on the intensity of input use. If there is an increase in education by one percent the intensity of input adoption is enhanced by 0.125 percent. Higher years of schooling implies better knowledge and awareness of the farmer and positive attitude toward modern input adoption.

Non-farm income was found to be significant at 1 percent level with positive impact on input intensity. 1 percent increase in non-farm income increases intensity of input adoption by 1.309 percent. Thus, farmers with access to non-farm income tend to have higher input adoption as it supplements the farmer's income from paddy.

Area under paddy was found to be statistically significant and having positive impact on input use intensity of the farmers. If there is an increase in area under paddy by one percent input intensity increases by 0.962 percent. Application of modern inputs is more feasible in terms of cost in larger farm size and thus farmers operating in small land are reluctant to adopt modern inputs.

Livestock holding was found to be significantly affecting input intensity at 5 percent. This finding is expected as ownership of livestock implies access to income sources other than crops which then can be used for purchasing inputs. When there is an increase in livestock by one percent increases the intensity of input use by 0.62 percent in the study area.

Results of Quasi Maximum Likelihood Estimates (QMLE)							
Intensity of input adoption	Coef.	Std..Err.	t-value	p-value	95% Conf	Interval	Sig
FPO	3.794	.409	9.28	0.00	2.993	4.595	***

Age	-.064	.02	-3.17	.002	-.103	-.024	***
Gender	-.266	.647	-0.41	.681	-1.533	1.001	
Qualification	.125	.037	3.37	.001	.053	.198	***
Non-farm Income	1.309	.336	3.89	.000	.65	1.968	***
Household Size	-.096	.108	-0.88	.378	-.308	.117	
Livestock	.618	.299	2.07	.039	.032	1.204	**
Farm Size	.962	.295	3.27	.001	.385	1.54	***
Constant	.542	1.332	0.41	.684	-2.069	3.153	
Mean (DV)	0.633		SD (DV)		0.467		
No. of observation	399		Chi-square		142.704		
Prob > Chi-square	0.000		Akaike crit. (AIC)		295.626		
Breusch-Pagan / Cook-Weisberg test for heteroskedasticity							
chi2(1)	15.15		Prob > chi2		0.0001		
Variance inflation factor							
Mean VIF	1.431		.				
*** p<.01, ** p<.05, * p<.1							

Conclusion:

This study was conducted to analyse the factors like age, education, area under paddy, family size, paddy under input etc. affecting the input intensity adoption by farmers cultivating paddy in less than 2 acres in Tiruvannamalai district of Tamil Nadu. Survey data from 399 input adopters were analysed using a fractional logit QMLE. The findings of the paper revealed that the FPO membership, Age, Non-farm income, Livestock ownership, educational qualification, farm size to be significantly affecting the input intensity adoption among the paddy farmers operating in small landholding in the study area. We conclude that the participation in FPOs can significantly enhance the input adoption among the farmers as FPOs enables the farmers to access the inputs at lower costs as compared to private market and also contributes to increased knowledge of the farmers regarding efficient input use. Given these findings, strategies to uplift the condition of the smallholder paddy producing farmers should involve creation and dissemination of information on positive influence of input adoption and technology adoption to improve the production and productivity of the farmers. Extensive farm training and demonstration methods can enhance the knowledge stock of the farmer regarding the use of inputs.

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