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Quantifying the Role of Disembodied Technologies in Enhancing Farm Income: A Case of Dibbling Method of Redgram Cultivation in Kalaburgi District of Northern Karnataka

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ABSTRACT

Dibbling method of redgram cultivation is a technique of sowing seeds of semi-determinant variety with wider spacing, followed by nipping after 40 to 50 days. This technique is gaining popularity in parts of northern Karnataka due to its yield advantage over conventional method of cultivation. The present study has analysed the correlates of its adoption and quantified the effect of this technology on yield and farm income, using econometric approaches; Heckman two-step endogeneity correction model and Difference in Difference regressions. The result indicated that the dibbling method was mostly adopted by small and marginal farmers. Extension efforts of Krishi Vigyan Kendra was identified as an important correlate of adoption. The average yield advantage of dibbling was estimated to be 2.66 quintals per acre after accounting for endogeneity and trend effect. The partial budgeting framework was used to translate the yield advantage into monetary gains. Farmers who has dibbled redgram derived an additional net income of Rs.10, 170 per acre.

Keywords: Dibbling, Redgram, Impact, Heckman endogeneity correction model, Difference in difference, Partial budgeting.

JEL: O13, O33, Q10, Q12.

I

INTRODUCTION

For most of the developing countries, the performance of agriculture sector is crucial in ensuring a sound economic growth, however, such countries are constrained with lower agricultural productivity (Doss, 2006). Technological progress is a key factor for increasing productivity, catalysing agricultural growth as well as economic development (Barro and Sala-i-Martin, 1996). The role of improved agricultural technologies in enhancing India's food producing capacity is widely acknowledged (Chand and Raju, 2009; Fan *et al.*, 2008)). Rapid strides made by the country in food production was enabled by adoption of technology mix comprising high yielding variety (HYV) seeds, fertilisers and irrigation (Kumar and Mittal, 2006).

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The facile way of achieving the technological progress is by acquiring the technologies existing elsewhere in the world. Alternatively, nations can also attempt to enhance their own technological innovation capabilities (Shih and Chang, 2009). In India the task of technology development and transfer for the agriculture sector is mainly taken up by the Indian Council of Agricultural Research (ICAR), through its well spread network of research institutions (Pal *et al.*, 2012). Government investments in agricultural research and development have given the impetus required for the agriculture sector to stand on its own by the continuous process of technology development and dissemination (Pal *et al.*, 2005). Farmer innovations are also important source of location-specific technologies that can boost the income of farmers.

The agricultural technologies, in general, can be broadly classified as embodied and disembodied technologies. Embodied technologies are those, in which the technology is embodied in the form of a physical input. Whereas, in case of disembodied technologies, the technology will be in the form of knowledge, such as a new method of cultivation. Most of the embodied technologies are 'guarded' by patents and use of which is promoted by the owners of the innovation. But, in disembodied technologies, also known as low cost or no cost technologies, there is no physical product to promote, and there is little incentive for the private players to promote such kind of technologies (Sunding and Zilberman, 2001). Hence, publicly funded institutes should play a more active role in generation and upscaling of disembodied technologies. Measuring the impact of disembodied innovations, as well as adoption behaviour of farmers with respect to these technologies also becomes important in this context.

The role of technologies in enhancing farmer income is unequivocal: quantifying it is important, though challenging.With the Government of India announcing its ambitious target of doubling farmers' income by 2022, research focusing on measuring the effect of the specific technologies on farmers' income and livelihood becomes even more important.Analysing the adoption of technologies and measuring the impact also provide insights to refine technologies and in devising strategies for upscaling.

Keeping this in view, the present paper aims to measure the effect of "dibbling method of redgram cultivation" on farmers' income. The technology is farmer innovation, validated and improved by the KVK's and Universities working in North Karnataka (mainly KVK Bidar, KVK Gulbarga and University of Agricultural Sciences, Raichur). The technology involves, dibbling of seeds of redgram with a wider spacing between rows (usually 6 to 7 feet), using semi-determinant variety like BSMR 736, nipping at 40 to 50 DAS (days after sowing). Wider spacing coupled with nipping helps in better root growth and more branching.This results in increased number of pods/plants and consequentially yields of crop (Naik and Patil, 2015). This paper attempts to measure the yield advantage of this technology, its role in enhancing farm income and the correlates of adoption.

II

DATA AND METHODOLOGY

2.1. *Data*

Primary data for the study was collected from three tehsils of Kalburgi district of Karnataka, namely, Chincholli, Chitapur and Gulbarga. From the selected tehsils, four villages were randomly chosen and from each village, 18 redgram farmers were interviewed. Details on the socio-economic conditions and redgram cultivation, technology adoption were collected using a pre-tested schedule. Historical yield details for last three years were also collected from the farmers for parametric estimation of parallel trend assumption required for Difference in Difference (DID) method for assessing the impact. Similar strategy was adopted by Khan *et al*., 2016 in their study of impact of zero tillage in Haryana. However, the farmers, who did not remember the historic yield of crop, were dropped from DID analysis.

2.2. *Methodology*

Correlates of Adoption of Dibbling: Linear Probability Model

Correlates of adoption was analysed using linear probability model (LPM), with the adoption of dibbling is captured in the form of a dummy variable. As we are more interested in measuring the marginal effects of independent variables on probability of adoption, linear model is better suited compared to logit and probit models which produces estimates in the form index (Angrist and Pischke, 2009;Friedman 2012; Pischke 2012). A major criticism against the use of LPM is heteroskedasticity. Heteroskedasticity consistent robust standard errors are used as suggested by (Angrist and Pischke, 2009) to overcome this. Another limitation of the LPM model is, the model may not produce consistent estimates when the predicted probabilities are greater than one. However, if the predicted probabilities lies between 0.2 to 0.8, the model produces consistent results (Hausman, *et al*., 1998; Horrace and Oaxaca, 2006). In our case, predicted probabilities ranged from 0.3 to 0.81. Considering the purpose of the analysis and uncertainty regarding the cumulative distribution function of the error term, it is advantageous to persist with the linear model (Pischke, 2012; von Hippel and Workman, 2016, Ochalibe *et al*., 2015).

The general form the model used is

$$T_i = \propto + \beta_1 X_{1i} + \beta_2 X_{2i} \dots\dots\dots\dots\dots + \beta_j X_{ji} + \partial_i$$

where T_i is the dummy for treatment (=1 if the farmer has adopted dibbling method of cultivation, 0 otherwise)

Xj= Vector of independent variables used in the model (list of variables and their mean values given in results)

∂_i is the error term.

Heckman Two-Step Endogeneity Correction Model

Regression model with yield as dependent variable and a dummy variable for treatment (dibbling) along with other relevant explanatory variable is used to assess the impact of dibbling on yield of redgram. However, the estimates could be biased due to 'selection bias'; farmer with certain characters tends to self-select themselves into either treatment or control groups. Usually adopters of technologies are systematically different from non-adopters thus; estimation of impact would be biased. Heckman two step endogeneity correction model offers simple and intuitive solution to this problem. In the first step, a selection equation is estimated to capture the probability that a farmer will adopt the technology, dependent on a set of observed explanatory variables. Explicitly, the selection equation can be specified as:

$$T = z_j\gamma + \mu_{2j}$$

where, T=adoption of technology (Dibbling) and z_j represents the covariates used in the model (same as that of an LPM model). The model is estimated using a probit regression function to get an estimate for the bias term, by estimating the expected value of a truncated normal random variable, commonly known in literature as Inverse Mills ratio (IMS) or Hazard function. Using IMS as an explanatory variable in regression helps to minimise the confounding errors in the estimate.

Specifically, the outcome equation can be written as

$$Y_i = \propto + \gamma_1 T_i + \gamma_2 X_{1i} \ldots \ldots \ldots \ldots \ldots + \gamma_j X_{ji} + IMS + \partial_{1i}$$
$$\partial_1 \sim \mathrm{N}(0, \sigma)$$
$$\partial_2 \sim \mathrm{N}(0, \sigma)$$
$$\mathrm{corr}\,(\partial_1 , \partial_2) = \rho$$

where Y_i is the log yield, IMS is the Inverse Mills Ratio, derived from the selection equation and γ_1 is the estimate of interest, i.e., per cent increase in yield due to adoption of technology, i.e., dibbling.

Difference in Difference Regression for Measuring Impact

An alternative way of assessing impact is to use Difference-In-Difference (DID) regressions. DID controls for observed and unobserved time-invariant farmer specific variations that may influence the effect of dibbling on yield of redgram. The yield of treatment group before intervention can capture the impact of farmer-specific characteristics and change in yield on yield of control group in post-treatment period indicates the effect of time (Khan *et al.*, 2016). DID is a simple method which allows for minimising the bias due to endogeneity.

Formally, the DID model can be specified as a two-way fixed-effect linear regression model.

$$Y_{it} = \sum \beta D_t + \gamma W_{it} + \mu_i + \epsilon_{it}$$

The dependent variable in the model is Y_{it}, which represents the redgram yield of i-th farmer in t-th year. D_t represents variable to capture the time effect. It will take the value of 1 for post adoption period and value of zero for pre-adoption period. Treatment dummy, Fi, will take the value of 1 if the farmer has used dibbling method, or else, zero. But, Fi is not included in the model explicitly, as we are using fixed effect model. However, the variable of interest is W_{it}, which is the interaction of treatment dummy (Fi) and the time dummy (Wt). γ is the DID estimate for the impact of dibbling of redgram. μ_i will capture the farmer fix effects.

Testing for Parallel Trend

Validity of DID estimates lies on the assumption of parallel trend. One way to test this assumption is to check for the trends in treatment and control units before the adoption took place. Parallel trend assumption must be satisfied to get a reliable DID estimator (Angrist and Pischke, 2009). However, testing for parallel trend, requires yield data for past years. In similar studies, and Erenstein *et al*., 2007 have used recall data of yields. Similarly, in the present study, recall data of redgram yields for four years is used to test the parallel trend assumption. We use both graphical and parametric methods to check for parallel trend in the data.

In the parametric test for parallel trend, following Khan *et al*. 2016, we use a modified version of regression used for DID. Post-treatment time dummy is being replaced by a continuous variable indicating time. In this regression, if the estimate for interaction term is not significant, the parallel trend assumption is satisfied. The results of the test are discussed in the following section in detail.

III

RESULTS AND DISCUSSION

3.1. *Correlates of Adoption of Dibbling Method of Redgram Cultivation*

The summary statistics of key variables in the sample is given in Table 1. The average age of the respondents was about 45.76 years. The average area under redgram cultivation was found to be around 14 acres per farmer. As high as 42 per cent of farmers were found to be below the poverty line. Amongst the sample farmers, 37 per cent adopted the dibbling method of redgram cultivation. Linear probability model (LPM) was employed to analyse the correlates of adoption and the results are given in Table 2.

TABLE 1. SUMMARY OF KEY VARIABLES

Variable (1)	Mean value (2)	Unit (3)
Age	45.76	(years)
Farming experience	17.19	(years)
Area under redgram	14.10	(acres)
Literacy	0.77	Dummy (=1 if literate, 0 otherwise)
Land holding size	16.99	(acres)
Holding Kisan Credit card	0.59	Dummy (=1 if has KCC, 0 otherwise)
Below poverty line	0.42	Dummy (=1 if BPL, 0 otherwise)
KVK extension contact	0.41	Dummy (=1 if has extension contact with KVK, 0 otherwise)
Adopted dibbling method	0.36	Dummy (=1 if adopted dibbling method, 0 otherwise)
Irrigation	0.37	Dummy (=1 if has irrigation facility, 0 otherwise)

TABLE 2. CORRELATES OF ADOPTION OF DIBBLING METHOD OF REDGRAM CULTIVATION: RESULT OF LINEAR PROBABILITY MODEL

Dependent variable: Dummy for dibbling (1)	Coefficient (2)	Probability value (3)
Farming experience	0.009	0.002
Area under redgram	-0.002	0.031
Irrigation	0.164	0.018
Literacy	-0.094	0.189
KVK extension contact	0.741	0.000
Below poverty line	0.052	0.272
Constant	0.001	0.995

n=196, Heteroskedasticity consistent robust standard errors were used.

Extension contact with Krishi Vigyan Kendras (KVKs) and irrigation are found to be the two important positive correlates of adoption. Dibbling of redgram is a farmer innovation which is being further improved and supported by Krishi Vigyan Kendra of Bidar and Gulbarga. Both the KVKs have played a pivotal role in popularising the technology. Understandably, farmers who are in regular contact with KVK has adopted the technology more than other farmers.Further, in dibbling method of cultivation, semi-determinant varieties are used, which requires at least one protective irrigation for proper expression. Hence, mostlyfarmers who has irrigation (minimum of one irrigation in a season) has adopted the technology.

Interestingly, the coefficient to land variable is negative which supports the antitheses that agricultural technologies are scale neutral. Dibbling method of redgram cultivation is labour intensive. The studies of Fischer, 2016; Hull, 2014; White, 2012 have also reported similar findings that the agricultural technologies are non-scale neutral albeit in opposite direction. They reported that many technologies are labour intensive and only favour large holders as supply of cheap labour is not available. In case of dibbling, however, the small farmers are adopting technology more than the large farmers. The major hinderance for adoption of the method by large farmers is labour shortage during peak season which is also supported by anecdotal evidence.

3.2 *Effect of Dibbling of Redgram on Yield; Econometric Estimation*

Heckman Two-Step Endogeneity Correction Model

Measuring the impact of agricultural technology is very challenging; adoption process is seldom by random. Adopters of technology are usually first adopted by farmers who are motivated and well connected. So, the observed difference in yield between the adopters and non-adopters can be partly due to the fact that theadopters are better farmers. This two-way causation (yield of farmers who has adopted the technology (dibbling in our case) is higher due to technology or farmers who has higher yields have adopted the technology!) is also termed as endogeneity in economic literature. On an average, the farmers who has dibbled redgram got 3.3 quintals more yield than the other farmers who have grown redgram in the conventional method (see Appendix Table).

However, the observed difference in yield of redgram between the dibbling and conventional method cannot be attributed to the technology due to possible endogeneity. Hence, we have used the two-step endogeneity correction model to estimate the impact (or effect) and the results are given in Table 3. Yield was used as dependent variable after taking log. Along with dummy variable for dibbling (coefficient for which is the measure of impact), other variables are used as control. The estimated coefficient was found to be 0.46 indicating that dibbled redgram yield is 46 per cent more than the conventional method. This amounts to 2.99 quintals per acre. As per our expectation, simple average was over estimating the impact. However, even this method is not foolproof. The year 2016 was a normal year with respect to rainfall; redgram being predominantly grown as rainfed crop, the yield as well as the impact can be different in a year where the rainfall is scanty. So the estimated impact fails to account for element of time.

TABLE 3. IMPACT OF DIBBLING OF REDGRAM ON YIELD; RESULTS OF HECKMAN ENDOGENEITY CORRECTION MODEL

Dependent variable: Log Yield (1)	Coefficient (2)	Probability value (3)
Dummy for dibbling	0.46	0.014
Farming experience	0.01	0.000
Literacy	0.04	0.468
KVK extension contact	-0.04	0.710
Seed cost	0.00	0.761
Fertiliser cost	0.00	0.000
Irrigation	0.17	0.000
Constant	1.10	0.000
invmills1	0.05	0.192

n=196.

Difference in Difference (DID) Regression for Estimating Impact

Following the approach suggested by Khan *et al*. 2016, we have collected historic yield data of farmers for last four years. The farmers who didnot remember the yield were excluded from this analysis. Difference in Difference regression was used to measure the impact of dibbling. For DID method to provide efficient estimate of the effect size, assumption of parallel trend must be satisfied. This assumption requires that the redgram yield of those farmers who has dibbled redgram and those used conventional method to move in parallel before adoption of dibbling. One way to check this is to plot the yields of adopters and non- adopters before the adoption of technology and look for trends across two groups. The graph used for testing parallel trend is given in Figure 1 and this indicates that the yield of farmers in treatment and control groups moved in parallel before the adoption. The same assumption can also be tested using a placebo (Falsification test) regression. The regression uses same functional form as that of DID regression, however, the post adoption dummy is replaced by a continuous time variable. Here the interaction term thus indicate whether the yield across farmers who have dibbled the redgram and grow conventionally are moving in parallel or not. If the parallel trend assumption is satisfied, the placebo interaction dummy is expected to be statistically non-significant. As we can see from the Table 4, the coefficient is indeed non-significant indicating that parallel trend assumption is satisfied.

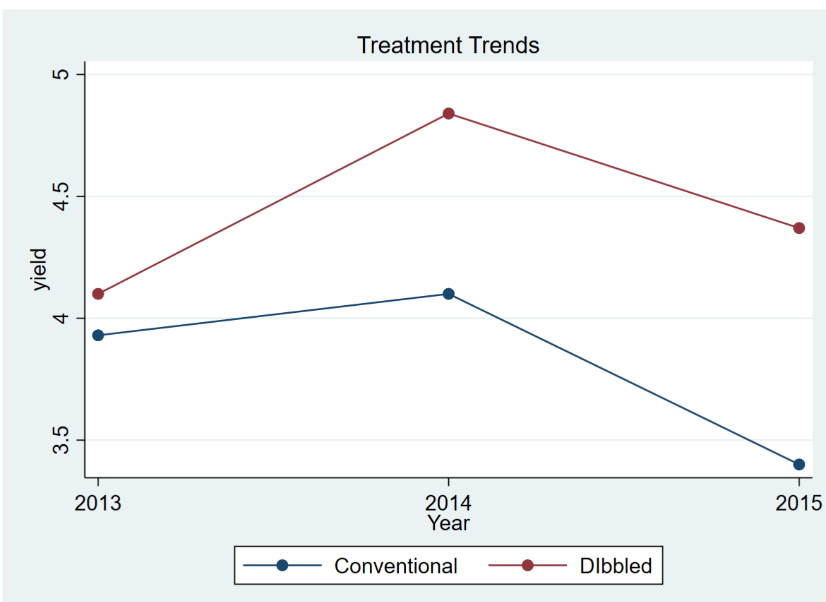

Figure 1. Testing for Parallel Trend in Yield before the Adoption-Graphical Method.

TABLE 4. PARAMETRIC TEST FOR PARALLEL TREND

Dependent variable: Yield (1)	Coefficient (2)	Probability value (3)
Placebo-interaction effect	-0.11	0.18
Dummy for treatment	0.63	0.00
Dummy for years	-0.07	0.47
Constant	3.96	0.00
R^2	0.09	

n=260.

The effect of Dibbling on redgram is estimated using function specified in methodology section. Farmer fixed effect panel data regression was used to estimate the function. The interaction effect (post-treatment dummy) provides the estimate of impact. As we can see from the Table 5, the impact of dibbling of redgram was estimated to be 2.34 quintals per acre. This is smaller than the size of effect estimated by Heckman model as it accounts for year on year variation in yield, which, to a large extent depends on the weather (mainly annual rainfall).

TABLE 5. IMPACT OF DIBBLING OF REDGRAM ON YIELD; RESULTS OF DIFFERENCE IN DIFFERENCE REGRESSION

Dependent variable: Yield (1)	Coefficient (2)	Probability value (3)
Interaction effect	2.34	0.00
Dummy for years	-0.76	0.04
Constant	4.02	0.00
R^2	0.52	

N=312, Panel regression fixed effect model.

3.3 *Effect of Dibbling on Net Farm Income from Redgram; Partial Budgeting Framework*

Table 6 depicts size of impact as measured by the different methods starting with simple difference in yield (3.34 qtls/acre). Econometric methods estimated effect sizes are Heckman endogeneity correction model (2.99 qtls/acre) and DID regression (2.34 qtls/acre). Both the econometric approaches have their own advantages and disadvantages and hence, we use the average of two estimators as size of impact in the future analysis, which is 2.66qtls/acre. The yield advantage and consequential

TABLE 6. EFFECT OF DIBBLING ON REDGRAM YIELD

Method used to measure impact (1)	Yield gain (qtls/acre) (2)
Average difference	3.34
Econometric methods	
Heckman endogeneity correction method	2.99
Difference in Difference estimate	2.33
Average impact	2.66

incremental income in the dibbling method of redgram cultivation is mainly due to the wider spacing provided. BSMR 376 being a semi determinant variety produces more branches due to the nipping operation done in 40 days after sowing. Experiments have shown that wider spacing of the crop helps in better root development contributing to yield advantage. Dibbling method, when viewed as a technology (dibbling seeds at wider spacing, using BSMR 736 variety, nipping and one-or two irrigation) is certainly beneficial to the farmers.

Once the 'effect size' is estimated in terms of yield advantage, it makes sense to convert that into monetary terms. Partial budgeting framework offers simple, comprehensible way to show the effect of dibbling of redgram on farmers' net income. Debit side accounts for factors which increase the net income due to the adoption of dibbling, whereas, credit side lists out factors negatively contributing to net income. The result of the analysis is given in Table 7. Added cost of labour for dibbling the seed and cost providing an additional irrigation were found to be the major element of credit side. On the debit side, yield advantage is the main component. There is also saving of seed, though the expenditure is less. On an average, the farmers who have dibbled the redgram alternative to conventional method of sowing, obtained approximately, Rs.10170 more income per acre.

TABLE 7. INCREMENTAL INCOME DUE TO DIBBLING OF REDGRAM; PARTIAL BUDGETING FRAMEWORK

Added cost (in Rs./acre) (1)	(2)	Reduced returns (Rs./acre) (3)	(4)
	DEBIT		
Labour for sowing (8 labour)	2400	Nil	
Labour for nipping (2 labour)	600		
Irrigation cost	900		
	3900		
		Total	3900
	CREDIT		
Reduced cost		Added returns	
Seed cost (Save 4 kg seeds)	240	Increase yield (2.66 qtls/acre)	13832
		Total	14072
		Incremental income	10172

IV

CONCLUSION AND POLICY IMPLICATION

Dibbling method of redgram cultivation is widely adopted in Northern Karnataka. The paper has attempted to identify the correlates of adoption of this technique, and to quantify its impact using econometric methods. The dibbling method of redgram was found to be scale non-neutral; large farmers find it difficult to adopt due to high labour requirement during peak season. Among all the factors, the analysis pointed out the efforts of KVK as an important correlate of adoption. This strengthens the claim that for upscaling of disembodied technologies, the role of public research and extension is very important. The effect of dibbling redgram on yield was estimated to be 2.66 quintals per acre, which translates into approximately Rs10,170 per acre. Kalaburagi being an economically backward region, this additional income is a substantial gain for the farmers. Overall, this technology has the potential, and can play an important role in achieving the target of doubling farmers' income by 2022 in the region, provided it is carefully promoted by the public extension system.

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APPENDIX

COMPARATIVE ECONOMICS OF DIBBLED REDGRAM VIS-À-VIS CONVENTIONALLY GROWN REDGRAM

Cost (1)	Dibbled redgram (2)	Conventional redgram (3)
Variable cost		
Seed	80	250
Fertiliser	771	608
Agrochemicals	1312	947
Irrigation	871	158
Machine labour	771	1451
Labour cost	6774	4941
Interest on VC	846	668
Fixed cost		
Depreciation	5139	2234
Land revenue	20	20
Imputed value of land rent	3500	3500
Interest on FC	693	460
Total cost	20777	15239
Returns		
Yield (qtls/acre)	8.6	5.3
Gross returns	44290	27058
Net returns	23513	11819
Returns per rupee of cost	2.13	1.78