Technical Efficiency of Paddy Cultivation and Its Non-Input Determinants: A Case Study in Char Areas of Barpeta District of Assam

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Abstract

This paper has measured technical efficiency of paddy cultivators in Char areas of Barpeta district of Assam on the basis of primary data of 143 sample cultivators selected from both char and non-char areas for the winter cropping season of 2018-19. Char areas are small riverine islands or sandy bars located in the vicinity of the river basin. A Cobb-Douglas stochastic production frontier with inefficiency effects is estimated and selected non-input factors are modelled to explain variations in technical inefficiency across cultivators. The non-input variables such as experience and education are found to have positive effects on technical efficiency. However percentage of self-consumption and engagement in alternative occupations have negative influences on the same. Mean technical efficiency estimated in non-char area is 81present while that in char areas is clearly lower at 73 percent. The study observes that frequent water-logging during monsoons along with recurrent floods, lead to both soil erosion and sand deposition on cultivable land making it difficult for char farmers to cultivate paddy throughout the summer and monsoon months. Hence such adversities are compelling them to cultivate one paddy crop along with winter vegetables in pursuit of their principal livelihood.

***Key words**: Char regions, Paddy cultivation, Technical Efficiency, non-input factors, inefficiency effects.*

1. Introduction

Assam is a riverine agrarian state of north-east India. The mighty Brahmaputra, the Barak and their numerous tributaries are scattered all over the state. There are three distinct agro-geological zones in Assam, viz., Brahmaputra Valley, Barak Valley and Hills regions (Singh and Sharma, 2007). One of the peculiar features of the river and its tributaries in Assam is presence of char or river islands with dense population observed during recent years (Goyari, 2015). 'Char' refers to sandy mid channel bars and sandy bank of the river. In other words the extremely braided channels of rivers along with its unique gradient, suspended particles and bed loaded combined together during flood give rise to an almond shaped alluvial formation, namely a char (Bhagabati, 2001). Char areas of Assam are purely agrarian and are regularly affected by floods and soil erosion every year (Chakraborty, 2014).The regions are invariably flood affected, and are socio-economically backward compared to higher plains within the region. Paddy cultivation is the principal livelihood of majority of the population in these flood plain regions. Alongside many other districts in the flood plains of the Brahmaputra, a common and recurrent economic problem in Barpeta district is the occurrence of frequent floods during the monsoons months. Soil erosion due to the passing flood-waters result in crop damages, loss of livestock, loss of property and family belongings, disruption of communication, sand casting or sandification of soil among others. The district consists of 47330 hectares of flood affected area, out of which 12400 hectares are cultivable. On an average 1,17,000 people covering 409 villages are affected by floods every year (Talukdar and Kalita, 2017). Paddy is the principal crop in the char areas of Barpeta district. Winter paddy is cultivated in both char and non-char (basically main-land adjoining the river-banks) areas. However it is problematic to cultivate summer paddy in the char areas as because a significant portion of land under the char gets inundated due to frequent flooding. Soil erosion and sand deposition during the monsoon months of July, August and September reduce soil fertility and make paddy cultivation economically unviable.

Barpeta district of Assam had second highest numbers of char village after Dhubri district (undivided Dhubri district), 30 percent of total geographical areas are lies in char areas of the river Brahmaputra and its tributaries (socio-economic survey report 2002-03). Rupshi and Mandia community development blocks of Barpeta district are agrarian in nature, major portion of farmers are engaged in cultivation of paddy and 47.74 percent of cultivable area are using for paddy cultivation (Chakraborty 2010). Flood and river erosion of mighty Brahmaputra and its tributaries creates crucial problems to the people who are living in char areas of Barpeta district of Assam (Khan, 2012).It is also found that char areas of Assam are not suitable for paddy cultivation, instead of it this region is suitable for cultivation of jute, sugarcane, mustered, wheat and verities of vegetables (Bokth 2014).

The present study focuses on a comparative analysis of technical efficiency of winter paddy cultivators across char and non-char areas of Bekiriver in Rupshi development block of Barpeta district of Assam. For this purpose Guleza village is selected from char area and Tapeswara village is selected from non-char area. The village selections are purposive in nature. Particularly the char village covers a significant proportion of cultivators who face frequent crop losses due to flooding and inundation, and the non-char village is chosen purposively on the basis of domination of paddy cultivators on one hand and sufficient distance from the char areas on the other. The study focuses purely on winter paddy as a'priori information suggests a severe drop in the number of char cultivators during summer and monsoon months. The study is significant especially in view of the fact that no studies are reported in literature on agricultural practices in char areas of Assam. Moreover the char and non-char yield and productivity comparison in paddy cultivation is entirely new in literature. The char areas are usually at a disadvantage when it comes to paddy cultivation primarily on account of two factors – flooding and inundation during monsoon months (when the non-char region enjoys favourable farming conditions) and sandification or sand deposition in the soil at the end of the monsoon. In other words a'priori information suggests that char cultivators are at a disadvantage vis-à-vis non-char cultivators when it comes to paddy cultivation. As no studies are reported in literature that compares char and non-char agricultural performances, it may be taken as a severe gap in literature. Moreover this comparison provides a scope of a policy intervention in favour of the disadvantaged group – the char cultivators in this case. Numerous studies have been conducted on the measurement of technical, allocative and scale efficiencies in Indian agriculture as well as in other South Asian nations. A detailed overview of major contributions of the stochastic frontier is beyond the scope of this paper. However a few significant and influential works done over the years need to be mentioned. Among early contributors, Kalirajan (1981) measured the specification of conventional production functions to a stochastic production frontier in order to explain productivity differences among firms. Assuming a Cobb-Douglas production relationship, the model was estimated by the maximum likelihood method. The causes for the farmer specific variability were identified. The study found that cultivators' understanding of the technology and access to extension advice were the most important factors influencing yield variability.

Based on panel data on paddy output, number of pre-harvest days of labour use, amount of fertilizer, area operated for the period 1981-83 in Tamil Nadu, Kalirajan and Shand (1989) estimated a translog production function by ML method and found that the production frontier is time-invariant. They also used time-specific dummies. Application of generalized shadow profit function by Kumbhakar and Bhattacharyya (1992) to farm-level data (1985-86) of 287 farms of West Bengal, India, on fertilizer, human labour, land and capital, and output of paddy rejects the profit maximization hypothesis. This may be an evidence of distortions. This study also pays emphasis on education in not only adopting modern technology and chemical fertilizers but also in more efficient allocation of existing and conventional inputs like human and bullock labour. Taddesese and Krishnamurty (1997) examined the level of technical efficiency across ecological zones and farm size groups in paddy farms in Tamil Nadu. The study showed that 90 percent of the variation in output among paddy (IR-20) farms ' in the state is due to differences in technical efficiency. Land, animal power and fertilisers had significant influence on the level of paddy production. Further, tests revealed that, at mean level, the level of technical efficiency among paddy farms of the state differs significantly across agro-ecological zones and size groups. Other significant contributions of the method in Indian agriculture may include Huang and Bagi (1984) who analysed Punjab and Haryana farm data of 1969-70. Parikh and Shah (1995) along with Ali and Flinn (1989) have significant contributions in farm level efficiency measurement in case of wheat production in Pakistan. Wadud and White (2002) estimated an inefficiency effects stochastic frontier model analysis on Bangladesh paddy farming on similar lines as done in this paper.

2. About the study region

The district head quarter of Barpeta is Barpeta town, located at 26^0 19’ 0” N, 91^0 0’ 0” E. The district occupies 3245 square kilometre with a population size of 1642430 as per the 2011 census. The district is also popularly known as Satra Nagari due to existence of many Satras within the district. Barpeta district is a socio-economically backward district consisting of two subdivisions –Barpeta and Bajali. There are eleven community development blocks, and 129 gaon Panchayats in the district. Out of 851 villages in the district 834 are inhabited. The topography of Barpeta district is wide varied from low lying plains to the elevated land having small hillocks in the South West corner of the region known as the “Baghbar Zone”.

The northern part of the district comprises of the foot hills of Bhutan and the southern part is comparatively low lying through which flows the mighty Brahmaputra, the longest river of the state flowing across the district from east to west through numerous char (sandy river plains) areas. That is why the soil of Barpeta is mostly sandy, sandy loamy and forest soil. The plain is of alluvial origin and along with sand, varied proportions of clay soil is also available. The other important tributaries of the river Brahmaputra in Barpeta are Manas, Saolkhowa, Kaldia, Pohumara, Nakhanda, palla and Beki. Some other small tributaries of the river Brahmaputra in the district are – Hakua, Busha, Dong, Dhir, Chikni, Saru-Beki, Bhelengi, Kumbhira, Gyatim-Chorphuli, Rabang, Rupshi etc. Two rivers - Saolkhowa and Mora Nodi (Dead River), both of which are tributaries to Brahmaputra run through the town.

Barpeta district has the second highest number of char villages after undivided Dhubri district, 30 percent of its total geographical area are lies in char areas of mighty Brahmaputra and its tributaries. The char areas are distributed across five community development blocks. Ruposhi block had second highest number of char village after Mandia block. Char area of Ruposhi block lies in the Beki river flood plain. The river Beki in Assam, also known as Kurissu in Bhutan, lies in between 26^0 20’00’’ N; $90^0$56’00’’E and is one of the right bank tributaries of the mighty Brahmaputra. The river originates in Bhutan, but a large portion flows through Assam. From Bhutan it flows to Moinbori in Barpeta district of Assam touching Mathanguri, Narayanpur, Khusrabari, Odalguri, Barpeta Road, Nichukha, Sorbhog, Bardanga, Kamarpara, Guilaza, Srirampur, Muamari, Kalgachia, Balaipathar, Kharballi, Daoukmari, Jania, Chanpur, Rubi, Sawpur, Gobindapur, Balikuri and Moinbori with vast area of char having high density of population.

3. Methodology and Data

This study applies the technical inefficiency effects model Kumbhakar et al (1991), to estimate the stochastic frontier and the inefficiency effect model parameters simultaneously, with the given assumption on inefficiency variables. The process of simultaneous estimation of stochastic frontier model of technical inefficiency applying maximum likelihood techniques also developed by Reifschneider and Stevenson (1991), Huang and Liu (1994) and Battese and Coelli (1995). This technique has been technically applied by Battese and Broca (1997). Some studies have used a twofold technique to determine factors effecting farm level technical inefficiency. Firstly, assuming technical inefficiency effects are identically distributed, the stochastic frontier model is estimated by using maximum likelihood model to calculate farm specific technical inefficiency. Here technical inefficiencies are not considered as a function of firm specific and exogenous variables. After estimating farm level technical inefficiencies it is regressed on a set of firm specific exogenous variables or non-input variables, which are beyond the firm's direct control but it may significantly explain inter-farm variation in technical inefficiencies. Here logit or probit is used, but this model is contradictory to the assumption that technical inefficiencies are identically distributed in stochastic frontier model since predicted inefficiencies are assumed to be a function of farm specific and exogenous variables. It reflects that the technical inefficiencies effects are not distributed identically without the coefficients of farm specific factors are simultaneously equal to zero (Kumbhakar and Lovell, 2003), Kumbhakar et al (1991), addressed the problems of two fold model. They estimated the stochastic frontier model and technical inefficiency effects simultaneously by using maximum likelihood model with the given distributional assumption on the efficiency components. This model was developed for cross-section data. Battese and Coelli (1995), develop a model for panel data.

This study applies Battese and Coelli (1995) model to estimate firm level technical inefficiency and to test a few farm specific non-input factors simultaneously on the level of technical inefficiency among paddy cultivators of Barpeta district of Assam on the basis of primary data collected during May-Jun (2018) and January (2019). The set of variables along with their measuring units for the Log-linear production frontier are listed below. Output (Y in rupees) of the winter cropping seasons of 2017-18 in kg human labour (L) including women workers in rupees, machineries (MACH) in rupees, Seeds (SEED) including cost on both seeds and chara (freshly germinated seedlings that are planted into the main bed) in rupees, fertilizer (FERT) including cost on both chemical fertilizer and biotic fertilizer (cow manure fertilizer), Pesticides (PEST) in rupees and irrigation (IRRI) including cost on both personal micro irrigation facilities and rental irrigation facilities. Bigha is taken as the unit of measurement for area cultivated instead of hectares, since there is a predominance of small and marginal size plots across the sample areas. The set of non-input variables with their measuring units for the inefficiency effect model are experience (Experience) measured in terms of number of year engaged in paddy cultivation, education (Education) measured in number of years of formal schooling of the cultivators, joint family dummy (joint family = 1 and unitary family = 0), leased in (leased in land as a percentage of total area cultivated), alternative occupation dummy (cultivators with alternative occupation = 1 and otherwise = 0).

3. Data

The present study focuses on a comparative analysis of technical efficiency of winter paddy cultivation across char and non-char areas of Bekiriver in Rupsi development block of Barpeta district of Assam. For this purpose Guleza village is selected from char area and Tapeswara village is selected from non-char area. The village selections are purposive in nature. Particularly the char village covers a significant proportion of cultivators who face frequent crop losses due to flooding and inundation, and the non-char village is chosen purposively on the basis of domination of paddy cultivators on one hand and sufficient distance from the char areas on the other. The econometric analysis is based on primary data. Surveys for collecting primary data were conducted on paddy cultivation of two villages under Ruposhi community development block of Barpeta district, one agriculturally dominant village from mainland (non-char) and another from char areas. Since char and non-char areas are to be compared, approximately 72 cultivators from char and 71 cultivators from non-char are purposively selected from the sample villages (total 143 sample cultivators). The sample survey was conducted twice on each respondent (same sample cultivator) of the selected villages, for winter paddy (February to June).

4. Analysis of empirical results

The bi-variate simple correlation coefficient matrix of the production function variables, i.e. all inputs and output for non-char region (N = 71) in case of winter paddy is presented in the appendix. The correlations are computed among natural log of all variables. As observed from the table most of the bivariate correlations are weak especially within the inputs with the exception of seed-labour and seed-irrigation which are natural as for a given session they are used in fixed proportion given the type of seed and soil quality. Thus multicollinearity among the Cobb-Douglas production function inputs may be neglected. The descriptive statistics of the variables on the basis of which the stochastic production frontier model for the winter paddy in non-char region is run are presented in Appendix 2, for inputs and output. Clearly the variation of output across cultivators is far higher compared to that of the inputs. The stochastic frontier estimates of winter paddy for non-char region (n = 71) are present in table 1.

The production function parameters of the Cobb-Douglas stochastic frontier model are represent in the top-half of the table. The model has been estimated by using Frontier 4.1 for Windows.

Table1. Estimates of the Cobb-Douglas production frontier with inefficiency effects for winter paddy of non-char village – Battese and Coelli (1995), N = 71, Output from the program FRONTIER (version 4.1) Dependent Variable: *Ln*(*y*)

Coefficients of	Estimated Values	t – Values
Constant	9.73	13.99
Ln(L)	0.71	1.44
Ln(MACH)	0.24	2.94
Ln(SEED)	0.26	1.29
Ln(FERT)	0.72	1.72
Ln(PEST)	0.12	1.95
Ln(IRRI)	0.15	2.76

Technical inefficiency effects Battese and Coelli (1995)		
Coefficients of	Estimated Values	t - values
Constant	0.26	1.16
Joint Family	-0.25	-1.61
Lease in	-0.13	-1.65
Education	-2.65	-7.63
Experience	-1.97	-1.95
Alternative Occupation	1.23	1.78
Variance of parameters		
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	5.07	8.77
$\gamma = \dfrac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$	0.91	2 .91
Log Likelihood Function	31.14	
LR Test with one Sided Error	16.65	

Source: Author's estimates based on sample observations using FRONTIER 4.1 for Windows. Inputs and output are taken in 'per Bigha' form.

As seen in the last part of the table, the parameter Gamma having a t-value of 2.91 is 0.91. This implies that 91 percent of the total variation in the composite error term can be accounted for by the variation in the inefficiency random variable alone. That is the share of the inefficiency random error in total error variation is 91 percent. Moreover Likelihood ratio test statistic for the absence of the one-sided error or zero restriction on Gamma actually follows a mixed chi-square distribution the critical values of which can be obtained from Kodde and Palm (1986) table 1.The critical value for 7 degrees of freedom (i.e., q+1 or 6+1) is 13.4 at 5 percent level.Thus the hypothesis of Gamma being zero is rejected. In other words the stochastic frontier is statistically more suited for this data compared to OLS. All estimated coefficients represent elasticity of output with respect to inputs. The labour elasticity is 0.71 which implies one percent rise in labour usage raises output by 0.71 percent. However the labour coefficient is insignificant which could be a small sample problem. All other inputs have lower elasticity values. Like labour the variable seed is also insignificant and interestingly the variable irrigation is highly significant. The second-half of table 1 represents technical inefficiency effect model of Battese and Coelli (1995). The coefficients of education and experience are statistically significant at 1 percent and 5 percent respectively but the rest of the coefficients are not. Here it is found that most of the signs of the inefficiency effect model variables are negative with the exception of alternative occupation. The economic significance of negative sign is that a rise in these variables reduces inefficiency and thus raises efficiency. Here joint family cultivators are found to be more efficient. Similarly cultivators who have leased in land are also technically more efficient. Further both the non-input variables education and experience have high coefficient values along with negative sign implying that years of education and experience have positive influences on technical efficiency. In the present study 33 of cultivators out of 71 in non-char areas are also engaged in some gainful alternative occupation during slack seasons. Here alternative occupation is taken as a binary dummy variable that takes value one if the person is engaged in alternative occupation and zero otherwise. In table 1, coefficient of alternative occupation turns out to be positive (and significant at 10 % but not at 5 %) implying that cultivators with alternative occupation are technically less efficient than others. In other words dedicated farmers in the study region are technically more efficient. Importantly the present sub-sample of non-char cultivators is also found to cultivate summer paddy with the exception of just a single cultivator. The non-char region does not suffer from excessive water-logging or flooding during summer and monsoon months. As a result, non-char cultivators are able to cultivate two paddy crops per annum. In other words, non-char cultivators are mostly multiple croppers. The frequency distribution of technical efficiency on the basis of this model is present in table 2.7 in Appendix 2. It shows that mean technical efficiency of non-char paddy cultivators for winter paddy is 81 percent. In particular 83 percent of cultivators have 70 percent or more level of technical efficiency. The bi-variate ordinary correlation coefficient matrix of the production function variables, i.e. all inputs and output in char region (N = 72) for winter paddy is presented in table 2.6 in Appendix 2. The correlations are computed among natural log of all variables which is similar to the previous analysis on non-char cultivators. As observed from the table, most of the bivariate correlations are weak especially within the inputs with the exception of seed-labour and seed-irrigation. These are natural as because, for a given season most inputs are used in fixed proportion given the type of seed and soil quality. If the type of seed and soil quality changes these proportions are likely to change. Thus multicollinearity in the Cobb-Douglas production function inputs may be ruled out. The descriptive statistics of the variables on the basis of which the stochastic production frontier model for the winter paddy in char region is run are represents in the table 2.3, for inputs and output. Clearly the variation of output across cultivators is far higher compare to that of the inputs. The stochastic frontier estimates of winter paddy for non-char region (N = 72) are present in table 2. The production function parameters of the Cobb-Douglas stochastic frontier model char cultivators are represented in the top-half of table 2 given below. The model has been estimated by using frontier 4.1 for windows. All estimated coefficients represent elasticity of output with respect to inputs. The labour elasticity is 0.26 which implies one percent rise in labour uses raises output by 0.26 percent. However the labour coefficient is insignificant. The factor SEED is statistically significant. All other inputs have lower elasticity values and are statistically insignificant as well. Irrigation is significant in the non-char areas but not so in the char areas. During winters the char region being low lying and located within the river basin, enjoys a moist or wet soil which is in sharp contrast to the non-char or high land plains which are invariably dry and require artificial irrigation especially when it comes to paddy cultivation where waterlogging is a must during the initial phase. Thus irrigation is not a significant factor for the char areas but is vital in the non-char or higher level plains.

Table 2. Estimates of the Cobb-Douglas production frontier with inefficiency effects for winter paddy of char village – Battese and Coelli (1995), N = 72, output from the program FRONTIER (version 4.1) Dependent variable: Ln(y)

Coefficient	Estimated values	t – values
Constant	7.53	7.29
Ln(L)	0.26	1.83
Ln(Mach)	0.72	1.86
Ln(SEED)	0.34	2.58
Ln(FERT)	-0.12	-0.26
Ln(PEST)	1.58	1.65
Ln(IRRI)	0.31	1.46
Technical inefficiency effects Battese and Coelli (1995)		
Coefficients of	Estimated Values	t – Values
Constant	0.48	2.17
Joint Family	-4.6	-0.48
Lease-in	-0.25	-1.85
Education	-0.25	-3.55
Experience	-1.57	-1.72
Alternative Occupation	0.09	1.88
Mono cropper	2.09	2.56

Variance Parameters		
$\sigma^2 = \sigma_v^2 + \sigma_u^2$	5.81	3.23
$\gamma = \dfrac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$	0.57	2.23
Log Likelihood Function	31.14	
LR Test with one Sided Error	13.22	

Source: Author's estimates based on sample observations using FRONTIER 4.1 for Window. Inputs and output are taken in 'per Bigha' form.

The second-half of table 2 presents the technical inefficiency effects model of Battese and Coelli (1995). The gamma zero hypothesis is rejected at 10 percent but not at 5 percent as the Kodde and Palm (1986) critical value 13.4 which is just more that the obtained or calculated value of the LR test statistic. Coming to the coefficients, it is found the coefficients of lease-in, education; alternative occupation and mono-cropper are statistically significant. Further most of the signs of the inefficiency effects model variables are negative exception of alternative occupation. The economic significance of negative sign is that a rise in these variables reduces inefficiency and thus raises efficiency. Here joint family cultivators are more efficient. Similarly cultivators who have leased in land are also technically more efficient. Further both the non-input variables education and experience have high coefficient values along with negative sign implying that years of education and experience have a positive influence on technical efficiency. Here alternative occupation is a binary dummy variable that takes value one if the person engaged in alternative occupation otherwise zero. In table 2 coefficient of alternative occupation turns out to be positive implying that cultivators with alternative occupation are technically less efficient than others. In other words dedicated farmers who are solely dependent on agriculture are technically more efficient. Moreover mono-croppers are technically less efficient as the estimated coefficient turns out to be positive. The key findings of the case study are summarized in the following section.

5. Summary and Conclusions

The present study aims to capture the contrasts in yield and technical efficiency of char and non-char paddy cultivators on one hand and attempts to estimate the impact of non-input variables on farm level technical efficiency on the other. The winter paddy crop of 2017-18 is taken for this purpose. The study uses farm level primary data of 143 purposively chosen sample cultivators selected from both Char (small riverine islands or sandy bars) and non-char areas for the winter cropping seasons of 2018-19. A Cobb-Douglas stochastic production frontier is estimated and selected non-input factors are modelled to explain variations in technical inefficiency across cultivators. The non-input variables like experience, education levels, proportion of land leased in and joint family status have positive influences on farm level technical efficiency. However engagements in alternative occupations have negative influences. Not surprisingly mono-croppers in char areas are technically more efficient. The mono-croppers are far greater in proportions in the char village than in the non-char village. Char mono-croppers are the ones who are forced to sacrifice the summer crop on account of excessive water logging, soil erosion and soil sandifications during the season of floods. But char cultivators are increasingly moving towards winter vegetable cultivation. The present char sub-sample has around 87 present winter vegetable cultivators. These are diversifiers as they are primarily summer paddy cultivators. Mean technical efficiency found in non-char area is 81 percent while that in char areas is 73 percent. The yield of winter paddy among sample cultivators in non-char areas turns out to be 861.45 kg per Bigha while the same computed for the char areas comes to 749.82 kg per Bigha. Thus, compared to the yield levels in non-char areas, the yield in the char areas drops by 14.89 percent or approximately 15 percent. This yield difference across char and non-char areas may be accounted for by the fertility loss of the soil because of excessive flooding, soil erosion, as well as sandification. Not surprisingly, the mean cultivated area in the non-char areas is 4.57 bigha for the present sample but the same is 3.63 bigha for char areas. This clearly shows that average cultivated area for winter paddy is lower in the char areas. The study observes that frequent water-logging during monsoons, along with floods, lead to both soil erosion and sandification making it difficult for char farmers to cultivate paddy all throughout the summer and monsoon months. Char farmers are forced to avoid the monsoon months with regard to paddy cultivation. As such a significant percentage of char farmers are found to be mono-croppers and who have to depend only on the winter paddy crop for their livelihood. The char cultivators have developed an increasing tendency to lease-in non-char land in winter in order to tackle the soil fertility loss in their own areas. Arguably this strategy provides economic viability of paddy cultivation. Furthermore, the char cultivators are increasingly moving towards winter vegetable cultivation during winter months on their own land and trying to recover the costs associated with floods. Although conducted on a limited scale this study comes up with a key policy suggestion for a certain section of the cultivators – namely the char cultivators. It is found that the yield gap between char and non-char is almost 15 percent on an average. Moreover there is also the issue of recurrent crop loss as well as property loss every monsoon. Thus char farmers are always at a disadvantage. Based on the present analysis it is thus logical to argue in favour of a financial protection in the form of a compensation for the char cultivators such that the compensation just covers the average yield gap and hence the income gap per bigha across char and non-char cultivators. This compensation has the potential of bringing the char farmers on a level playing field thereby enhancing their standards of living and purchasing powers.

Appendix 1

The Stochastic Production Frontier

For the present, we assume a cross-sectional stochastic production frontier model (specified in Kumbhakar *et al,* 1991) as

$$lny_i = f(x,\beta) + v_i - u_i \tag{1}$$

$$u_i = \gamma' z_i - \varepsilon_i \tag{2}$$

The random noise component in the production function is introduced through the error term $v_i$which is$iidN(0,\sigma^2)$in equation (1). The second error term is $\gamma' z_i$ which captures the effects of technical inefficiency and has a systematic associated with the firm specific variables and exogenous variables along with a random component ε_i. As we insert equation (2) in (1) we will get the single stage production frontier model as

$$lny_i = lnf\left(x_{i,\beta}\right) + v_i - (\gamma z_i - \varepsilon_i) \tag{3}$$

Here for $u_{i\geq}0$ requires that $\varepsilon_i \geq (-\gamma z_i)$ but not $\gamma z_i \geq 0$ for each producer. Now it is necessary to impose the distributional assumptions on v_i and ε_i and restrictions on $\varepsilon_i \geq (-\gamma z_i)$ in order to derive the likelihood function.

Kumbhakar et et al (1991) imposed distributional assumptions onv_i and $u_i$and ignored ε_i . They assume that $u_i \sim N^+(\gamma' z_i, \sigma_u^2)$i.e., the one-sided technical inefficiency error component has truncated into normal structure with variable mode depending onz_i. It is still not necessary that $\gamma z_i \geq 0$. If $z_{1i} = 1$and $\gamma_1 = \gamma_2 = \cdots \dots \dots . \gamma_n = 0$ then this model collapses to

Stevenson's (1980) truncated normal stochastic frontier model with constant mode γ_1, which further collapses to the Aigner, Lovell and Schmidt (1977) half normal stochastic frontier model with zero mode if$\gamma_1 = 0$, each of these restrictions can be statistically tested. Finally ifu_i andv_i are independently distributed. All parameters of equation (1) can be estimated by using maximum likelihood estimation method. The log likelihood function is a simple generalization of that of Stevenson's (1980) truncated normal model having constant mode μ, which is now replaced by the variable mode$\mu_i = \gamma' z_i$. Therefore the log likelihood function will be

$$lnL = constant\ t - \frac{N}{2} ln(\sigma_v^2 + \sigma_u^2) - \sum_{i=1}^{N} ln\Phi\left(\frac{\gamma'^{z_i}}{\sigma_u}\right) + \sum_{i=1}^{N} ln\Phi\left(\frac{\mu_i^*}{\sigma^*}\right) - \frac{1}{2}\sum_{i=1}^{N}\left(\frac{(\mathrm{e_i} + \gamma'^{\mathrm{z_i}})^2}{\sigma_u^2 + \sigma_v^2}\right)$$

Here,

$$\mu_i^* = \frac{\sigma_v^2 \gamma' z_i - \sigma_u^2 e_i}{\sigma_v^2 + \sigma_u^2}, \sigma^{*2} = \frac{\sigma_v^2 \sigma_u^2}{\sigma_v^2 + \sigma_u^2}$$

And$e_i = lnf(x_{i,}\beta)$are the residuals obtained from estimating equation (1) simply by using OLS. To obtain MLE of $(\beta, \gamma, \sigma_v^2, \sigma_u^2)$ we have to maximize the log likelihood function of (2). Then these estimates are we can use to obtain producer specific estimates of technical efficiency, by using the Jondrow, Lovell, Materov and Schmidt (1982) approach to find the best point estimates of technical efficiency. These estimates are either

$$E\left({}^{u_i}/_{e_i}\right) = \mu_i^* + \sigma^* \frac{\phi\left({}^{\mu_i^*}/_{\sigma^*}\right)}{\Phi\left({}^{\mu_i^*}/_{\sigma^*}\right)} \tag{5}$$

Or

$$M\left({}^{u_i}/_{e_i}\right) = \mu_i^*\ if\ \mu_i^* \geq 0, otherwise\ 0 \tag{6}$$

Once the technical efficiency has been estimated, the effect of each exogenous or environmental variable on technical efficiency can be calculated from either

$$\frac{\partial E\left({}^{u_i}/_{e_i}\right)}{\partial z_{ik}}\ or\ \frac{\partial M\left({}^{u_i}/_{e_i}\right)}{\partial z_{ik}}$$

Battese and Coelli (1995) model is an improvement over the Kumbhakar et al (1991) model as, (i) It is based on panel data and

(ii) The non-negativity requirement$u_i = (\gamma' z_i + \varepsilon_i) \geq 0$ is modeled as $\varepsilon_i \sim N(0, \sigma_s^2)$ with the distribution of$\varepsilon_i$bounded below by the variable truncation point$-\gamma' z_i$.

Battese and Coelli (1995) have verified that the new distributional assumption on ε_i is consistent with the distributional assumption on u_i that is $u_i \sim N^+(\gamma' z_i \sigma_u^2)$. We assume a Cobb-Douglas production function model with 6 inputs to specify the underlying technology. All the six inputs are mentioned below.

$$lny = \beta_0 + \sum_{k=1}^{6} \beta_{jk} lnx_j + (v - u) \quad (7)$$

Here (7) is the Cobb-Douglas technological specification assuming six inputs. Here *y*represents paddy output of the ithcultivator over the studied cropping season.

Further

$$\gamma' z_i = \gamma_0 + \gamma_1 z_{1i} + \gamma_2 z_{2i} + \gamma_3 z_{3i} + \gamma_4 z_{4i} + \gamma_5 z_{5i} + \gamma_6 z_{6i} \quad (8)$$

Here the $z_i's$ are firm specific non-input variables, which may influence the technical efficiency of cultivators. Specifically,

z_{1i} =Joint family (binary dummy variable, 1 for joint 0 otherwise)

z_{2i} =Land leased-in by the cultivator expressed as a percentage of total cultivated area,

z_{3i} =Education of the cultivator as measured by number of years of formal schooling,

z_{4i} =Experience in cultivation in years,

z_{5i} =Alternative occupation (1 if present, 0 otherwise)

z_{6i} =Mono cropper dummy (1 for mono croppers, 0 for multiple-croppers).

All inputs are taken as rupee cost for the entire season. Labour (L) is measured in terms of total wage cost incurred throughout the cropping season till harvest and similarly seeds (SEED), pesticides (PEST), fertilizers (FERT), irrigation (IRRI). Machinery (MACH) captures the rupee cost of hiring mechanized equipments such as tractors, power tillers, including fuel costs. Irrigation cost includes all costs associated with irrigation such as that on pump sets, generators, fuel etc.

Testing the null hypothesis no technical inefficiency is important. The null hypothesis of no technical inefficiency can be tested by applying the Likelihood Ratio Test. The likelihood ratio test is based on the likelihood ratio statistic (LR) defined as,

$$LR = 2ln\left[L\left({}^{L(H_0)}\!\big/_{L(H_1)}\right)\right]$$

Here *L (H_0)* and *L (H_A)* are the values of the likelihood function (optimum) under the null and alternative hypotheses respectively. But since the hypothesized value of λ lies on the boundary of the parameter space it is difficult to interpret the test statistic. It can be shown that the *LR* statistic follows a mixed χ^2 distribution that asymptotically approaches χ^2 distribution with degrees of freedom equal to the number of restrictions imposed in the model (Coelli, 1995). Similar is the test of the hypothesis that inefficiency effects are absent in the model. All estimations were done using the software package FRONTIER 4.1 (Coelli, 1995). The Battese and Coelli (1995) inefficiency effects model is adopted for single step estimation of production function and inefficiency effects parameters.

Appendix 2

Descriptive Statistics, Correlation Matrixes and Distribution of Technical Efficiency across Char and non-char Regions

Table2.1 Descriptive statistics of winter paddy model of non-char region (N = 71)

	Yield/Bigha	Y	L	MACH	SEED	FERT	PEST	IRRI
Mean	861.45	14213.8	1092.2	633.8	2004.8	1097.5	230.6	932.5
Standard Deviation	2856.96	3151.7	380.7	152.8	505.4	401.9	189.1	349.3
Range	701.70	14500	1983.3	750	1925	1630	5	1575
Minimum	400.65	6500	100	250	1000	120	5	100
Maximum	1102.35	21000	2083.3	1000	2925	1750	5	1675

Source: Authors calculation on the basis of primary data.
Note: All variables are measured in Rs/Bigha except yield/Bigha which is in kg/Bigha form.

Table2.2 Descriptive statistics of Non-input variables for winter paddy model of non-char region (N = 71)*

	Lease-in (%)	Education (years)	Experience (years)
Mean	31.8	8.7	18.7
Standard Deviation	102.4	2.9	52.9
Range	30.6	10	29
Minimum	18.6	4	4
Maximum	49.2	14	33

Source: Authors' calculation on the basis of primary data.

*Note: Here ratio-scale variables are presented only (non-categorical). The binary variables for non-char region inefficiency effects are 'Joint Family' and 'Alternative Occupation'. The sample has 37.1 percent joint families and 46.5 percent cultivators with alternative occupations. Leased-in is measured as a percentage of area cultivated.

Table 2.3 Correlation matrices of winter non-char paddy production frontier model (N = 71)

	Y	L	MACH	SEED	FERT	PEST	IRRI
Y	1						
L	0.15	1					
MACH	0.43	0.32	1				
SEED	0.22	0.67	0.12	1			
FERT	0.01	-0.04	0.23	0.19	1		
PEST	0.13	-0.4	0.03	-0.19	0.1	1	
IRRI	0.51	-0.09	-0.16	0.6	0.34	0.14	1

Source: Authors calculation on the basis of primary data.

Table 2.4 Descriptive statistics for winter paddy model of char areas (N = 72)

	Yield/Bigha	Y	L	MACH	SEED	FERT	PEST	IRRI
Mean	749.85	11877.9	1336.2	842.4	2924.8	1653.2	261.8	1588.6
Standard Deviation	3177.4	3179.5	454.8	229.6	964.8	627.7	110.6	716.3
Kurtosis	4.8	5	1.3	0.6	0.1	0.8	6.9	-0.5
Skewness	1.1	1.1	0.7	0.5	0.4	-0.1	1.7	0.1

Range	292.31	21128.6	2350	1060	4980	3375	700	2855
Minimum	643.24	5271.4	150	440	525	125	100	250
Maximum	929.83	26400	2500	1500	5505	3500	800	3105

Source: Authors' calculation on the basis of primary data.
Note: All variables are measured in Rs/Bigha except yield/Bigha which is in kg/Bigha form.

Table2.5 Descriptive statistics of Non-input variables for winter paddy model of char region (N = 72)*

	Lease-in (%)	Education (years)	Experience (years)
Mean	31.8	8.7	18.7
Standard Deviation	102.4	2.9	52.9
Range	30.6	10	29
Minimum	18.6	4	4
Maximum	49.2	14	33

Source: Authors' calculation on the basis of primary data.

*Note: Here ratio-scale variables are presented only (non-categorical). The binary variables for char region inefficiency effects are 'Joint Family', 'Alternative Occupation' and 'mono-cropper'. The sample has 31.4 percent joint families, 50.8 percent cultivators with alternative occupations. Lease-in is measured as a percentage of area cultivated.

Table 2.6 Correlation matrices for winter paddy production frontier model of char areas (N=72)

Variables	Y	L	MACH	SEED	FERT	PEST	IRRI
Y	1						
L	0.29	1					
MACH	0.18	0.29	1				
SEED	0.3	0.71	0.25	1			
FERT	0.24	0.25	0.27	0.42	1		
PEST	0.18	0.34	0.15	0.34	0.16	1	
IRRI	0.23	0.32	0.15	0.9	0.41	0.24	1

Source: Authors calculation on the basis of primary data.

Table 2.7. Frequency distribution of farm specific technical efficiency of winter paddy of non-char and char regions compared

Class intervals	Non-char Frequency	Char Frequency
0.40-0.50	1	4
0.50-0.60	3	9
0.60-0.70	8	14
0.70-0.80	19	17
0.80-0.90	18	16
0.90-1.00	22	10
	N = 71 Mean TE = 0.81 (81 %) SD = 17.27	N = 72 Mean TE = 0.73 (73 %) SD = 12.74

Source: Author's estimates based on FRONTIER 4.1 output file.

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