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Scale Efficiency of Indian Farmers: A Non-Parametric Approach

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I

INTRODUCTION

It was a brilliant article written in the mid-sixties (Mazumdar, 1965) that really fuelled the farm size productivity debate soon after its inception by Sen (Sen, 1962,1964). There seems to be reawakening of this debate for underdeveloped agrarian economies in the recent years ever since the publications of fresh results that are based on more recent data on farm level economic characteristics and application of some new methodologies. The latest debate has been based on the alleged confirmation of inverse relation in agriculturally advanced zones (Khan, 1979; Carter, 1984; Dyer, 1991,1998; Chattopadhyay and Sengupta, 1997,1999).

The basic argument is the ability of small farmers in reaping the benefit of new technology (Sharma and Sharma, 2000). In the traditional logic, new technology is heavily biased towards rich farmers because of the large setup cost involved in adopting such technologies (Dyer, 1998). However recently several studies have felt that there are certain aspects of new technology (such as efficient use of water resources, proper selection of crop mix, etc.) that might benefit even the small farmers (Chattopadhyay and Sengupta, 1997,1999). However, the debate remains as yet inconclusive.

The arguments advanced in this debate, so far, are however highly unsatisfactory. Firstly, the analysis was not carried out properly for different types of crops as well as all crops taken together (Dyer, 1998; Sharma and Sharma, 2000). The large farmers tend to diversify in order to alleviate risks involved in agrarian production. Small farmers with their limited resource ability concentrate only on a few crops. As such comparison between these types of farmers should involve inter-crop variation.[1] Secondly, the distinction between the so-called advanced and backward zones is not rigorous (Dyer, 1998). It appears that these distinctions are made on subjective basis with some *a priori* assumptions. However, in statistical sense, such distinctions must be based on the observed sample characteristics and derived from them properly. Thirdly, the very basis of the debate is questionable. As argued by Lee and Somwaru

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(1993), land productivity and input intensity are valid measures of relative efficiency only under very restrictive assumptions such as constant returns to scale. They suggest the use of efficiency as an ideal parameter in this regard. The simple productivity analysis using yield per hectare and farm size might not be sufficient to understand the pattern of farm efficiency. This is because efficiency depends on a number of factors that could not be captured by yield per hectare alone (e.g., productivity of other inputs besides land, level of technology used, etc., may be incorporated in the analysis).[2]

The present study deals with all these issues in the context of some new data set that is being available from rural India. First, we provide our data description in Section II. In Section III, the study provides the estimates of scale efficiency. The analysis was carried out for two varieties of paddy as well as all the crops taken together. In Section IV, the measures of scale efficiency are regressed on a number of factors to identify the factors that may explain the differential efficiency pattern. The last Section presents the conclusions of the study.

II

DATA DESCRIPTION

The farmers in underdeveloped areas exhibit wide differences in their resource use pattern. It thus seems interesting to study scale efficiency differentials among farmers of different categories and to analyse the factors that may lead to such difference in the observed behaviour. In our exercise, for example, we have considered the cultivation of different crops in the Midnapur district of West Bengal. West Bengal is one of the states in India where large-scale land reforms have resulted in breaking up of vested interests in land holding pattern to a certain extent (Dyer, 1998). Several authors have argued that such measures have contributed to significant efficiency gains (Banerjee *et al.,* 2002). It thus remains imperative to examine the extent to which these gains have been translated in production economies. However since this is a micro-level analysis, it is difficult to include policy variables directly. Their effects can only be gauged indirectly. In the region under study paddy is the main crop (Dyer, 1998). The crop is generally cultivated more than once a year (normally referred to as aman, boro and aus). In recent years, aus have been substituted by some other crops (such as vegetables, pulses, oilseed, etc.). Aman is the traditional variety while boro is the modern variety with high return, huge investment and large risk involved.

The data used in this exercise were collected by the Ministry of Agriculture, Government of West Bengal through the Cost of Cultivation Scheme. The data were collected for every district of this state each year. A multi-stage random sampling design was adopted from blocks to mouza and then from mouza to households. The landless labourers were excluded from the set of households. In this study farm-level disaggregate data are used pertaining to the year 1999-2000 for Midnapur district only. Midnapur district was purposively selected since it had varying socio-economic and geographical features.

This data set supplies information on various inputs like human labour, bullock labour, fertiliser, manure, machine and output of all the crops cultivated both in value and quantitative terms. For our efficiency estimates we have taken only three inputs, namely, human labour hour, bullock hour and fertiliser, that presumably explain production of most of the crops very well. All these variables are measured in per unit area. The time period is one year. Information is also provided for other items of farm expenditure as well. There are in all 180 sample farmers out of which information was available for only 165 farmers. For the classification of blocks (Table 1), we have constructed an Agricultural Development Index (ADI)[3] that includes a host of factors such as the average composite yield per unit area, average productivity of labour, irrigation facilities available, use of chemical fertilisers, degree of mechanisation, etc. Blocks having above average value of A.D.I. are considered as advanced and others backward (A and B).

TABLE 1. AGRO-ECONOMIC INDICES AND THE BLOCK CLASSIFICATION

Block (1)	Village (2)	N (3)	yld (4)	AP_L (5)	h (6)	mh (7)	chm (8)	irr (9)	range (10)	A.D.I. (11)	Type (12)
Block 1	2	18	0.15	0.39	0.49	0.15	0.42	0.84	0.69	0.41	A
Block 2	2	20	0	0	0.07	0.04	0	0	0.07	0.02	B
Block 3	2	20	0.18	0.41	0.64	0.53	0.1	0.13	0.54	0.33	B
Block 4	2	19	0.27	0.53	0.45	0.49	0.59	0.8	0.53	0.52	A
Block 5	2	20	1	0.52	0	1	1	1	0.48	0.75	A
Block 6	2	20	0.19	0.46	0.04	0.27	0.18	0.11	0.35	0.21	B
Block 7	2	16	0.3	1	0.67	0.11	0.89	0.84	0.89	0.64	A
Block 8	2	19	0.4	0.61	1	0.75	0.11	0.96	0.89	0.64	A
Block 9	2	14	0.3	0.5	0.18	0	0.05	0.31	0.31	0.22	B

N = Number of farmers; yld = yield; AP_L = Average product of labour; h = % of hired labour; mh = machine cost per unit area; chm = Chemical fertiliser used per unit area; irr = irrigation cost per unit area.

III

DATA ENVELOPMENT ANALYSIS AND SCALE EFFICIENCY

We propose to study the performance of farmers using the framework of Data Envelopment Analysis (DEA). The linear programming technique is applied to estimate the values of the parameter E_i that capture the degree of efficiency. Now, Farrell's measure of efficiency based on frontier technology is defined as follows:

$$\max_{E_f \lambda} E_f \quad \text{subject to: } y_f \leq Y\lambda, \quad X\lambda \leq E_f x_f, \qquad \text{....(1)}$$

The imposition of constraint on the intensity vector λ guarantees that E_i lies between zero and one. The problem (1) assumes Constant Returns to Scale (CRS). Banker *et al.,* (1984) have relaxed this assumption. Their model is essentially the same as that of the above but relaxing CRS everywhere. In this context, Färe *et al.* (1994) have defined scale efficiency (S.E.) as:

$$SE(y_i, x_{ij}) = \frac{E_i^{CCR}}{E_i^{BCC}} \qquad \text{....(2)}$$

where E_i gives efficiency score for the i-th farm respectively under CRS and VRS specifications. S.E. can be termed as scale efficiency, measured for farms producing y_i output-using inputs x_{ij} (j stands for the input-specific subscript). Färe *et al.* (1994) posited certain properties for $SE(y_i, x_{ij})$. First, it lies between zero and unity. Again, it is homogeneous of degree zero in inputs. Finally, it is independent of the unit of measurement.

The concept of scale efficiency was introduced by Lovell and Sickles (1983) and later elaborated by Färe *et al.* (1994). Scale efficiency measures the efficiency of the scale of operation. Suppose that a firm enjoys increasing returns to scale so that it is possible to sustain a large output vector given the input vector. However, if the observed output vector is unduly small so that there still remains enough scope for expanding output, the firm is scale inefficient. Similarly, scale inefficiency occurs if the produced output is unduly high while decreasing returns to scale is in operation. Scale efficiency is measured by comparing efficiency scores under Constant Returns to Scale (CRS) and Variable Returns to Scale (VRS) under a DEA framework.

Since it had been a common contention that the apparent inverse relationship between farm size and productivity is largely due to scale diseconomies, the concept of scale efficiency might be used to study the impact of scale economies on productive performances of farms. Under traditional agriculture, inputs used by various categories of farms are largely homogeneous. Moreover, knowledge about traditional technology is widespread among the farmers. As a consequence, scale diseconomies occur when net area cultivated rises beyond a certain level. As a result productivity declines as farm size increases. However, with the advent of new agricultural technology, it is the large farms that enjoy the benefits of advanced technical know-how. This has been possible due to the fact that some inputs that are endorsed by the new technology (such as improved seeds, fertilisers, etc.) can be afforded mostly by the large farmers. Moreover, knowledge about the new technology is yet to be widespread. As a consequence, it is the large farms that can go for technical improvement for raising productivity of land while small farmers lag behind.

However, the picture might be altered substantially if a process of "Catch-up" is in operation (Dyer, 1998). According to this process, small farmers might eventually gain "access to new technologies, particularly tubewell irrigation, high-yielding variety (HYV) seeds and chemical fertilisers thereby re-establishing the inverse relation" (Dyer, 1998; Berry and Cline, 1979; Bhalla, 1979). The concept of scale efficiency can now be used in studying the productive efficiencies of different categories of farms separately for the sample region of West Bengal to examine the "catching up" effect on land productivity.

The efficiency scores pertaining to BCC and CCR methods as well as that of the scale efficiency are presented in Tables 2 and 3. It is interesting to note that there are apparently some common features in the efficiency pattern of different crops. For all the efficiency measures, the average scale efficiency is much larger than either the Banker, Charnes and Cooper (BCC) or Charnes Cooper and Rhodes (CCR) models [Charnes *et al.* (1978, 1979, 1981)]. Given that the standard deviations are of comparable levels, it implies that, on an average, the farmers are able to exploit scale economies to a certain extent. However the distribution of scale efficiency indicates a negative skewness for all the crops.[4] As for crop-specific features, it appears that apparently the distribution of efficiency appears to be more symmetric when we consider the BCC and CCR models for the aman crop in comparison with the other crops. Also mean efficiency with aman is rather high (with comparable standard deviations). This confirms the traditional nature of aman crop as opposed to the boro variety. However, even for aman, scale efficiency shows a strong negative bias. Hence it becomes difficult for us to sustain the “catching up” effect for West Bengal agriculture. This simply contradicts the recent findings based on size-productivity debate. However since the coverage of our data set and the methodology followed is in complete contrast to the former findings, the point cannot be stressed too far.[5]

TABLE 2. FREQUENCY DISTRIBUTION OF TECHNICAL EFFICIENCY (DEA)

	All crops			Aman			Boro		
(1)	CCR (2)	BCC (3)	Scale (4)	CCR (5)	BCC (6)	Scale (7)	CCR (8)	BCC (9)	Scale (10)
0-10	0	0	0	0	0	0	0	0	0
10-20	22	6	0	0	0	0	8	1	0
20-30	25	18	1	1	0	0	23	6	0
30-40	56	48	8	2	1	1	24	17	2
40-50	28	25	2	5	1	0	10	24	4
50-60	15	30	11	16	6	1	17	16	12
60-70	8	11	11	28	26	2	8	19	17
70-80	4	8	16	35	33	8	4	6	17
80-90	2	9	53	10	24	21	2	4	26
90-<100	0	1	58	7	5	71	0	1	18
100	5	9	5	9	17	9	3	5	3
Total	165	165	165	113	113	113	99	99	99

TABLE 3. SUMMARY STATISTICS OF THE EFFICIENCY MEASURES

	All crops			Aman			Boro		
(1)	BCC (2)	CCR (3)	Scale (4)	BCC (5)	CCR (6)	Scale (7)	BCC (8)	CCR (9)	Scale (10)
Mean	39.52	48.97	82.19	70.94	77.62	91.44	42.48	54.72	76.02
Standard Error	1.41	1.65	1.33	1.43	1.31	0.96	1.99	1.93	1.53
Median	36.59	41.22	88.49	70.82	77.27	94.59	36.85	50.95	79.89
Sample Variance	327.88	442.52	291.76	230.80	193.90	103.76	390.54	366.85	230.39
Kurtosis	2.39	0.14	1.29	0.17	-0.12	8.80	0.71	-0.03	-0.40
Skewness	1.32	0.91	-1.40	0.04	-0.07	-2.40	0.95	0.63	-0.56
Range	89.38	85.42	74.62	70.39	66.8	65.47	88.58	80.89	63.78
Minimum	10.62	14.58	25.37	29.61	33.2	34.53	11.42	19.11	36.22
Total	165	165	165	113	113	113	99	99	99

Next, we provide the summary of slack and surplus variables in both the CCR and BCC models. Slack variables represent the amounts of excessive input use. They reveal the extent to which use of a particular input be reduced given that a farm has already reached the frontier of the production set. The analyses of slack variables from CCR model (similarly for BCC model), for example, suggest that on an average there is considerable scope for reducing the current input use. The problem appears quite severe if we consider all the crops taken together than for either aman or boro variety of paddy. This is quite expected since the variety all crops are more heterogeneous. However over-utilisation of the inputs is more severe for boro variety than for aman that is more traditional. Again the number of farms with zero slacks is relatively high for the aman variety. A farm is efficient only if it has zero slacks and E_f =1. There may be observations with E_f =1 but non-zero slacks. Such farms are not efficient. This may imply that farmers are better acquainted with aman, a traditional variety than with boro. Input wise analysis reveals that the extent of over-utilisation is more severe for human labour and fertiliser than for bullock labour. The findings broadly support some earlier exercises based on West Bengal agriculture while using separate methodologies (Pal and Sengupta, 1999). In the low-income countries where farmers have to face a high risk, low-income situation with little or no formal insurance mechanisms, bullock purchase and sale forms a very important risk-bearing instrument (Rosenzweig and Wolphin, 1993; Townsend, 1994). As such farmers would rarely try to over use it. However the over-utilisation of a modern input such as fertiliser may be a direct impact of subsidisation of the input. It is to be rued upon particularly bearing in mind its harmful toxic effects and the substantial gain in farmer’s income that results from a reduction in the use of this costly input. Hence rationalisation of the current subsidy structure in Indian agriculture may lead to a substantial welfare gain. In contrast, surplus variables reveal how much a farm on the production frontier could further increase its output without consuming additional units. Thus under CCR, output for all crops and the boro variety can increase roughly around twice its current level. The result for aman is less dramatic, indicating only an increase of about 49 per cent of the current output. This again reveals the traditional nature of aman crop to which farmers are more accustomed than with boro variety. For all crops, however, this in effect may change the mix of the farmer's output. Thus efficient reorientation of output may result a change in cropping pattern itself.

TABLE 4. ANALYSIS OF SLACK AND SURPLUS VARIABLES

Inputs/Output (1)	No. of farms with zero slack/surplus CCR (2)	BCC (3)	Slack/surplus as a proportion of total (inputs/output) CCR (4)	BCC (5)	Number of farmers (6)
			All crops		
Labour	5	9	-0.6139	-0.5138	165
Bullock	4	6	-0.3970	-0.3696	165
Fertiliser	2	6	-0.7171	-0.5653	165
Output	5	9	+2.0953	+1.0282	165
			Aman		
Labour	9	17	-0.2939	-0.2238	113
Bullock	5	12	-0.1521	-0.1287	113
Fertiliser	8	15	-0.2891	-0.2237	113
Output	9	17	+0.4855	+0.3532	113
			Boro		
Labour	3	5	-0.5760	-0.4558	99
Bullock	1	3	-0.3625	-0.3541	99
Fertiliser	3	5	-0.5752	-0.4528	99
Output	3	5	+1.9168	+0.6398	99

IV

DETERMINANTS OF SCALE EFFICIENCY

Now we try to disentangle the effect of factors beyond a farm's control that might influence the distribution of scale efficiency. There are at least two ways for achieving this (McCarty and Yaisawarng, 1993). In the first technique such factors are included in the original DEA programme and the resulting efficiency scores are judged with that of the original model. The process may be compared with the parametric technical error component model (Kumbhakar *et al.,* 1991) where the mean of technical error is assumed to be a function of uncontrollable factors. However we have not pursued this technique in the present paper.

An alternative way is to consider the efficiency scores estimated by DEA as dependent variable and regress it on the uncontrollable variables (Kalirajan and Shand, 1985,1992; Dusansky and Wilson 1990; Lovell *et al.,* 1997; Banker and Johnston, 1997; McCarty and Yaisawarng, 1993). However since the efficiency scores computed from the DEA model are truncated between zero and one, an ordinary least squares (OLS) regression of the standard type will produce biased and inconsistent estimates (Maddala, 1983). There are several ways in which this problem can be solved. Lovell *et al.* (1997) have suggested a tie-breaking technique to generate efficiency scores with no upper bound. A simple logarithmic transformation of these scores generated unbounded scores that can be used in OLS regression. Some authors, on the other hand, suggested the transformation to an inefficiency parameter $\ln(1/\theta - 1)$ where θ is the ordinary efficiency score (Kalirajan and Shand, 1985,1992; Banker and Johnston, 1997). A third way is to use the ordinary efficiency scores in OLS regression with a truncated regression model (Dusansky and Wilson, 1990; McCarty and Yaisawarng, 1993).

In this paper we have considered two different approaches. First, we used the transformation $\theta' = \left(\frac{1}{\theta} - 1\right)$ where θ is the ordinary efficiency score (rather than the tie-break scores) and considered the OLS technique for the logarithmic transformation of θ'. Finally, since the efficiency scores are themselves non-parametric, a Jackknife semi-parametric regression technique is used for this estimation. We have considered a number of dependent variables that can explain the extent and distribution of scale inefficiency. We have considered dummy variables in order to get consistent estimates. Three dummies are used for this purpose. A block dummy is used to separate out the effects of a block being backward or advanced. The irrigation dummy captures an important aspect of farm economics - the use of modern inputs. In order to address the size-productivity relations, we propose the use of a size dummy. We classified the farmers into several size groups following the government outlines. It is then pertinent to see whether such classifications have any implications for scale efficiency. A major debate in economics is the relative efficiency of owners versus tenants. In West Bengal, sharecropping is the dominant form of tenancy arrangement (Banerjee *et al.*, 2002). In our exercise, it is possible to test their relative efficiency using the ownership dummy.

TABLE 5. RESULTS OF REGRESSION ANALYSIS

DEPENDENT VARIABLE: LOG (θ')

	All Crops		Aman		Boro	
	R^2= 0.1162	n=165	R^2= 0.1858	n= 113	R^2=0.0982	n=99
Variables (1)	OLS (HETCOV) (2)	Jackknife (3)	OLS (HETCOV) (4)	Jackknife (5)	OLS (HETCOV) (6)	Jackknife (7)
Block dummy	0.95405** (0.2193)	0.94989 (0.22722)	-1.2383** (0.3096)	-1.2513 (0.3188)	0.33981** (0.1636)	0.26430 (0.0792)
Size dummy	-0.20229** (0.0901)	-0.20008 (0.092928)	0.14091 (0.1323)	0.1170 (0.1511)	-1.1523** (0.1439)	-0.02784 (0.0486)
Irrigation dummy	-0.88141** (0.2666)	-0.88311 (0.27499)	-0.38998 (0.5103)	-0.2966 (0.5976)	-0.27126** (0.1058)	-0.31820 (0.0744)
Ownership dummy	-0.57396** (0.2341)	-0.57911 (0.37128)	2.2163 (1.5470)	2.3264 (2.3992)	-0.48369 (0.3991)	-0.03307 (0.0612)
Constant	-0.96876** (0.3153)	-0.96401 (0.42937)	-4.2875** (-2.7260)	-4.3760 (2.4315)	0.30001 (0.3991)	-0.01332 (0.0601)

Figures in parentheses represent standard errors. ** indicates level of Significance at 1 per cent.

The results provided in Table 5 represent the results for both OLS (with heteroscedastic covariance estimator) and Jackknife estimators.[6] The significant results for OLS are marked by asterisks. However so far as the Jackknife estimators are concerned the significant results are akin to the OLS if we follow the same logic.[7] The results provide a contrasting feature between the traditional variety (aman) and the modern variety (boro). It is seen that if we consider all crops together, the pattern closely follows that of the modern variety. Thus for example, there exists a positive relationship between size and inefficiency so far as the traditional variety is concerned whereas it is negative for all crops and boro. However, the relationship is not significant for the former case. Similar results are seen for block dummy and ownership pattern.

In other words, we can thus speak of a *dual economic* structure that has arisen in the countryside due to the adoption of new technology. While small farmers are in an advantageous position for traditional variety they are slowly losing the battle as the newer varieties are introduced that favours the large farmers. However as argued by Dyer (1998), the tenancy reform and decentralised decision-making process initiated by the state governments, have been helpful in maintaining the small cultivators who generally prefer traditional cultivation.

V

CONCLUSION

In this paper we are concerned about the pattern of scale efficiency. The concept has important implications for size productivity relationship and the extent to which farms have adopted the current technology. Using farm level data on crop production of a set of farmers in West Bengal, we have tried to ascertain the nature of scale efficiency using non-parametric DEA. Our analysis reveals over-utilisation of the available resources as well as considerable scope for expanding output. However there appears to be a wide contrast between the scale efficiency of a traditional variety of paddy and its modern variety. For the traditional variety, small farmers enjoy certain advantages that are readily wiped out under the new variety. Thus there emerges a *dual economic structure* in West Bengal agriculture due to the government policies of protecting the interests of the poor. The study is in consonance with Dyer (1998) that the alleged negative relationship in West Bengal agriculture is a manifestation of government policies that have prevented the market forces from operating to its full. However further studies using different data sets and alternative methodologies are required before one can come to firm conclusions in this regard.

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NOTES

1. Two issues are important here. Firstly, large farmers take their decision on the perspective of cultivating a whole gamut of crops while the small farmers concentrate on the cultivation of a single or a few crops. In a *multi-crop* setup, input used and efficiency achieved for a particular crop has its spill-over effect over input decisions of other crops (Pal and Sengupta, 1999). Hence it would be wrong to treat them identically as is usually done. Secondly, large farmers generally prefer highly remunerative crops that may require substantial cost and use of modern inputs. Small farmers are more cautious. They normally prefer traditional crops with low risk that are essential for their survival. Thus multi-crop comparison is essential in the case of size-productivity relationship.

2. It is difficult to accept yields as a comprehensive measure of efficiency.

3. The ADI is constructed using the UNDP formula. It is unit free and lie between zero and one.

4. This result clearly implies that the average scale efficiency level is quite high though the distribution is asymmetric.

5. The "catching up" effect indicates on overall technical improvement of the small farmers so that they close their gaps with the large farmers. This claim cannot be sustained here. Though small farmers may have improved their position with respect to the traditional variety of paddy, it is not so for other crops. As such it might be a direct consequence of government policies such as land-reform, decentralisation, etc. It is however difficult to include policy variables at the micro-level analysis such as ours. Again our data covers only a sample district of the entire state. Consequently the conclusions, though indicative, are strictly not comparable with the analyses based on overall state-level data.

6. Recently Desli and Ray (2004) have used Bootstrap method that is based on Jackknife (Efron, 1979) in studying input-specific effects under DEA.

7. In fact, too much weight should not be placed on the low R^2 since our aims is not prediction. Rather the Jackknife estimators that are based on repetitive re-sampling of the original data set clearly indicate the stability of our estimated coefficients. This might be a reasonable ground for drawing inferences from the estimated relationships.

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