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Size, Fragmentation, and Inefficiency: A Single-Stage Stochastic Parametric Approach for Wheat Production in Iran

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Abstract

Although studies on the relation between size and efficiency are ample, studies on the relation between size, fragmentation, and efficiency are limited. It is the purpose of this study in which a single-stage stochastic parametric approach is used. For this purpose production of wheat in Iran is a good case because wheat is the core commodity of the Iranian agricultural system which is dominated by small and fragmented family farms. The data comes from a survey of wheat producers in West Azarbayjan province, a major agricultural region, located in the north-west of Iran, in which around 50 percent of the lands under annual crops is allocated to wheat, almost the same proportion as in the whole country. Mean size of farmland in the sample was 2.2 hectares (10,000 meters) ranging from 0.3 to 12 hectares; mean number of plots of land was 1.7 ranging from 1 to 7 plots. It was found that mean technical efficiency was 63.4 percent ranging from 11.6 to 95.1 percent. Significant inverse relation between total costs of inputs, as index of size, and positive relation between number of plots of land, as index of fragmentation, and technical inefficiency were found.

Key words: size, fragmentation, technical efficiency, wheat, Iran.

Introduction

Studies on the relations between size and productivity, size and costs of production, fragmentation and productivity, fragmentation and production costs, and size, fragmentation, productivity and production costs are not scarce. In fact there is a rich literature on these issues which are the reports of researches on agricultures of five continents. The empirical findings of these research efforts

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are mixed: ranging from negative to positive and no relation at all. And of course a number of studies have reported the ordinary textbook quadratic relation. Because of increasing returns to scale and size as small and fragmented farms get larger and less fragmented productivity increases and production costs decrease and after a certain point because of diseconomies of scale and size as farms get larger productivity falls and production costs rise. On the other hand studies on the relation between size, fragmentation, and efficiency are limited and it is the purpose of this study. By size we mean the extent of productive operation; and by fragmentation we mean the number of aparted plots of land each producer uses in his productive activity.

For the purpose of this study, wheat production in Iran is a good case. Food and Agriculture Organization of the United Nations reports that Iran's agricultural sector is dominated by small family farms and some 96 percent of all holdings are owner-operated. Eighty percent of the farms have less than 10 hectares and 66 percent less than 5 hectares of land. Another issue in this country is land fragmentation. The average number of plots per farm is 15 (FAO).

Wheat is the core commodity of the Iranian food and agriculture system and is the main crop in most parts of the country. In the year 2001, 70.13 percent of the lands under annual crops were allocated to cereals of which 71.86 percent were allocated to wheat (Ministry of Agriculture). In other words, in the same year more than 50 percent of lands under annual crops were allocated to wheat. West Azarbayjan province located in north- west of Iran and bordering with Iraq and Turkey was chosen as the sample. In the year 2001, 50.19 percent of the lands under annual crops were allocated to wheat (Ministry of Agriculture), which is close to the corresponding figure for the whole country. In the next section the methodology of the study is presented followed by data, results, discussion, and some concluding remarks.

Methodology

A single–stage stochastic parametric model of technical inefficiency measurement and its determinants is used in this study. The model is based on the concept of Pareto efficiency in production and Farrell notion of relative efficiency in the sense that efficiency of each producer is measured relative to the efficiency of the best practicing producers, determining the frontier.

The stochastic parametric approach to measuring technical efficiencies was first independently suggested by Aigner, Lovell, and Schmit and also by Meeusen and Van den Broeck and made it possible to estimate the mean efficiency (inefficiency) of the sample producers. Jondrow, Lovell, Materov, and Schmidt made it possible to estimate the efficiency of individual sample producers.

Following most studies of technical efficiency in agriculture, Battese, Bravo-Ureta and Pinheiro, Coelli, and Thiam, Bravo-Ureta, and Rivas, in this study we use a Cobb-Douglas production function. The stochastic Cobb-Douglas function with five variable inputs in this study is specified as the following:

$$Y_i = e^{\beta 0} X_{i1}^{\beta 1} \ldots\ldots\ldots\ldots\ldots X_{i5}^{\beta 5} e^{Vi-Ui} \qquad i = 1, 2, \ldots\ldots\ldots, N \qquad (1)$$

Where Y_i is the production level of the i_{th} producer, X_{i1} to X_{i5} are the levels of five inputs used by i_{th} producer, e is the Neperian number, V_i is a stochastic error term standing for all the factors not at the control of the i_{th} producer, U_i is a non-negative random variable associated with farm-specific factors which contribute to the i_{th} producer not attaining maximum efficiency in production, N represents the number of producers in a cross-sectional survey of the producers, β_0 is a constant and β_1 to β_5 are coefficients to be estimated. Taking the natural logarithms of both sides of (1) we get:

$$LnY_i = \beta_0 + \beta_1 LnX_{i1} + \ldots\ldots\ldots\ldots\ldots + \beta_5 LnX_{i5} + V_i - U_i \qquad (2)$$

Where the random errors, V_i, i = 1, 2, ……,N, are assumed to be independently and identically distributed as $N(0, \sigma^2)$ random errors independent of U_i which, in this study following Greene's conclusion, is assumed to have a truncated half-normal distribution. The corresponding frontier is the following:

$$Y_i^* = e^{\beta 0} X_{i1}^{\beta 1} \ldots\ldots\ldots\ldots\ldots X_{i5}^{\beta 5} e^{Vi} \qquad (3)$$

And the technical efficiency of the i_{th} producer, bounded by 0 and 1, will be:

$$TE_i = Y_i / Y_i^* = e^{-U_i} \tag{4}$$

Given that the random variable $e_i = V_i - U_i$ is observable, U_i could be predicted by the conditional expectation of U_i, $E(U_i \mid V_i - U_i)$, (Jondrow, Lovell, Materov, and Schmidt).

Given the assumptions of the model specified the parameters of the model could be estimated using maximum-likelihood (ML) method. Following Battese and Corra the parameters of the model are obtained considering the parameter gamma, $\gamma \equiv \sigma_U^2 / \left(\sigma_V^2 + \sigma_U^2\right)$, which is bounded by 0 and 1, and $\sigma^2 \equiv \sigma_V^2 + \sigma_U^2$ is the variance of the composite error term $V_i - U_i$. In the case of $\sigma_V^2 = 0$ all the differences in error terms of the frontier production function are the results of management factors under the control of the producer and, in the case of $\sigma_U^2 = 0$, γ would be equal to zero which means all the difference in error terms of the frontier production function are the results of factors that the producer has no control on them. Therefore, γ statistic is used for hypothesis testing on existence of inefficiencies. If ($H_0 : \gamma = 0$) is rejected, it means that there are inefficiencies and the function could be estimated using maximum likelihood (ML) method. If H_0 is not rejected, ordinary least squares (OLS) method gives the best estimation of the production function.

Inefficiency measures are expressed as follows:

$$Ineff = 1 - TE_i = 1 - e^{-U_i} \tag{5}$$

and hypothesized to have a linear relation with size and fragmentation as the following:

$$Ineff = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 \tag{6}$$

in which *Ineff* is the measure of inefficiency, Z_1 is index of size, Z_2 is index of fragmentation, and δ_0 is a constant and δ_1 and δ_2 are coefficients to be estimated. Since it is assumed that inefficiency effects are independently and identically distributed following suggestions by Reifschneider and Stevenson

and also by Kumbhakar, Ghosh and McGuckin, the inefficiency effects are made an explicit function of size and fragmentation, and all parameters of production function and inefficiency function are estimated in a single stage.

Data

The data on 227 randomly chosen wheat producers for 8 variables were used in this study. The data on 8 variables are based on the results of a survey of wheat production in the sample province. The variables are: wheat produced in kilo grams, land in hectares, seed in kilo grams, fertilizer in kilo grams, machinery in tractor hours, labor in man days, input costs in ten rials (Iranian money unit), and number of plots. The variables and their descriptive statistics are presented in Table 1. They are self evident and need no more description.

Table 1: Descriptive Statistics of Variables

	Wheat Produced (kg)	Land (ha)	Seed (kg)	Fertilizer (kg)	Machinery (th)	Labor (md)	Input Costs (10 rials)	No. of Plots
Statistics	**Y**	**X1**	**X2**	**X3**	**X4**	**X5**	**Z1**	**Z2**
Mean	4767.154	2.214758	425.9295	362.2687	9.814512	24.333	213448.5	1.665198
Standard Error	340.7125	0.111961	26.22659	29.10843	0.671381	1.270526	13243.79	0.070163
Median	3200	2	320	250	7.166667	19.5	152750	1
Mode	2000	1	200	1	3.5	15	104950	1
Standard Deviation	5133.352	1.686866	395.1434	438.5627	10.11538	19.14241	199537.8	1.057119
Sample Variance	26351298	2.845516	156138.3	192337.3	102.3208	366.4319	3.98E+10	1.1175
Kurtosis	29.48909	7.533905	21.13739	25.15534	45.19836	10.76065	24.14649	8.332085
Skewness	4.440233	2.298372	3.71835	4.015008	5.24605	2.544716	4.048064	2.562788
Range	47700	11.7	3433	3999	109.9048	154.2	1785400	6
Minimum	300	0.3	70	1	1.428571	1.8	22200	1
Maximum	48000	12	3503	4000	111.3333	156	1807600	7
Sum	1082144	502.75	96686	82235	2227.894	5523.59	48452801	378
Count	227	227	227	227	227	227	227	227

Results

Using FRONTIER Version 4.1 software (Coelli) the model specified in the previous section was estimated and is presented in Table 2.

Table 2: The Results of OLS and ML Estimates of Production and Inefficiency Functions

The OLS estimates:

	Coefficient	Standard-error	T-ratio	Significance(p)
β_0 (Constant)	2.543	0.641	3.967	<0.01
β_1 (Land)	-0.365	0.140	-2.594	<0.01
β_2 (Seed)	0.706	0.120	5.864	<0.01
β_3 (Fertilizer)	0.073	0.016	4.568	<0.01
β_4 (Machinery)	0.443	0.016	6.577	<0.01
β_5 (Labor)	0.157	0.056	2.798	<0.01
Sigma-squared	0.224			<0.01

The ML estimates:

	Coefficient	Standard-error	T-ratio	Significance(p)
β_0 (Constant)	5.046	0.647	7.794	<0.01
β_1 (Land)	-0.005	0.143	-0.039	ns [a]
β_2 (Seed)	0.413	0.121	3.408	<0.01
β_3 (Fertilizer)	0.061	0.012	4.939	<0.01
β_4 (Machinery)	0.363	0.061	5.973	<0.01
β_5 (Labor)	0.072	0.041	1.764	<0.10
δ_0 (Constant)	0.501	0.238	2.104	<0.05
δ_1 (Size)	-0.000004	0.000001	-3.176	<0.01
δ_2 (Fragmentation)	0.153	0.122	1.250	<0.30
Sigma-squared	0.460	0.123	3.745	<0.01
Gamma	0.933	0.025	37.820	<0.01

α Not significant

The gamma coefficient, 0.933, and its significance level at less than 1 per cent indicate that there are inefficiencies in the production of wheat in the area under study. δ_1 being negative and significant at less than 1 percent implies that there is an inverse relation between measures of inefficiency and total cost spent on five inputs under study as an index of size. δ_2 being positive and significant at less than 1 percent implies that there is a positive relation between measures of inefficiency and number of plots of land as an index of fragmentation. In other words, these results show that in the area under study the larger and less fragmented wheat farms are relatively more efficient.

It was estimated that the mean efficiency of 227 wheat producers under study was 63.4 percent. The descriptive statistics and frequencies of measures of efficiency are presented in Table 3 and Figure 1. They are quite self-evident.

Table 3: Descriptive Statistics of Efficiency Measures

Mean	0.63401313
Standard Error	0.013576656
Median	0.67212854
Standard Deviation	0.204552948
Sample Variance	0.041841908
Kurtosis	-0.490423282
Skewness	-0.585236251
Range	0.83458503
Minimum	0.11623092
Maximum	0.95081595
Sum	143.9209804
Count	227

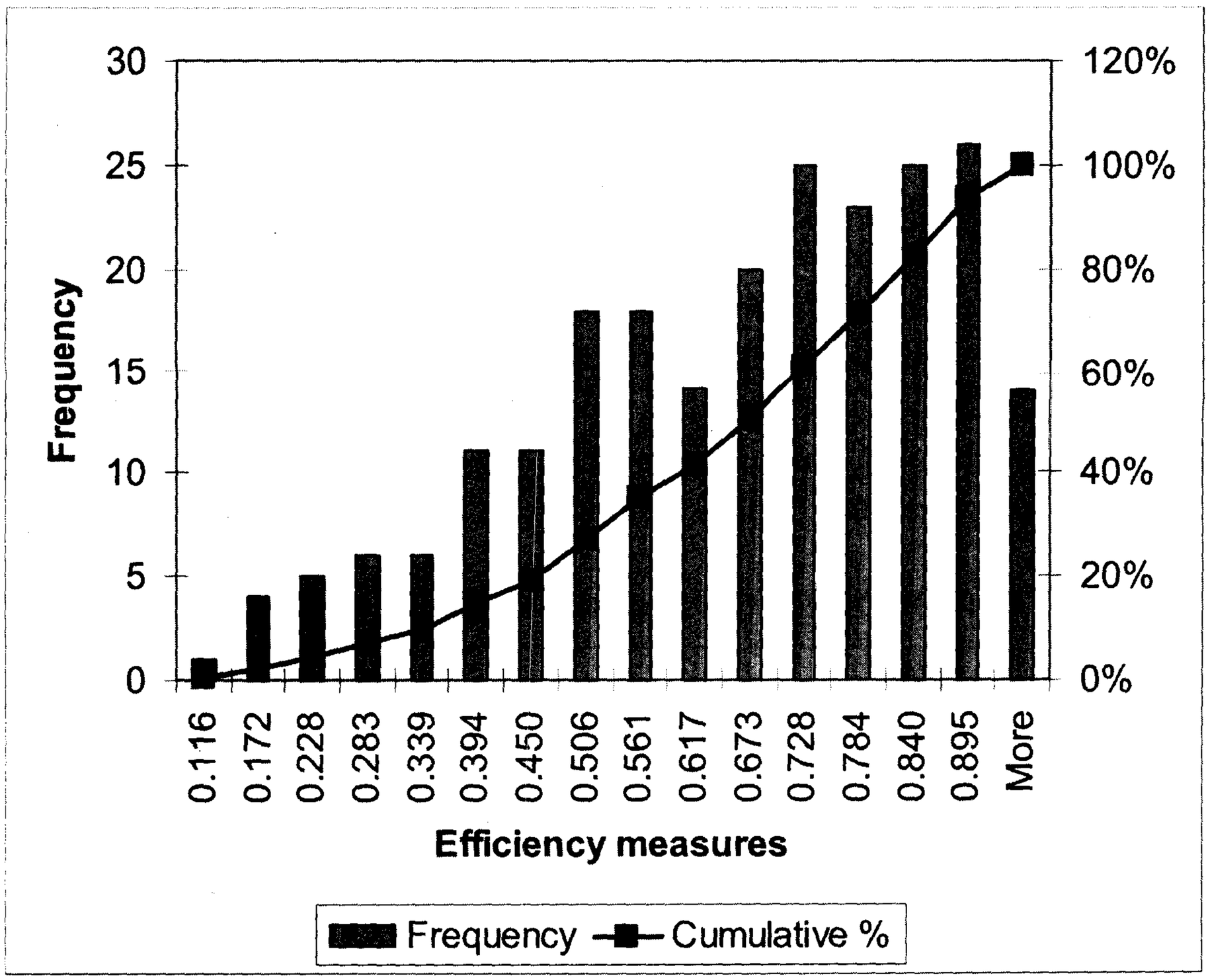

Figure 1: Frequencies of Efficiency Measures

These results indicate that there is a large room to increase production of wheat through enhancing the efficiency of wheat farmers.

Discussion

A study on wheat producers of the same region showed inverse relation between costs per hectare of producing wheat and size of the farm and positive relation with the fragmentation of the farm (Arsalanbod and Esmailpour) which are consistent with the results of this study, namely, there is positive relation between measures of efficiency with size and negative relation with fragmentation.

While rice has been the most studied crop in developing countries with contradicting results concerning the size, with no study concerning fragmentation, there has been a few studies of wheat (Thiam, Bravo-Ureta, and Rivas) concerning size, but neither of them concerning fragmentation. For example, Daryanto, Battese, and Fleming report inverse relationships between land size and technical efficiency for rice farmers in West Java and Wadud reports that in Bangladesh farmers with greater land size were more efficient.

Battese, Malik, and Gill report that mean technical efficiencies of wheat producers in Pakistan, a neighbor country of Iran, has been 68 percent, 4.6 percent more than the results of our study. The effects of size and fragmentation on efficiency were not reported in their article. Huang and Kalirajan report that mean technical efficiency of Chinese wheat producers has been 73 per cent. Using two-stage approach they found a positive relation between measures of technical efficiency and size of arable land, which is consistent with our results. In their study, the effect of fragmentation on efficiency has not been studied.

Wilson, Hadley, and Asby estimated the mean technical efficiency of wheat farmers in eastern England equal to 87.01 percent, much higher than the results of this study. Using a single –stage approach they reported a negative relation between measures of inefficiency and total area of each farm, which is consistent with the results of this study. There are no reports on influence of fragmentation on technical efficiency in their article.

Concluding Remarks

Objectives of competitiveness, food security and food self-sufficiency are major concerns around the world, especially in food importing countries, like Iran. To produce more food the farmers not only need more favorable environment and more appropriate technologies but also they are required to be efficient in their production , especially in the production of core commodities, such as wheat in Iran. Although it is true that the results of many studies around the world especially in developing countries on different crops show inefficiency as a serious problem, knowledge especially on the first-order determinants of inefficiency is scarce.

This study is a limited one, both in terms of region covered and also the determinants of inefficiency. However wheat is a core commodity, and farm smallness and fragmentation are widespread problems in many countries and

also in different parts of Iran. Therefore it is hoped this study contributes to paying attention to further research on both the problem of inefficiency and its determinants in production of core agricultural commodities, especially in food importing countries like Iran.

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