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A Comparative Efficiency Analysis of Wheat Farms using Parametric and Nonparametric Methods

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Lijia Mo

Kansas State University

Department of Agricultural Economics

Manhattan KS 66505

lijiamo@agecon.ksu.edu

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Abstract

This study examined whether the efficiency measures were invariant to choice of parametric and nonparametric methods for a sample of 183 wheat farms. The efficiency measures from the deterministic parametric method were smaller than those from the deterministic method. There was a trade-off between scale efficiency and economic efficiency. In the deterministic nonparametric method, the economic efficiency, scale efficiency and overall efficiency results were invariant to the number of inputs or the dimensionality. Only allocative and pure technical efficiency measures depended on the dimensionality. This work illustrated the importance of holding curvature for the cost function in stochastic frontier results.

Keywords: *Efficiency Analysis; Deterministic Nonparametric Method; Parametric; Stochastic Frontier.*

JEL Classifications: Q11

1 Introduction

Wheat price variability increased by 50% from 2003-2006 to 2007 in the U.S. according to Infotech Future Database of the Commodity Research Bureau (Source: <http://www.crbtrader.com> 2009). A sample of 183 wheat farms data from 2003 to 2007 provided by the Kansas Farm Management Association is used for the efficiency analysis on Kansas, the largest producer of wheat in the U.S. This paper examines whether efficiency estimates are sensitive to the choice of study approaches. Moreover, it compares the results of both parametric and nonparametric approaches for consistent results.

Debate about the extent to which the efficiency measures are sensitive to measurement methods was studied by Bravo-Ureta et.al (2007) who undertook a meta-regression analysis examining 167 farm level frontier technical efficiency studies in developing and developed countries by changing attributes of a study on technical efficiency estimates. Technical efficiency gains came from the improvements in decision-making. Country effects on mean technical efficiency (MTE) incorporated by regional and income dummy variables revealed econometric results, which suggested that MTE estimates from the stochastic frontier model were lower than estimates of the non-parametric deterministic model. MTE estimates from the parametric deterministic frontier model were lower than estimates of the stochastic approach.

Wadud and White (2000) found that the selection of the methodology used to measure TE was arbitrary and based on the objective of empirical study and the data available. They also agreed that the choice of specific methodology might affect the estimated efficiency scores, especially technical efficiency. Existing literature on studying the variability of cost efficiency measures to research approaches are limited.

The Production Frontier Function Methodology is consistent with economic theory, and therefore it is a popular tool in applied production analysis. There are two basic types of production frontier models, parametric and nonparametric. It was argued by Greene (1993) that any one-sided measurement error embedded in the dependent variables was the reason for efficiency measurement sensitive to outliers, which could be problem in deterministic frontier. The nonparametric method or Data Envelopment Analysis (DEA) did not require a specific functional form and therefore had some advantages over parametric methods. However, this mathematical programming-based technology also had the drawback of being sensitive to outliers and the number of observations and, furthermore, the dimensionality of the frontier (Rammanathan 2003). This paper uses the deterministic parametric production

frontier and nonparametric production frontier to measure efficiency on wheat enterprise data over five years, and to analyze annual efficiency changes, thereafter compares the results of two methods. Parametric efficiency measures are obtained by formulating an ordinary least squares into a nonlinear programming optimization problem with an one-sided error and a frontier production function estimation uses Färe's nonparametric linear programming procedures.

2 Data and Analysis

Wheat enterprise data from 2003 to 2007, provided by the Kansas Farm Management Association, is used for this analysis on 183 sample Kansas farms. Individual original 24 inputs are summed up into 9 categories. In descending order of the magnitude 9 categories of inputs include: capital including repairs, interest paid, machinery hired, undivided auto, cash farm rent, depreciation, and interest charge; Labor includes unpaid operational labor and hired labor; fertilizer chemical; land charge; utility and fuel, which is composed of undivided utility, farm utility and fuel; seed; herbicide chemical; crop insurance; others includes fees, storage, perils crop tax, farm insurance, conservation, grain futures and revenue tax. The data has an advantage of providing detailed information on inputs over five years, which allows an explanation of efficiency fluctuation from the input cost aspect. Under the assumption law of one price, all unit prices of inputs are the same in respective years, therefore cost data can be used in analysis as quality.

Mean values for important variables in Table 1 provide a glance of fluctuation over five years. Per acre variables are calculated from dividing aggregate values by the sum of rented and owned land acres. The aggregate variables fluctuate significantly: total acres are leveling off around 600 acres from 2003 to 2006; in 2007, there is a significant increase to over 700 acres. Total production decreases from 33,000

Variables	Unit		2003	2004	2005	2006	2007
Total Acre	Acre	Mean	648.53	636	663.59	649.02	721.49
		SD	481.91	463.52	539.87	507.1	572.37
Total Yield	Bushel	Mean	32892.69	22962.7	25877.03	22469.3	18647.87
		SD	24729.97	20581.16	21405.09	19489.34	20230.77
Total Expense	Dollar	Mean	83464.51	86087.74	96466.09	98341.25	130258.64
		SD	60235.6	57695.3	68314.11	70240.32	93987.14
Crop Income	Dollar	Mean	89003.43	61295.67	69319.64	78308.07	91249.51
		SD	71019.04	55245.14	55437.86	65540.2	105630.49
Gross Income	Dollar	Mean	105122.27	84987.79	87211.04	97757.67	137521.33
		SD	80700.11	61453.97	67242.96	74435.82	121795.23
Net Return	Dollar	Mean	21657.76	-1099.95	-9255.05	-583.59	7262.69
		SD	35071.89	22353.1	20588.15	26445.37	60856.22
Yield	Bushel/Acre	Mean	53.12	39.45	39.91	37.52	26.56
		SD	14.09	17.96	10.24	14.35	16.85
Expense	Dollar/Acre	Mean	141.95	152.73	162.84	172.75	205.39
		SD	46.47	53.75	46.33	58.47	79.29
Gross Income	Dollar/Acre	Mean	170.75	142.56	138.2	165.54	188.78
		SD	53.64	50.08	39.77	57.26	81.43
Net Income	Dollar/Acre	Mean	28.8	-10.18	-24.65	-7.21	-16.62
		SD	43.94	39.9	38.55	47.06	84.51

Table 1: Summary statistics of important variables from 2003 to 2007

bushels in 2003 to 19,000 bushels in 2007, which is accompanied with an increase in total expenses from 84,000 dollars in 2003 to 130,000 dollars in 2007. Crop income decreases from 89,000 in 2003 to less than 80,000 in the sequent years until an inverse to 90,000 occurred in 2007. Gross income fluctuates similarly, with more than 100,000 dollars in 2003 and 2007. Net income decreases from 2003 to 2004 dramatically and is negative in 2004, 2005 and 2006, followed by an increase to 7,000 in 2005. Per acre variables change more regularly: per acre gross income decreases from 2003 to 2005 and increases after 2005. Per acre total expense increases from 2003 to 2007. Total yield and net income had a similar decrease trend; net income is negative from 2004 to 2007. The total trend of changes in expenses does not coincide with the cost amount used in efficiency measures listed in Table 2.

3 Parametric, Nonparametric Production Efficiency Measures

3.1 Parametric Production Analysis

1. Deterministic Parametric Production Frontier using Ordinary Least Squares (OLS)

Deterministic parametric efficiency measures are obtained by formulating an ordinary least squares nonlinear programming optimization problem. With an assumed quadratic cost functional form:

$$Cost_i = \beta_0 + \beta_1 Output_i + \beta_2 Output_i^2 + e_i \quad (1)$$

The error terms, e_i , are constrained to be greater than or equal to zero with an

objective function:

$$\begin{aligned}
\text{Minimize Function}(\text{Output}_i) &= \sum_{i=1}^{183} e_i^2 & (2) \\
\text{s.t. Constraints :} & \\
e_1 = \text{Cost}_1 - \widehat{\text{Cost}}_1 &= \text{Cost}_1 - (\widehat{\beta}_0 + \widehat{\beta}_1 \text{Output}_1 + \widehat{\beta}_2 \text{Output}_1^2) \\
&\vdots \\
e_{183} = \text{Cost}_{183} - \widehat{\text{Cost}}_{183} &= \text{Cost}_{183} - (\widehat{\beta}_0 + \widehat{\beta}_1 \text{Output}_{183} + \widehat{\beta}_2 \text{Output}_{183}^2)
\end{aligned}$$

The parametric cost frontier under variable returns to scale is estimated by imposing curvature restrictions on the cost function, a positive β_2 and a negative β_1 .

Using the General Algebraic Modeling System (GAMS), estimation of the quadratic cost frontier coefficients are obtained by solving the nonlinear programming problem for each year. With the above restrictions imposed, the estimated total cost functions under variable returns to scale assumption $\text{Cost}_i(w, y, Tv)$ in thousands of dollars are listed as follows:

$$\begin{aligned}
\text{Cost}_{2003} &= 2.69 + 0.0134 \times \text{Output}_{2003}^2 \\
\text{Cost}_{2004} &= 3.61 + 0.0217 \times \text{Output}_{2004}^2 \\
\text{Cost}_{2005} &= 6.3 + 0.0235 \times \text{Output}_{2005}^2 \\
\text{Cost}_{2006} &= 3.43 + 0.0233 \times \text{Output}_{2006}^2 \\
\text{Cost}_{2007} &= 5.61 + 0.021 \times \text{Output}_{2007}^2
\end{aligned}$$

Here, to facilitate the calculation: plug the actual output into the estimation results of the quadratic functional form to get the cost under variable returns to scale. The constant return to scale yield is calculated based on equalizing the marginal cost and average cost functions i.e. the CRS point. The average cost of the cost frontier

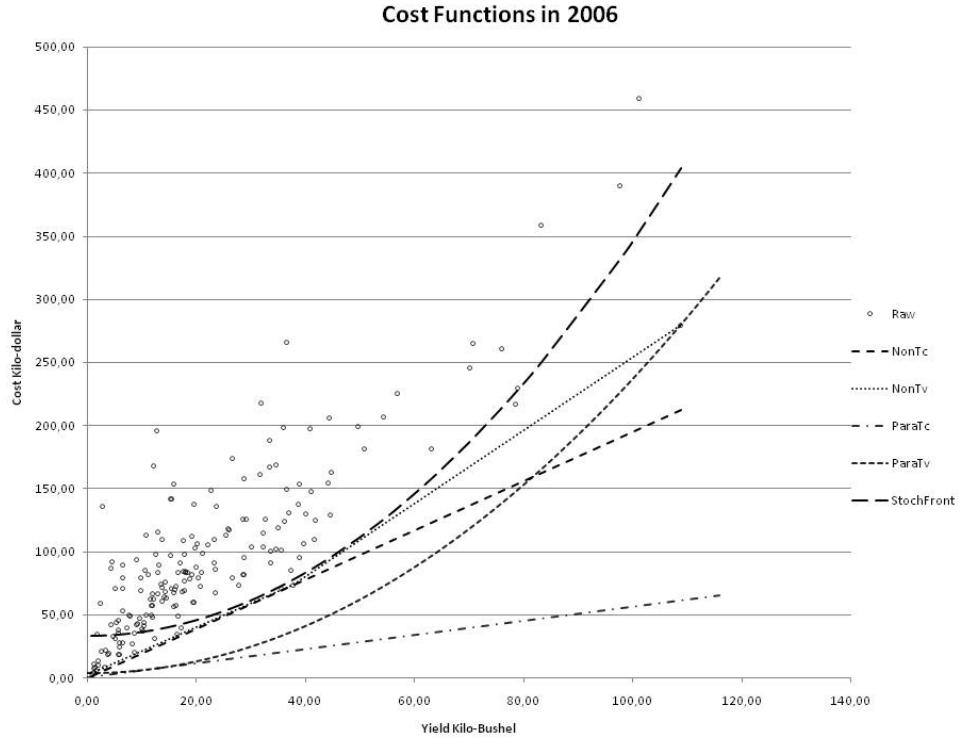


Figure 1: Parametric, nonparametric cost functions comparison in 2006

is calculated by dividing constant returns to scale point cost with constant returns output. Cost under constant returns to scale can be obtained by multiplying actual output of farms with average cost of the cost frontier.

In years 2003, 2004, 2005, 2006 and 2007, the constant returns to scale production point outputs are 14,163; 12,902; 16,368; 12,126; 16,255 bushels respectively. By comparing each farm's production level with these constant returns to scale production levels, the farms' returns to scale can be calculated. The numbers of increasing returns to scale farms are 141; 65; 183; 183; 183 and the numbers of decreasing returns to scale farms are 42; 118; 0; 0; 0 respectively for 2003 to 2007. The increasing number of farms under increasing returns to scale after 2005 indicates that the cost efficiency has been enhanced after 2005. The change from increasing to decreasing returns to scale is caused by increasing yield per acre, most likely accompanying more utilization of owned land and inputs in each acre, whereas the

change from decreasing to increasing returns to scale is the consequence of reduced per acre factor inputs and land acres.

The variable returns to scale cost functions are drawn as the quadratic form, denoted by “ParaTv” in Figure 1, whereas the constant returns to scale cost functions are drawn as straight lines tangent to the quadratic functions, denoted by “ParaTc”. The values of cost under constant returns are calculated based on the actual yield times the average cost of the cost frontier. The values of cost under variable returns are calculated using the cost function coefficients with curvature imposed for the actual yield. The cost amounts under various measurement methods are listed in Table 2.

2. Stochastic Frontier Production Estimation

Due to its closer relationship with the theoretical definition of a cost function relating the minimum cost attainable from producing a set of outputs, stochastic frontier cost estimation is preferred to ordinary least-squares estimation (Coelli 1992). Unless otherwise specified, the stochastic frontier production estimation is constructed in a similar way to Coelli (1996).

With the cost function specified in equation 1, a stochastic frontier cost function with the error term specified in Coelli(1996) as observable $V_i + U_i$, $i = 1...183$ can be expressed as:

$$Cost_i = \beta_0 + \beta_1 Output_i + \beta_2 Output_i^2 + V_i + U_i \quad (3)$$

The unobservable U_i is closely related to the cost of inefficiency, a one-sided component, and it measures how far the firm is operating above the stochastic cost frontier; V_i is the measure of measurement error, a two-sided symmetric term. The efficiency measure relative to a cost frontier is referred as “cost efficiency” in Coelli(1996) approach. With correct curvature imposed, the linear term is dropped from the

stochastic cost function.

By employing of iterative methods, the non-linear log-likelihood function of the stochastic frontier model can be found of its maximum. The cost efficiency can be estimated by:

$$Efficiency_i = \frac{E(C_i|U_i, Y_i)}{E(C_i|U_i = 0, Y_i)} = \frac{Y_i\beta + U_i}{Y_i\beta} \quad (4)$$

Since U_i is unobservable, the conditional expectation of U_i can be derived as conditional upon the observable $V_i + U_i$.

By using maximum likelihood estimates of FRONTIER 4.1, the cost functions expressed in thousand of dollars can be estimated as follows:

$$\begin{aligned} Cost_{2003} &= 16.1737 + 0.015 \times Output_{2003}^2 \\ &\quad (3.0165)(0.0009) \\ \hat{\sigma}^2 &= 3082.5(450.1); \hat{\gamma}^2 = 0.9294(0.0342); \\ log - likelihood &= -902.4 \\ Cost_{2004} &= 21.4029 + 0.0229 \times Output_{2004}^2 \\ &\quad (3.6215)(0.0013) \\ \hat{\sigma}^2 &= 3162.64(489.02); \hat{\gamma}^2 = 0.9282(0.0393); \\ log - likelihood &= -905.26 \\ Cost_{2005} &= 21.8938 + 0.0247 \times Output_{2005}^2 \\ &\quad (3.595)(0.001) \\ \hat{\sigma}^2 &= 3794.5(490.6); \hat{\gamma}^2 = 0.9397(0.0299); \\ log - likelihood &= -918.7 \\ Cost_{2006} &= 33.62 + 0.0312 \times Output_{2006}^2 \end{aligned}$$

$$(6.1356)(0.0021)$$

$$\hat{\sigma}^2 = 3058.9(639.78); \hat{\gamma}^2 = 0.7186(0.1349);$$

$$\log - \text{likelihood} = -936.53$$

$$Cost_{2007} = 20.025 + 0.0209 \times Output_{2007}^2$$

$$(4.505)(0.0017)$$

$$\hat{\sigma}^2 = 15147.8(1.0012); \hat{\gamma}^2 = 0.9886(0.0086);$$

$$\log - \text{likelihood} = -1028.55$$

The production frontier is plotted in Figure 1 as “StochFront.” The cost amounts and cost efficiency measures in Table 2 are calculated based on the coefficient estimation results and actual yield.

3.2 Nonparametric Production Analysis

Färe’s nonparametric measures of the cost efficiency can be obtained by linear programming. Unless otherwise specified, the following linear programming is constructed in a similar way to the DEA method in Featherstone, Langemeier and Ismet(1997). The wheat production process under study employs 9 inputs to produce one output.

$x_1...x_9$ are inputs, and y is the output-wheat. $x_1^*...x_9^*$ denote the optimal inputs employed to yield the output wheat. w denotes an input price vector. k denotes 183 farms. z is an intensity vector for each farm, which denotes the extent to which the farm affects the aggregate efficiency by using its technology. The variable z constructs the frontier technology set. z_k is the intensity variable assigned to firm k from the vector of intensity variable z in the construction of the piece-wise linear frontier on which the data is based. With z_k assumed to be greater than or equal to zero, the minimum cost under variable returns to scale can be computed by a linear

programming:

$$\begin{aligned}
Cost_i(w, y, Tv) &= Minimize : w'x^* \\
s.t. Constraints : \\
\sum_{k=1}^{183} x_{1k} z_k &\leq x_1^* \\
&\vdots \\
\sum_{k=1}^{183} x_{9k} z_k &\leq x_9^* \\
\sum_{k=1}^{183} y_k z_k - y &\geq 0 \\
\sum_{k=1}^{183} z_k &= 1
\end{aligned} \tag{5}$$

The minimum cost under constant returns to scale can be computed in a similar linear programming by releasing the restriction on the intensity factor summed up to one:

$$\begin{aligned}
Cost_i(w, y, Tc) &= Minimize : w'x^* \\
s.t. Constraints : \\
\sum_{k=1}^{183} x_{1k} z_k &\leq x_1^* \\
&\vdots \\
\sum_{k=1}^{183} x_{9k} z_k &\leq x_9^* \\
\sum_{k=1}^{183} y_k z_k - y &\geq 0
\end{aligned} \tag{6}$$

The variable returns to scale cost function is drawn as a nonlinear form, denoted by “NonTv” in Figure 1, whereas the constant returns to scale cost function is

drawn as straight lines starting from the origin under “NonTv” function, denoted by “NonTc.” The cost amounts under various measurement methods are listed in Table 2. “NonTv” overlaps five most cost efficient farms in 2003, and four most cost efficient farms in 2006, which means the “NonTv” depicts the exact cost function frontier all farms can not overtake. It does not exaggerate the cost function frontier as what the stochastic frontier depicts but does not underestimate the cost function frontier as the parametric method does.

3.3 Efficiency Analysis

Based on above results on economies of scale analysis and Featherstone, Langemeier and Ismet(1997), the scale efficiency, overall efficiency and economic efficiency can be measured as follows: scale efficiency for the cost functions measures the extent to which a farm is producing of an efficient scale.

$$\beta_i = \frac{Cost_i(w, y, Tc)}{Cost_i(w, y, Tv)} = \frac{AverageCost \times ActualOutput}{Cost_i(w, y, Tv)} \quad (7)$$

Scale efficiency is measured on whether the farm is of the most efficient size or operating on an optimum scale. From cost perspective, it is denoted as dividing the minimum cost under constant returns to scale by the minimum cost under variable returns to scale. When scale efficiency is not equal to one, the farm is not in a constant returns to scale operation.

Overall efficiency is measured by the minimum cost of producing y , given input prices w under constant return to scale technology, which can be solved in parametric and linear programming depicted in above subsections, in comparison with the actual cost for producing y .

$$\rho_i = \frac{Cost_i(w, y, Tc)}{w'x} = \frac{AverageCost \times ActualOutput}{ActualCost} \quad (8)$$

Summary statistics		Average	Std. Dev.	Maximum	Minimum
Parametric	C(Tc)	12697.54	11013.54	61508.92	436.44
	C(Tv)	23992.42	39897.25	279478.19	3440.2
Nonparametric	C(Tc)	43756.36	37953.23	211962.68	1503.38
	C(Tv)	47622.12	46408.95	279480.00	3443.00
Stochastic Frontier	Cost Eff	1.73	0.4115	3.91	1.02
	C(Tc)	61200	53500	404000	33600

Table 2: Comparative statistics of cost under variable returns, constant returns and stochastic frontier 2006

Economic efficiency means a unit of good is produced at the lowest possible cost, or the maximum output can be produced given certain inputs.

$$EconomicEfficiency = \frac{Cost_i(w, y, Tv)}{w'x} = \frac{Cost_i(w, y, Tv)}{ActualCost} \quad (9)$$

Overall and economic inefficiency are due to farms' producing above the cost frontiers. $C_i(w, y, Tv)$ is estimated above. Overall efficiency is the product of allocative, pure technical, and scale efficiency (Featherstone, Langemeier and Ismet 1997).

4 Results and Comparison

As table 2 indicates, if cost efficiency is defined by the minimum cost expended to produce certain output, the rank from the minimum to the maximum cost efficiency in terms of average C(Tc) in nonparametric method is 2005, 2006, 2003, 2004 and 2007; in terms of average C(Tv) in nonparametric method is 2005, 2006, 2003, 2004 and 2007, which means nonparametric measures are identically ranked. The rank from minimum to maximum cost efficiency in terms of average C(Tc) in parametric method is 2005, 2007, 2004, 2006 and 2003; in terms of average C(Tv) in parametric method is 2005, 2003, 2004, 2006 and 2007, which means nonparametric measures are not identically ranked. The rank from minimum to maximum cost efficiency

Summary statistics of efficiency	Average	Std. Dev.	Maximum	Minimum
2005				
ParaSE	0.77	0.22	1.00	0.16
NonSE	0.87	0.13	1.00	0.38
ParaOE	0.20	0.06	0.44	0.07
NonOE	0.46	0.15	1.00	0.16
ParaEE	0.30	0.18	1.00	0.10
NonEE	0.53	0.19	1.00	0.19
2006				
ParaSE	0.74	0.23	1.00	0.13
NonSE	0.92	0.10	1.00	0.44
ParaOE	0.13	0.05	0.29	0.01
NonOE	0.44	0.18	1.00	0.04
ParaEE	0.21	0.16	1.00	0.03
NonEE	0.48	0.20	1.00	0.05
2007				
ParaSE	0.68	0.27	1.00	0.00
NonSE	0.76	0.21	1.00	0.00
ParaOE	0.10	0.08	0.43	0.00
NonOE	0.23	0.18	1.00	0.00
ParaEE	0.17	0.17	1.00	0.02
NonEE	0.29	0.21	1.00	0.03

Table 3: Comparative statistics of scale efficiency, overall efficiency and economic efficiency in 2005 to 2007

in terms of average $C(T_c)$ in stochastic frontier method is 2005, 2006, 2003, 2004 and 2007. The cost efficiency measures defined in Coelli (1996) in terms of averages are ranked in 2005, 2006, 2007, 2004 and 2003 sequence, which means stochastic frontier measures are not identically ranked. Overall the most consistent result on cost efficiency is that 2005 is the least cost efficient, and 2007 is the most cost efficient year. The cost efficiency measures are not same as the actual cost expended in production listed in Table 1, where 2003 is the year with the minimum cost expenditure, but 2007 is the year with the maximum cost expenditure. Overall the price fluctuation is caused by the enhanced cost efficiency from 2005 to 2007.

1. Results of Ordinary Least Squares (OLS) regressing parametric efficiency measures on nonparametric efficiency measures

Parameter	Estimate	Std Err	t Value	Pr > t
2006				
Scale efficiency	Parametric	Adj R-square	0.8207	
Overall efficiency	7.6672	.3636	21.09	0.000
Economic efficiency	-1.6634	.1904	-8.74	0.000
Scale efficiency	Nonparametric	Adj R-square	0.8679	
Overall efficiency	2.4360	.3756	6.48	0.000
Economic efficiency	-.5788	.3424	-1.69	0.093

Table 4: Regression of scale efficiency on overall, economic efficiency measures in parametric and nonparametric methods

Efficiency measures using the nonparametric method are listed in Table 3. The consistent result from both methods is that scale efficiency is decreasing, especially from 2006 to 2007, accompanying the decreases in economic efficiency, overall efficiency from 2005 to 2007 in both methods. All efficiency estimates using nonparametric method are greater than the efficiency measures in the parametric method.

Table 4 reports the regressing scale efficiency on overall, economic efficiency measures in 2006. The common result is that the negative coefficients of economic efficiency in both methods for all years, which means a trade-off between scale efficiency and economic efficiency. Scale efficiency and overall efficiency complement each other in explanation. This is explained by the fact that scale efficiency can also be obtained by dividing overall efficiency with economic efficiency.

2. Results of correlation analysis on parametric efficiency measures and nonparametric efficiency measures

Table 5 shows the correlation of all efficiency measures in respective years. Interpreting across different time periods, scale and economic efficiency correlation measures are less identical in both methods. Overall efficiency's correlations with other efficiency measures in both methods are very identical. In identical years, there are total correlations between nonparametric and parametric overall efficiency. The correlations between parametric and nonparametric scale efficiency measures are moderate,

2006	SEPara	SEnon	OEPara	OEnon	EEPara	EEnon	CostEff
SEPara	1						
SEnon	0.6515	1					
OEPara	-0.1716	0.2374	1				
OEnon	-0.1716	0.2374	1	1			
EEPara	-0.7484	-0.4713	0.5981	0.5981	1		
EEnon	-0.3822	-0.0989	0.9318	0.9318	0.8086	1	
CostEff	0.4035	0.2506	-0.6672	-0.6672	-0.6094	-0.7359	1
2007							
SEPara	1						
SEnon	0.8139	1					
OEPara	0.1509	0.5246	1				
OEnon	0.1509	0.5246	1	1			
EEPara	-0.3410	0.0252	0.7604	0.7604	1		
EEnon	-0.0970	0.2137	0.8914	0.8914	0.9268	1	
CostEff	0.2791	0.0927	-0.513	-0.513	-0.5462	-0.625	1

Table 5: Correlation of all efficiency measures from 2006 to 2007

which are higher than 0.5 in absolute values. There are high economic efficiency measure correlations between parametric and nonparametric measures, which were higher than 0.85 in absolute values. Economic efficiency parametric measures are moderately correlated with overall efficiency in both parametric and nonparametric approaches, which are identically more than 0.6. Economic efficiency nonparametric measures are highly correlated with overall efficiency in both approaches, which are identically more than 0.8. The overall efficiency parametric and nonparametric measures are correlated identically with other efficiency measures. Since the overall efficiency is the ratio between cost under constant and actual cost, the identical correlation of overall efficiency with other efficiency measure means costs under constant returns to scale are highly correlated between parametric and nonparametric methods. Scale efficiency measures are least correlated with economic and overall efficiency measures. Scale efficiency is the least correlated factor with economic and overall efficiency measures. Cost efficiency measures of stochastic frontier are negatively correlated with other efficiency measures.

5 Conclusion

Parametric and nonparametric methods have been used to analyze efficiency of a sample of 183 wheat farms over five years. Generally speaking, scale efficiency measures from the parametric method are smaller in respective years. The scale efficiency estimates in parametric and nonparametric cost methods have been used in a specific investigation to indicate the underlying reason for the changes in inefficiency.

The correlation analysis of efficiency measures shows that there is a trade-off between scale efficiency and economic efficiency. Scale efficiency and overall efficiency complement each other in explanation. Interpreting across different time periods, scale and economic efficiency correlation measures are less identical in both methods. Overall efficiency's correlations with other efficiency measures in both methods are very identical. In identical years, there are total correlations between nonparametric and parametric overall efficiency. The correlations between parametric and nonparametric scale efficiency measures are moderate, which were higher than 0.5 in absolute values. There are high economic efficiency measure correlations between parametric and nonparametric measures, which were higher than 0.85 in absolute values. Economic efficiency parametric measures are moderately correlated with overall efficiency in both parametric and nonparametric approaches, which are identically more than 0.6. Economic efficiency nonparametric measures are highly correlated with overall efficiency in both approaches, which are identically more than 0.8. The overall efficiency parametric and nonparametric measures are correlated identically with other efficiency measures. Since the overall efficiency is the ratio between cost under constant and actual cost, the identical correlation of Overall efficiency with other efficiency measure means costs under constant returns to scale are highly correlated between parametric and nonparametric methods. Scale efficiency measures are least correlated with economic and overall efficiency measures.

The increasing number of farms under increasing returns to scale after 2005 indicates that the cost efficiency has been enhanced after 2005. Scale efficiency is decreasing, especially from 2006 to 2007, accompanying the decreases in economic efficiency, overall efficiency from 2005 to 2007 in both methods. Scale efficiency are least correlated with economic and overall efficiency measures. 2005 is the least cost efficient year, whereas 2007 is the most cost efficient year. Though cost efficiency measures are not identical among different approaches being used, frontier cost efficiency measures are negatively correlated with other efficiency measures. Overall the price fluctuation is caused by the enhanced cost efficiency from 2005 to 2007.

The efficiency measures from the deterministic parametric method are smaller than those from the deterministic nonparametric method. Generally, there is a trade-off between scale efficiency and economic efficiency. In deterministic nonparametric method, the economic efficiency, scale efficiency and overall efficiency results are invariant to the number of inputs or the dimensionality. Thus, Ramanathan's (2003) concerns regarding the dimensionality of the frontier only hold for allocative and pure technical efficiency measures. If allocative and pure technical efficiency are examined, these results depend on the number of input categories. Across years, scale and economic efficiency correlation measures are less identical between the nonparametric and parametric methods. Overall efficiency is highly correlated with other efficiency measures in both methods. The stochastic parametric efficiency results are closely aligned to the results from the deterministic methods with an imposition of curvature in the cost function. This work illustrates the importance of holding curvature properties in the underlying cost function when calculating stochastic frontier results.

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