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

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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 nonparametric 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. The cost function under stochastic frontier was the maximum in comparison with deterministic results. Cost efficiency relative to a cost frontier, which measures inefficiency, after being inversed to a percentage measurement with imposed curvature, was highly positively correlated with economic efficiency in deterministic parametric method. Cost efficiency was bigger than economic efficiency from deterministic parametric method and its relationship with economic efficiency in deterministic nonparametric method was ambiguous. 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: Q12

1 Introduction

Wheat price variability increased by 50% from 2003-2006 to 2007 in the U.S.. A sample of 183 wheat farms data from 2003 to 2007 provided by the Kansas Farm Management Association (KFMA) is used to examine the efficiency of Kansas farms, 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 efficiency measures are sensitive to approach 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. Technical efficiency gains came from the improvements in decision-making. Country effects on mean technical efficiency (MTE) varied by regional and income variables. Results also 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 methodology used to measure TE was arbitrary and based on the objective of the empirical study and the data available. They also suggested 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.

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 to be sensitive to outliers, that could be a problem with the deterministic frontier. The nonparametric method or Data Envelopment Analysis (DEA) does not require a specific functional form and therefore has some advantages over parametric methods. However, this mathematical programming-based technology also has 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, stochastic frontier and deterministic nonparametric production frontier to measure efficiency on wheat enterprise data over five years, in order to analyze annual efficiency changes, thereafter compares the result of 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.

The study shows the efficiency measures are variant to the choice of parametric and nonparametric methods. The efficiency measures from the deterministic parametric method are smaller than those from the deterministic nonparametric method. There is a tradeoff between scale efficiency and economic efficiency. Scale efficiency and overall efficiency compliment each other in explanation. There are high economic efficiency correlations between parametric and nonparametric measures. In the deterministic nonparametric method, the economic efficiency, scale efficiency and overall efficiency results are invariant to the number of inputs or the dimensionality. Only allocative and pure technical efficiency measures depend on the dimensionality. The cost function under stochastic frontier is the maximum in comparison with deterministic results. Cost efficiency relative to a cost frontier, which measures inefficiency, after being inversed to a percentage measurement with imposed curvature, is highly positively correlated with economic efficiency in deterministic parametric method. Imposing curvature in the cost function in stochastic frontier results significantly improves the comparability of cost efficiency measurement with deterministic method results.

2 Data and Analysis

Wheat enterprise data from 2003 to 2007, provided by the KFMA, is used for this analysis on 183 sample Kansas farms. The KFMA individual originally collected data of 24 input categories, and had been reclassified into data with nine input categories on capital including repairs, interest paid, machinery hired, undivided auto, cash farm rent, depreciation, and interest charge; Labor includes unpaid operational labor and hired

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

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

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

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:

$$\begin{aligned} MinimizeFunction(Output_i) &= \sum_{i=1}^{183} e_i^2 \quad (2) \\ s.t.: & \\ e_1 = Cost_1 - \widehat{Cost}_1 &= Cost_1 - (\widehat{\beta_0} + \widehat{\beta_1} Output_1 + \widehat{\beta_2} Output_1^2) \\ &\vdots \\ e_{183} = Cost_{183} - \widehat{Cost}_{183} &= Cost_{183} - (\widehat{\beta_0} + \widehat{\beta_1} Output_{183} + \widehat{\beta_2} Output_{183}^2) \end{aligned}$$

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

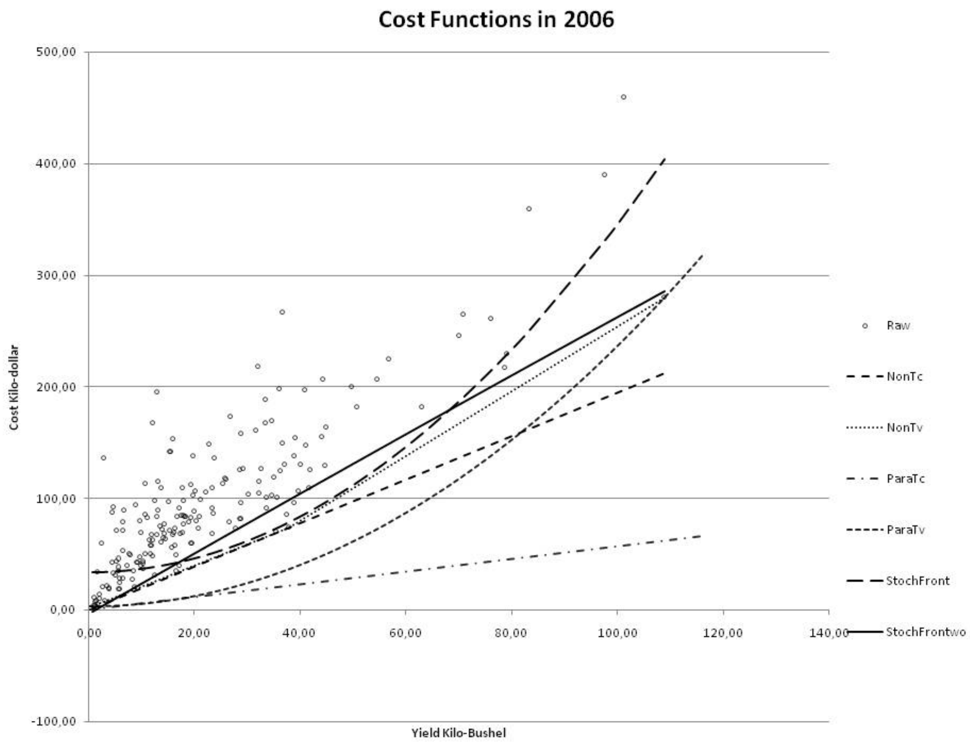

Figure 1: Parametric, nonparametric cost functions comparison in 2006

Using the General Algebraic Modeling System (GAMS), estimation of the quadratic cost frontier coefficients is 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 $Cost_i(w, y, Tv)$ in thousands of dollars are found in Table 2. To estimate the frontier: plug the actual output into the estimated 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 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 calculated above. 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 the constant returns to scale production levels, the farms' returns to scale can be obtained. 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 variable returns to scale cost function is in a quadratic form, denoted by "ParaTv" in Figure 1, whereas the constant returns to scale cost function is a straight line tangent to the quadratic function, denoted by "ParaTc". The values of cost under constant returns are calculated based on multiplying the actual yield by the average cost of the cost frontier. The values of cost under variable returns are calculated using the estimated coefficients of cost function with curvature imposed for the actual yield. The cost amounts of various analysis methods are found in Table 3.

2. Stochastic Frontier Production Estimation

Due to its 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 by Coelli (1996) as observable $V_i + U_i$, $i = 1...183$ can be expressed as:

$$Cost_i = \beta_0 + \beta_1 Output_i + \beta_2 Output_i^2 + V_i + U_i \tag{3}$$

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. To correctly impose the curvature, the linear term $\beta_1 Output_i$ is dropped from the stochastic cost function.

Employing of iterative methods, the non-linear log-likelihood function of the stochastic

Table 2: Estimation Results of Parametric Cost Function * significant at 5%, Standard Errors are in [ ]

Cost of i: Year	Explanatory	OLS	StochFrontw	StochFrontwo
2006	Intercept	3.43	33.62*	-3.62
			[6.1356]	[3.73]
	Output			2.72*
				[0.25]
	Output^2	0.0233	0.0312*	-0.0006
			[0.0021]	[0.002]
	log-likelihood		-936.53	-891.7

frontier model is maximized. Cost efficiency can be estimated by:

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

The efficiency relies on the value of unobservable U_i being predicted, which can be achieved by the derived conditional expectation of U_i upon the observable $V_i + U_i$. In the cost function case, it takes a value between one and infinity. In contrast to the cost efficiency defined in Coelli, Rahman and Thirtle (2002), the larger "cost" efficiency relative to a cost frontier denotes a more inefficient farm production with the assumed allocative efficiency. To be consistent with the efficiency measurements in other methods, inversing the "cost" efficiency relative to a cost frontier yields a comparable cost efficiency to efficiency in deterministic methods.

Using maximum likelihood estimates of FRONTIER 4.1, the cost functions expressed in thousands of dollars are estimated in Table 2. Without imposing curvature, the only significant parameter is the one of the linear term β_1. However, with curvature being imposed, the significant parameters become the intercept β_0 and the one of quadratic term β_2. Moreover, the log-likelihood absolute values are bigger than the case without imposed curvature. In comparison with the estimation results of OLS, the difference in β_2 is very minor and significant difference lies in the intercepts.

The production frontier is plotted in Figure 1 as "StochFront." For comparison, the production frontier without correctly imposed curvature is denoted as "StochFrontwo," which is a straight line. With imposed curvature, the stochastic frontier cost function shows the biggest cost value in all functions. The cost amounts in Table 3 are calculated based on the estimated coefficient results and actual yield. C(Tv) denotes cost value obtained from estimation with imposed correct curvature, and C(Tc) denotes cost value of estimation without imposing correct curvature respectively. Generally speaking, with 2006 as an exemption, the values and standard errors of total cost are smaller in curvature imposed case than the case without imposed curvature.

3.2 Nonparametric Production Analysis

Färe's nonparametric measures of the cost efficiency can be obtained by linear programming (Färe et.al 1985,1994). Four efficiency measures: technical, allocative, cost and scale efficiency are briefly covered in Coelli, Rahman and Thirtle (2002). 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 nine inputs to produce one output.

$$\begin{aligned} Cost_i(w, y, Tv) &= Minimize : W^{'}X^{*} \\ s.t. Xz &\leq X^{*} \\ Yz - YI &\geq 0 \\ zI &= 1 \end{aligned} \tag{5}$$

$X = [x_{ki}]$ is a 9 × 183 input matrix, and $Y^{'} = [y_i]$ is a 1× 183 the output-wheat vector. I is a 1 × 183 identity vector. $X^{*} = [x^{*}_{k}]$ denotes the optimal 9× 1 input vector employed to yield the output wheat. $W^{'} = [w_k]$ denotes an 1× 9 input price vector. k denotes 9 inputs and takes value from 1 to 9. i from 1 to 183 denotes 183 farms. z is an intensity i-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_i is the intensity variable assigned to firm i from the vector of intensity variable z in the construction of the piece-wise linear frontier on which the data is based. With z_i assumed to be greater than or equal to zero, the minimum cost under variable returns to scale can be computed by linear programming.

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:

$$\begin{aligned} Cost_i(w, y, Tc) &= Minimize : W'X^* \\ s.t. Xz &\leq X^* \\ Yz - YI &\geq 0 \end{aligned} \tag{6}$$

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 found in Table 3. Without exception, the cost values of nonparametric method are greater than their corresponding measurements in deterministic parametric method.

3.3 Efficiency Analysis

Based on above results, 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.

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

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.

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

Economic efficiency (or cost efficiency defined in Coelli, Rahman and Thirtle 2002) means a unit of good is produced at the lowest possible cost, or the maximum output can be produced given certain inputs.

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

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 or the product of economic (or cost efficiency defined in Coelli, Rahman and Thirtle 2002) and scale efficiency (Featherstone, Langemeier and Ismet 1997).

Changing the input categories from nine back to original 24 input categories, the invariance of efficiency to input dimensionality can be verified through a linear reprogramming in General Algebraic Modeling System (GAMS). Economic efficiency, scale efficiency and overall efficiency results are invariant to the number of inputs or the dimensionality. Only allocative and pure technical efficiency measures depended on the dimensionality.

Table 3: Comparative statistics of cost under variable returns, constant returns and stochastic frontier

Summary statistics		Average	Std. Dev.	Maximum	Minimum
Parametric					
2003	C(Tc)	12474.65	9378.92	48498.5	358.55
	C(Tv)	25313.7	34135.88	221620.3	2697.82
2004	C(Tc)	12856.79	11523.37	55046.47	0
	C(Tv)	24192.9	36886.44	213331.81	3612.1
2005	C(Tc)	19919.96	16477.49	97598.23	1042.68
	C(Tv)	32761.35	47545.35	384290.41	6343.18
2006	C(Tc)	12697.54	11013.54	61508.92	436.44
	C(Tv)	23992.42	39897.25	279478.19	3440.2
2007	C(Tc)	12881.56	13974.99	74665.03	0
	C(Tv)	21651.66	34215.71	253844.3	5614.63
Nonparametric					
2003	C(Tc)	34785.04	26152.68	135235.95	999.37
	C(Tv)	44178.19	39269.91	221626	2699
2004	C(Tc)	30399.61	27246.65	130155.99	0
	C(Tv)	37234.46	41045.27	252316.00	3632.00
2005	C(Tc)	45456.32	37600.7	222714.03	2380.23
	C(Tv)	53472.59	54410.86	384293.00	6344.00
2006	C(Tc)	43756.36	37953.23	211962.68	1503.38
	C(Tv)	47622.12	46408.95	279480.00	3443.00
2007	C(Tc)	29840.72	32373.67	172964.65	0
	C(Tv)	36098.58	47396.71	481262.00	5626.00
Stochastic Frontier					
2003	C(Tc)wo	47400	40272	208000	-292000
	C(Tv)w	41500	38246	261000	16200
2004	C(Tc)wo	45300	41478	206000	1460
	C(Tv)w	43200	39016	243000	21400
2005	C(Tc)wo	62000	54206	334000	2650
	C(Tv)w	49700	49941	419000	21900
2006	C(Tc)wo	57000	52078	285000	-1520
	C(Tv)w	61200	53500	404000	33600
2007	C(Tc)wo	41500	35848	195000	7680
	C(Tv)w	35800	33657	264000	20000

4 Results and Comparison

As table 3 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 in terms of average C(Tc) 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, as 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 2006.

Efficiency measures of different analysis methods are listed in Table 4. 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 all methods. All mean efficiency estimates using nonparametric method are greater than the efficiency measures in the deterministic parametric method. With 2003 and 2005 as exception, mean cost efficiency in stochastic frontier with correct curvature are greater than mean economic efficiency estimates using nonparametric method.

In terms of economic efficiency indicator, without exception, there is no fully efficient farm from curvature imposed stochastic frontier method. In 2007, the average economic

Table 4: Comparative statistics of scale, overall, economic and cost efficiency from 2006 to 2007

Efficiency	Average	Std. Dev.	Maximum	Minimum
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
CostEffw	0.60	0.12	0.99	0.26
CostEffwo	0.55	0.24	1.00	0.00
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
CostEffw	0.33	0.18	0.97	0.01
CostEffwo	0.36	0.20	0.97	0.00

efficiency in deterministic parametric method is 0.17 with two fully efficient farms, and in nonparametric method mean economic efficiency is 0.29 with three fully efficient farms. There are two identical fully efficient farms with one extra full efficient farm in nonparametric method. In 2006, the average economic efficiency in nonparametric method is 0.48 with two fully efficient farms and four farms defining the frontier but in deterministic parametric method, the average economic efficiency is 0.21 without fully efficient farms. Similarly, in 2005, the numbers of fully efficient farms are two and three in parametric and nonparametric methods with two identical farms. In 2004, the numbers of fully efficient farms change to two identical farms. In 2003, there is one fully efficient farm in deterministic parametric method with five farms defining the frontier and four fully efficient farms in nonparametric method. Overall the numbers of fully efficient farms are not the same over different methods and farms are producing at half more than the lowest possible per unit cost.

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

Table 5: Regression Results of Parametric on Nonparametric, Cost Efficiency * significant at 5%, Standard Errors are in [ ]

Dependent	Explanatory					
ParaEE	Intc	NonEE	Intc	CostEffw	Intc	CostEffwo
2007	-.0536*	.7629*	-0.0839*	0.7793*	-0.071*	0.6745*
	[.0081]	[.0229]	[0.0136]	[0.0365]	[0.0147]	[0.0358]
$AdjR^2$		0.8582		0.7143		0.661
ParaSE	Intc	ParaOE	ParaEE	CostEffw		$AdjR^2$
2006	.5864*	2.2952*	-1.4029*	.0913*		0.686
	[.0856]	[.2679]	[.0815]	[.0341]		
NonSE	Intc	NonOE	NonEE			$AdjR^2$
2006	.8923*	1.4182*	-1.2436*			0.8325
	[.0082]	[.0473]	[.0427]			

on nonparametric efficiency and stochastic frontier efficiency measures

Table 5 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 compliment each other in explanation. This is explained by the fact that scale efficiency can also be obtained by dividing overall efficiency with economic efficiency.

Table 5 also indicates the parametric economic efficiency is highly positively correlated with cost efficiency, which means the cost efficiency in stochastic frontier method after being inversed measures efficiency. Imposing curvature on the stochastic frontier improves the results by enhancing the correlation between both parametric methods.

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

Table 6 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

Table 6: Correlation of all efficiency measures

2006	SEPara	SEnon	OEPara	OEnon	EEPara	EEnon	CostEffw	2006
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		
CostEffw	-0.5353	-0.3315	0.7178	0.7178	0.7707	0.8172	1	
CostEffwo	-0.2297	0.1939	0.8334	0.8334	0.618	0.7943	0.6277	1

between nonparametric and parametric overall efficiency. The correlations between parametric and nonparametric scale efficiency measures are moderate, 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 without imposed curvature are positively correlated with efficiency measures from deterministic methods, but with imposed curvature the correlation level increases, which indicates imposing curvature improves the stochastic frontier measures of efficiency.

Table 6 also reports the result of correlation between cost efficiency with imposed curvature and cost efficiency without curvature being imposed. The common result is the highly positive correlation between cost efficiencies for all years, which shows compliment between stochastic frontiers with and without curvature.

5 Conclusion

Parametric and nonparametric methods have been used to analyze efficiency of a sample of 183 wheat farms over five years. Generally speaking, efficiency measures are variant to the choice of approaches, i.e. efficiency measures from the deterministic parametric method are smaller in respective years. The scale efficiency estimates in parametric and nonparametric cost methods as well as cost efficiency 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 compliment 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. Correlations between economic, overall efficiency from deterministic methods with cost efficiency in stochastic frontier with imposed curvature are negatively moderate. 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 identically correlated 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 efficiency measures from the deterministic parametric method are smaller than those from the deterministic nonparametric method. In most cases, the stochastic frontier cost efficiency are greater than the economic efficiency in 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 relative to a cost frontier results, are highly positively aligned to the economic efficiency 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 of stochastic frontier results.

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