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RESEARCH ARTICLE

Farm Level Technical Efficiency in Paddy Production: A Translog Frontier Production Function Approach

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Abstract

The Paper empirically estimated the technical efficiency scores and the factors of inefficiency of the 200 farm households of paddy production in the study area in Odisha. Frontier production form was tested to be significant over the ordinary form. The joint estimation of the parameters of the production function and inefficiency function suggested that 99% of the variation in the efficiency is due to technical efficiency. The mean technical efficiency of 97.04% implied that there was possibility of improvement in efficiency and the experience, high school as well as college education were positively contributing in improving the technical efficiency. Both Cobb Douglas and Translog forms were fitted because of the robustness of the later. Focus on educating farmers through public and private participation was very important for improving the efficiency. Farm oriented education should be introduced for better farming skills of the farm people.

Introduction

Indian agriculture, the major source of direct employment (65% of the total population) accounts for around 22% of the Gross Domestic Product (GDP) of the economy. Since Land, water and government subsidy are limited in supply sustainable agricultural production especially food production in the context of national food security is a major issue of concern. To enable enhancement of production, augmentation of government procurement, improving productivity through efficient resource allocation under the existing technology is the urgent need of the time. The target rate of 4% growth of Indian agriculture cannot be achieved unless farm households at micro level are efficient. The failure of being more efficient is reflected in terms of low productivity and low economic growth. Hence, examination of farm-specific technical efficiency and the factors contributing to such inefficiency has major academic and economic policy implications.

Farrell (1951) distinguishes between technical efficiency and allocative efficiency (or price efficiency) in production through the use of a frontier function approach. Given that the production function had constant returns to scale, Farrell (1957) assumed that the observed input per unit of output values for firms would be above the so called unit isoquant. The deviation of observed input per unit of output was considered to be associated with technical inefficiency. Hence, the technical efficiency is the ability to produce a given level of output with minimum quantity of inputs under a given technology. Farrell (1957) suggested that the efficient unit isoquant be estimated by programming methods such that the convex function involved was never above any of the observed input-per-unit-of-output ratios.

Production frontier models are used either in deterministic form (Aigner and Chu, 1968) in the context of Cobb-Douglas model and first presented by Afriat (1972), or in stochastic frontier model independently proposed by Aigner, Lovell and Schmidt (1977) and Meeusen and Van Den Broeck (1977) or through the panel model (Pitt and Lee, 1981). More recently stochastic frontier models for panel data have been presented in which the time varying effects have been specified (Cornwell,

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Schmidt and Sickles, 1990). Richmond (1979) had considered the deterministic model under the assumption that the random error had gamma distribution. Schmidt (1976) pointed out that linear and quadratic programming technique if the random variables had exponential or half normal distribution could obtain the maximum likelihood estimates for the beta parameter of the model. Kumbhakar (1990) presented a model in which the non-negative farm effects were the product of an exponential function of time invariant random variable. Battese (1990) suggested a time varying firm effects model for incomplete panel data, such that the technical efficiencies of firms either monotonically increased or decreased or remained constant over time.

Aigner, Lovell and Schmidt (1977) applied the stochastic frontier production function in the analysis of aggregative data on the US primary metals industry (involving 28 states) and US agricultural data for six years and the 48 coterminous states. For these applications, the stochastic frontier was not significantly different from the deterministic frontier. by Meeusen and Van den Broeck (1977) were also obtained similar results in their analyses for ten French manufacturing industries. Amongst the studies, Battese and Corra (1977) made the first application of stochastic frontier model to farm level agricultural data. The subsequent studies made on farm production are (Kalirajan, 1981, 1982; Bagi 1982a). Bagi and Huang (1980) estimated a translog stochastic production. The Cobb-Douglas stochastic frontier model was not found to be adequate representation of the data, given the specification of the translog model for both crop and mixed firm were estimated to be 0.73 and 0.67 respectively. In case of Bagi (1982b) the Cobb-Douglas form was judged not to be an adequate representation of the data given the assumption of translog model. The other studies related to translog frontier functions are Kalirajan and Flinn (1983); Huang and Bagi (1984); Kalirajan and Shand (1986) and Ali and Flinn (1989). Who also found inadequacy of the Cobb-Douglas production function over the translog function. However, Bravo Eureta and Rieger (1990) found that different methods were highly correlated and gave similar ordinary ranking of the farms.

The present paper employs stochastic frontier production function having composite error as proposed by Aigner, Lovell and Schmidt (1977). As proposed by Battese and Coelli (1995), the farm specific efficiency scores and parameters of the inefficiency factors have been jointly estimated by using the Frontier 4.1c. The choice of appropriate functional form between Cobb Douglas and Translog frontier production functions have been tested using the generalized likelihood ratio test and the maximum Likelihood estimates of the parameters of the functions have been estimated. Secondly, the significance of the factors (education of the effective head, family education experience) contributing to technical inefficiency has been explored. Thirdly, the contribution of inefficiency and the random factors to the paddy production function have also been estimated.

MATERIALS AND METHODS:

Primary data on the Paddy production from the Goleipur Panchayat of the Jajpur district of Odisha, India has been collected from 200 farm households through the questionnaire. The study area is chosen on the basis that it is well connected to the big markets of the districts as well as the capital city of the state through the National Highway-5. Secondly, the area is located on the bank of the river Kharashrota. Hence, the farm households grow multiple crops. The paddy crop is popularly known as Swarna.

The stochastic frontier models as originally proposed by Battese and Coelli (1995) can be written for the cross section data as

$$\mathbf{Y_i = \exp(\beta X_i + V_i - U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)}$$

Where, Y_i is the output of the ith farm , X_i is the vector of the ith farm, V_i is the statistical noise of the ith farm assumed to be independently and identically distributed random errors which have normal distribution with (0, σ_v^2). U_i' s are nonnegative unobservable random variable of technical inefficiency of production such that for given technology and levels of input the observed output falls short of its potential output. The technical inefficiency model is proposed by Battese and Coelli (1995) is described by

$$\mathbf{U_i = \delta_0 + \delta_i Z_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)}$$

Z_i is the explanatory variable of technical inefficiency of the ith farm and δ is the unknown parameters to be estimated . The Maximum Likelihood Estimator specifies U_i and V_i are independent to each other. The technical efficiency of the ith farm is estimated as the ratio of observed to maximum feasible output where the later is provided by the stochastic frontier production function.

$$\mathbf{TE_i = \exp(\beta X_i + V_i - U_i) / \exp(\beta X_i + V_i)}$$

$$\mathbf{TEi = \exp(-U_i) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)}$$

If U_i is zero the farm under consideration is 100 per cent efficient. The parametric model is estimated in terms of the variance parameters $\boldsymbol{\sigma_s^2 = (\sigma_u^2 + \sigma_v^2)}$ and $\boldsymbol{\gamma = \left(\sigma_u^2 / (\sigma_u^2 + \sigma_v^2)\right)}$. In case of cross sectional data the technical inefficiency model can only be estimated if the inefficiency component U_i are stochastic and have particular distributional properties. Therefore, it is of interest to test the null hypothesis that **γ** are non stochastic. The parameter γ has a value between 0 and 1 in such a way that it is desirable to test the null hypothesis that Ho: **γ =0** whether traditional production function is an adequate representation of the sample data. If so the non negative random variable U_i is absent from the model. The Generalized Likelihood Ratio test statistic can be calculated as

$$\Lambda = \left\{-2\log\left[L(H_1) - L(H_0)\right]\right\} \quad \ldots\ldots(4)$$

$L(H_0)$ is the value of the likelihood function for the frontier model in which parameter restrictions specified by null hypothesis are imposed and $L(H_1)$ is the value of likelihood function of the frontier model. If H_0 is true then λ has approximately a chi-square distribution with degrees of freedom equal to the difference between the parameter estimated under H_1 and H_0 respectively. The two functional forms for stochastic frontier production (Cobb-Douglas and Translog) are as

$$LnY_i = \beta_0 + \Sigma^5_{i=1} \beta_i \ln X_i + (V_i - U_i) \ldots\ldots(5)$$

$$LnYi = \beta_0 + \Sigma^5_{j=1} \beta_j \ln X_{ji} + ½ \Sigma^5_{j=1} \Sigma^5_{k=1} \beta_{jk} LnX_{ji} LnX_{ki} + V_i - U_i \ldots\ldots(6)$$

The specific form of the Cobb Douglas and Translog production function model are as:

$$LnYi = \beta_0 + \beta_1 \ln VC + \beta_2 \ln NSA + \beta_3 \ln LBD + \beta_4 \ln MANR + \beta_5 \ln FER + (V_I - U_i) \ldots\ldots(7)$$

$$\begin{aligned} Ln\ Y = {} & \beta_0 + \beta_1 Ln\ VC + \beta_2 Ln\ NSA + \beta_3 Ln\ LD + \beta_4 Ln\ MAN + \beta_5 Ln\ FER + \\ & ½\ \beta_{11} Ln\ VC^2 + ½\ \beta_{22} Ln\ NSA^2 + ½\ \beta_{33} Ln\ LD^2 + ½\ \beta_{44} Ln\ MAN^2 + \\ & ½\ \beta_{55} Ln\ FER^2 + \beta_{12} Ln\ VC\ Ln\ NSA + \beta_{13} Ln(VC) Ln(LBD) + \\ & \beta_{14} Ln(VC) Ln(MANR) + \beta_{15} Ln(VC) Ln(FER) + \beta_{23} Ln(NSA) Ln(LBD) + \\ & \beta_{24} Ln(NSA) Ln(MANR) + \beta_{25} Ln(NSA) Ln(FER) + \beta_{34} Ln(LBD) Ln(MANR) + \\ & \beta_{35} Ln(LBD) Ln(FER) + \beta_{45} Ln(MANR) Ln(FER) + (V_I - U_i) \ldots\ldots(8) \end{aligned}$$

Where, Y_i = value of output in Rupees;

VC = Value of the capital (calculated at 12% depreciation per annum)

NSA = Net Sown Area in Acres (1acre = 100 $meter^2$)

LBD = Labor Days (one LBD is equal to 6 hours);

MANR = Manures and Composts (in quintals)

FER = Fertilizer in Kg. (N+P+K); β_0 is the constant term, $\boldsymbol{\beta_1}$ to $\boldsymbol{\beta_5}$ **are the first derivatives;** $\boldsymbol{\beta_{11}, \beta_{22}, \beta_{33}, \beta_{44}}$ and $\boldsymbol{\beta_{55}}$ are the own second derivatives; $\boldsymbol{\beta_{12}, \beta_{13}, \beta_{14}, \beta_{15}, \beta_{23}, \beta_{24}, \beta_{25}, \beta_{34}, \beta_{35}}$ **and** $\boldsymbol{\beta_{45}}$ are the cross second derivatives. β s are unknown parameters to be estimated, Vi's are iid [N (0, σ_v^2)] and Ui's are nonnegative random variables called technical inefficiency effects, which are associated with technical inefficiency of production of the farm households and are assumed to be independent of the V_i such that Ui's are nonnegative truncation (at zero) of the normal distribution with mean, μ and variance σ^2.

$$\mu_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 D_1 + \delta_4 D_2 + \delta_5 D_2 \ldots\ldots(9)$$

Where:

$\boldsymbol{Z_1, Z_2, D_1, D_2}$ **and** $\boldsymbol{D_3}$ are the average education of the family, experience of the effective farm households dummy variable of college education ($13 \le D_1 \ge 15$ years of schooling), ($8 \le D_1 \ge 12$ years of schooling) and ($5 \le D_1 \ge 7$years of schooling) $\boldsymbol{\beta_i}$ **s** and $\boldsymbol{\delta_i}$ **s** are the unknown parameters to be estimated.

RESULTS AND DISCUSSION:

Table-1 shows the basic statistics of the inputs used in the paddy production. The value of capital includes the shed cost, the bullock cost and the plough wood cost including the cost of granary. Number of years of formal schooling completed is considered for education.

Table-1: Statistics of the Inputs and Out in Paddy Production

Items	Minimum	Maximum	Average	Standard Deviation
Paddy Output (`)	13800	70560	33436	10812
Capital expenditure (`)	2300	6800	4816.25	730.632
NSA(in Acres)	2	8	4	1
Labour (Man days)	192	832	408	125
Manures (quintals)	168	2120	885	302
Fertiliser (kgs)	100	7500	1023	596
Education (School)[1]	3	15	8	2
FamEdu(School)	3	19	8	3
Exp (years)	8	20	12	3

The joint estimation ML estimates of the equation 7 and 9 (for C-D production) as well as 8 and 9 (for Translog Production) had been carried out by FRONTIER 4.1, developed by Coelli (1996) are presented in the **Table-2 and Table-3**. The estimate of the value of capital (the Plough wood, expenses on Bullocks, Bullock carts, expenses on cow shed) was positive but not significant. The fact was that the maintenance of the fixed assets useful for the paddy production. But some farm households were expressing the desire to be free from the burden of the all such fixed assets and can substitute the modern machinery readily available on demand to perform such works. The coefficient of the Net Shown area was negative and but not statistically significant. Since HYV paddy required more monetary investment in purchasing the fertilizer, pesticides, manures and seeds in proper time, depending on the financial condition, some of the farm household could not ensure timely supply of these inputs. The more scattered plots of land did not allow most of the farmers to use tractors for better cultivation and poses lot of difficulties in the timely supervision of the crop. It was also a fact that the supply of the hired labor during the plantation time was very less. In order to avail the required number of the hired laborers, the farmers had to pay more wages to them. Hence, this possessed a restraint on the part of the farmers for better production. Hence, the more the size of the net shown area under the crop, the more would be the requirement of the monetary investment and that is the cause why the production decreased with the increase in the size of the area under the crop. The coefficient of the Labor Days was positively significant.

Since labor was the integral part of the farm production, the statistically significant coefficient shown its importance in the agriculture. The coefficient of manures was positive and but not statistically significant. High dose of manures did not raise the quantity of output. Rather chemical fertilizer has significant effect on increasing the output.. The coefficient of fertilizer (N+K+P) was positive and significant. It revealed the fact that the response of the farmers to the fertilizer use had increased and it is a significant improvement in the behavior of the farmers in the study area. Since, chemical fertilizer was an important component of paddy production, use of fertilizer shown positive and significant effect on the volume of production and the revenue earned from it. The estimated inefficiency function provides some information on the factors that lead to the technical inefficiency in the paddy production. The

[1] Education is of the effective head of the household i.e. the individual who is the actual cultivator and may or may not be the head of the house. The Fam Edu is the average education of the family as a whole.

coefficient of the Average education of the family was negative but not statistically significant. The implication is that the family with higher education seems to have influence in the production decision making but not so frequently. The college education and high school education had significant impact in reducing the technical inefficiency is positive and significant as found by Bravo-Eureta and Pinheiro (1993). However the experience had no significant impact even though it is negative. It revealed the fact that inefficiency level of the farmer increases with the increase in the year of experience. It means, the more experienced farmers were more aged and hence, the traditional approach of cultivation method they adopt did not change even if the facilities and appropriate information were available to them. They feel that they had been adopting the best method of cultivation practice. For example some aged farmers hesitated to use tractors in the fear that it will reduce the fertility of the soil. The gamma value was 0.99, which indicated that the vast majority of error variation was due to inefficiency error U_i not due to random component V_i. The one sided LR test that $\gamma = 0$ provided a statistic of 43.40 which exceeds the χ^2 value at 5% critical value. Hence the stochastic frontier model did appear to be significant improvement over the simple production function. The MLE of the parameters of the translog function were presented in the table-3. The parameters of Labour, Fertilizer and Net shown area were statistically significant to the paddy production. The inefficiency was significantly reduced due to more education specially high school and college education. This supports the study (Nandolnyak *et al*., 2006; Asogwa, 2011, Basnayake and Gunaratne. 2002.)

(Table-2)

ML Estimates of the Parameters of C-D Production Function

Parameter	Value of the parameter	t-Value
β_0	0.171	2.72*
β_1 (VC)	0.142	1.59
β_2 (NSA)	-0.1	-1.00
β_3 (BLD)	0.378	3.98**
β_4 (MAN)	0.102	1.74
β_5 (FER)	0.211	14.97
δ_0	0.106	10.67**
δ_1 (Fam Edu)	-0.105	1.33
δ_2 (EXP)	-.0046	-0.750
δ_3 (College dummy)	-0.029	-2.9*
δ_4 High school dummy	-0.073	7.3*
δ_5	0.0074	0.44
Sigma Squared	0.71	
Gamma	0.99	
Log Likelihood	290.640	
LR Test	43.4	

*,** t values significant at 5% and 1%.

Table-3: ML Estimates of the Parameters of Translog Production Function

Coefficients	Values of coefficients	t- value
β_0	0.4097	6.2718**
β_1	0.1144	1.5006
β_2	-0.6391	3.0368**

β_3	0.5613	7.7318**
β_4	0.1345	1.29
β_5	0.2955	5.6238**
β_{11}	1.4286	0.7482
β_{22}	-0.76033	2.5081*
β_{33}	0.72481	7.5853**
β_{44}	0.05025	0.3199
B_{55}	0.04230	2.0438*
β_{12}	0.0946	1.5392
β_{13}	- 0.7712	5.9009**
β_{14}	0.00304	10.2661**
β_{15}	0.6557	1.0936
β_{23}	0.2576	2.5186*
β_{24}	0 .0233	0.5656
β_{25}	0.78260	4.7843**
β_{34}	0.0203	1.9792*
β_{35}	0.4276	4.0636**
β_{45}	0.0441	0.0603
δ_0	- 9.7100	1.238
δ_1	0.006249	0.7167
δ_2	-0.0035	2.943*
δ_3	- 0.02236	-2.4528*
δ_4	-0.0345	-3.7534*
δ_5	0.003	1.763
σ^2(Sigma square)	.74	5.206**
Gamma	0.99	29.093
Log Likelihood	465.671	

*,** t values significant at 5% and 1%.

The technical efficiency indices are derived from the MLE results of the stochastic production function, using the FRONTIER 4.1. The indices in the Table- 4 shown that the mean technical efficiency of the farmers in the study area was 97.04%. Their range of the technical efficiency of the farmers was between 91% and 99%. Two percent of the total farmers are between 90 and 92 percent technical efficiency; 10 percent in the range of 94 to 96; 20 per cent in the range of 96 to 98 and rest of the farmers are in between 98 and 99 %. From this estimation, it is clear that the farmers in the study area are more accessible to the modern farm techniques and use best available farm practices. The level of education of the farmer is an important indicator of the differences in the technical efficiency of the farmers.

Table-4: Distribution of the Technical Efficiency Scores

Efficiency index class	Frequency	Percentage
90- 92	4	2
92-94	2	1
94-96	20	10
96-98	40	20
98-1.00	134	67

CONCLUSION:

The study concluded that labour, land fertilizers were important input in the paddy production. The deviation in actual estimated production was due largely to technical inefficiency. As far as efficiency was concerned 33% of the farmers were 96% efficient in comparison to the 100% technically efficient farmers. Ninety nine percent of the variation in efficiency was ascribed due to the technical efficiency. The level of inefficiency was significantly reduced whenever the farm household has levels of schooling in high school and college level. The investment both by public sector and private sector in educating the people through more training, extension activities should be focused on more seriously. In addition to this, the course curriculum at school and college level should be more oriented towards farming activities. The policy implication of the study was that the government should give more priority on the education in the rural area where, most of the people are depending on agriculture.

REFERENCES:

Afriat, S.N. (1972): Efficiency Estimation of Production Functions, International Economic Review.,13: 568-598.

Aigner, D. J. and S. F. Chu. (1968): On Estimating the Industry Production Function. American Economic Review., 58: 826-839.

Aigner, D. J., C. A. K. Lovell and P. Schmidt. (1977): Formulation and Estimation of Stochastic Frontier Production Function Models. Journal of Econometrics., 6: 21-37.

Aigner, D.J. and P. Schmidt. (1980): (eds.), Specification and Estimation of Frontier Production, Profit and Cost Functions, A Supplement to the Journal of Econometrics., 13.

Ali, M. and J. C. Flinn (1989): Profit Efficiency Among Basmati Rice Producers in Pakistan Punjab. American Journal of Agricultural Economics., 71: 303-310.

Asogwa, B.C., Ihemeje, J.C. and Ezihe, J.A.C. (2011): Technical and Allocative Efficiency Analysis of Nigeria Rural Farmers Implication: for Poverty Reduction. Agricultural Journal., 6(5): 243-251.

Bagi, F.S. (1982a): Relationship Between Farm Size and Technical Efficiency in West Tennessee Agriculture. Southern Journal of Agricultural Economics., 14: 139-144.

Bagi, F.S. (1982b): Economic Efficiency of Sharecropping: Reply and Some Further Results. Malayan Economic Review., 27: 86-95.

Bagi, F.S. and C. J. Huang. (1983): Estimating Production Technical Efficiency for Individual Farms in Tennessee. Canadian Journal of Agricultural Economics., 31: 249-256.

Battese, G.E. (1990): Frontier Production Functions, Technical Efficiency and Panel Data Invited Paper presented in the "Productivity and Efficiency Analysis sessions at the Operations Research Society of America and The Institute of Management Sciences (ORSA/TIMS) 30th Joint National Meeting, Philadelphia. 29-310ctober.

Battese, G.E. and T.J. Coelli. (1988): Prediction of Firm-Level Technical Efficiencies With a Generalized Frontier Production Function and Panel Data. Journal of Econometrics., 38: 387-399.

Battese, G.E. and G.S. Corra. (1977): Estimation of A Production Frontier Model: With Application to the Pastoral Zone of Eastern Australia. Australian Journal of Agricultural Economics., 21: 169-179.

Basnayake, B. M. J.K. and Gunaratne, L.H.P.(2002): Estimation of Technical Efficiency and It's Determinants in the Tea Small Holding Sector in the Mid Country Wet Zone of Sri Lanka Sri Lankan Journal of Agricultural Economics., 4. (1): 137-150.

Bravo-Ureta, B.E. and Pinheiro, A.E. (1993): Efficiency Analysis of Developing Country Agriculture: A Review of the Frontier Function Literature. Agriculture and Resource Economics Review., 22: 88–101.

Bravo-Ureta, B.E. and L. Rieger. (1990): Alternative Production Frontier Methodologies and Dairy Farm Efficiencies. Journal of Agricultural Economics., 41: 215-226.

Coelli, T.J. (1995): Recent Developments in Frontier Modeling and Efficiency Measurement. Australian Journal of Agricultural Economics., 39: 219-245.

Coelli, T.J. (1996): A Guide to FRONTIER Version 4.1c: A Computer Programme for Stochastic Frontier Production and Cost Function Estimation, Working Paper 96/07, Centre for Efficiency and Productivity Analysis, Dept. of Econometrics. University of New England, Armidale, Australia

Cornwell, C., P. Schmidt and R.C. Sickles. (1990): Production Frontiers With Cross-sectional and Time-series Variation in Efficiency Levels. Journal of Econometrics., 46: 185-200.

Farrell, M. J. (1957): The Measurement of Productive Efficiency. Journal of the Royal Statistical Society., A: 120, 253-290.

Huang, C.J. and F.S. Bagi. (1984): Technical Efficiency on Individual Farms in Northwest India. Southern Economic Journal., 51. 108-115.

Huang, C. J., A. M. Tang and F.S. Bagi. (1986): Two Views of Efficiency in Indian Agriculture. Canadian Journal of Agricultural Economics., 34: 209-226.

Kalirajan, K. (1981): An Econometric Analysis of Yield Variability in Paddy Production. Canadian Journal of Agricultural Economics., 29: 283-294.

Kalirajan, K. (1982): On Measuring Yield Potential of the High Yielding Varieties Technology at Farm Level. Journal of Agricultural Economics., 33: 227-236.

Kalirajan, K.P. and J.C. Flinn (1983): The Measurement of Farm-Specific Technical Efficiency. Pakistan Journal of Applied Economics., 2: 167-180.

Kumbhakar, S.C. (1990): Production Frontiers, Panel Data and Time-Varying Technical Inefficiency. Journal of Econometrics., 46: 201-211.

Meeusen, W. and J. van den Broeck (1977): Efficiency Estimation from Cobb-Douglas Production Functions With Composed Error. International Economic Review., 18: 435-444.

Nadolnyak, D. A., Fletcher, S. M. and Hartarska, V.M. (2006): Southeastern Pea nut Production Cost Efficiency Under the Quota System: Implication for the Farm Level Impact of 2002. Farm Journal of Agricultural and Applied Economics. 38(1): 213-251.

Pitt, M.M. and L.F. Lee. (1981): Measurement and Sources of Technical Inefficiency in the Indonesian Weaving Industry. Journal of Development Economics., 9: 43-64.

Richmond, 3. (1974): Estimating the Efficiency of Production. International Economic Review., 15: 515-521.

Schmidt, P. (1976): On the Statistical Estimation of Parametric Frontier Production Functions. The Review of Economics and Statistics., 58: 238-239.