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Technical Efficiency of Dairy Farms: A Stochastic Frontier Application on Dairy Farms in Jordan

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Abstract

The present study was conducted to determine the level of technical efficiency of dairy producing farms in Jordan by applying the stochastic production frontier (SPF) methodology. Technical efficiency estimates were generated for 100 dairy farms in Jordan. The results of the study indicated that technical efficiency of milk production by most of dairy farms in Jordan is low. The mean technical efficiency was estimated to be only 39.5% for the sampled dairy farms. This means that an average farm in the sample could in principle increase its level of milk production by 60.5% using the current input quantities. The results also implies that the dairy farms in Jordan are producing milk to only about 40% of the potential frontier production levels of this industry, implying that the production is about 60% below the frontier due to technical inefficiency. To enhance farm efficiency there is a need to improve farmers' access to extension services. The need to involve farmers more in the extension process itself should be encouraged.

Keywords: technical efficiency, technical inefficiency, dairy farms, stochastic, production frontier

1. Introduction

Despite the fact that most of the Jordanian dairy production is realized as a family operated production units with a small scale, the dairy sector in Jordan has been one of the most important livestock sectors. The total value of the organized cattle holdings including dairy holdings was 75,165,400 Jordanian Dinars (JDs) according to the 2011 agricultural statistics report. This value is equivalent to 105,231,560 US dollars (Department of Statistics, or DoS, 2011). Dairy sector in Jordan gained its importance from the fact that it is the main source of fresh milk production in the country and it is placed in the second rank in terms of investment volume among livestock sectors after poultry sector. The total number of dairy cows in Jordan is 48840 in 628 working dairy farms distributed all over the country governorates and producing around 234000 metric tons of fresh milk which represents almost 50% of the country consumption and almost 72% of the total milk production (Ministry of Agriculture, or MoA, 2011). Dairy sector in Jordan suffered from many complications which has been reflected largely on its productivity. The yearly increase of feed staffs, fluctuations of prices of fresh milk, animal health problems and weak and inefficient marketing system are the most remarked causes of these complications. As a result, a low productivity problem of Jordanian dairy farming system has been recognized as a major problem. This problem of low productivity can be solved through increasing farm efficiency. The efficiency of the Jordanian dairy sector is a subject that has not been fully investigated at farm level.

In developing countries, as Jordan, it is so useful for policy makers to measure the efficiency of agricultural production. The concept of economic efficiency provides a theoretical basis for such a measure (Russel & Young, 1983). Parkish et al. (1995) stated that in developing countries' agriculture farm efficiency is an important subject. In case of inefficient farming practices output could be increased with less cost through extension and education to enhance farm efficiency.

An inefficient firm is that one which is not reducing its average costs and wasting inputs because it is not producing the maximum attainable output given the quantity of inputs used (Bauer et al., 1998). Also, it could be generalized that an efficient producer is that who's output improvement is done without worsening inputs or other outputs (Cooper et al., 2004). The reason for the two previous important notes is that the firms with high technical efficiency is more competitive than those with low technical efficiency, also the costs of production are reduced with high technical efficiency (Alvarez & Arias, 2004). It is so important from a practical and a policy point of view to study farm efficiency and the potential sources of inefficiency (Solís et al., 2009).

Efficiency of dairy farms has been investigated in many studies. Recent reliable studies which investigated dairy production efficiency, in both developed and developing countries, include Fraser and Coridna (1999), Mbaga et al. (2002), Dalton (2004).

Frontier production functions have been applied to farm-level data in many developed and developing countries. These empirical analyses have yielded many useful results and suggested areas in which further research is required (Coelli, 1996).

Stochastic Production Frontier (SPF) is a parametric stochastic approach which was developed by Meeusen and Van den Broeck (1977). The analytical framework section in this study will explain the application of SPF.

Scarcity of dairy feed resources in Jordan has led to think about the reallocation of existing resources to have more output with given level of input combinations or to produce a prescribed level of output with the minimum cost to achieve the required production efficiency. In Jordan as well as many other developing countries the efficient use of inputs is not yet fully understood. On the other hand, the measurement of the productive efficiency in agricultural production is an important issue because it gives pertinent information for making sound management decision in resource allocation.

Considering the above facts, the present study was conducted to determine the level of technical efficiency of the dairy producing farms in Jordan by applying the stochastic frontier methodology.

2. Materials and Methods

2.1 The Sample and the Data

A sample survey of 100 commercial dairy producers was conducted. The selection criterion of the sample was based on the relative importance of the number of dairy cows in each governorate in the country (number of dairy cows in the governorate divided by the total number of dairy cows in the country). The sample size was determined according to the following equation (Newbold, 1995):

$n = [(pxqxz^2)/e^2]/[(Nxe^2) + (z^2xpxq)/(Nxe^2)]$

Where:

n = Sample size.

p = The proportion that the sample will occur.

q = The proportion that the sample will not occur = (1- p).

z = The standardized score.

e = Error term.

N = Population.

The sample size was determined at a confidence level of 0.90; this level was an appropriated level due to the reason that the population itself was relatively small in size. The error term was 0.10 and the Z value correspondent to this level is 1.65. The proportion that the sample will occur was 0.50 and proportion that the sample will not occur was also 0.50, and the population was 628. According to the above mentioned equation the dairy producers to be interviewed were 61. For precession and questionnaire testing reasons additional 39 farmers were interviewed. Table 1 shows total number of dairy cows and their percentages in the country according to governorate. The dairy cows were assumed to be 74% of the total cattle in each governorate. Tables 2 and 3 show the distribution of the sample according to governorate and the total number of the interviewed producers according to cow groups respectively.

The data used in this study were collected through personal interviews with dairy farmers included in the sample throughout the whole country (see tables 2 and 3). A structured questionnaire was designed to obtain information from respondents regarding the elicited socio-economic and business characteristics to be answered in the interview. These characteristics include inputs (feed, labor, and capital), number of cows, amount of milk produced, contact with the extension, membership in cooperative and producer organizations, farmer education and experience and other related characteristics. These characteristics have been included in many previous studies of production efficiency (Binam et al. 2004; Bravo-Ureta & Rieger, 1991; Mbaga et al., 2003).

The reference period for the present study was from March 2011 to September 2011. Secondary data sources include the Department of Statistics, the Ministry of Agriculture and the Agricultural Directorates in each governorate and other related sources.

Table 1. Number of dairy cows and their percentages in the country according to governorate

Area	Governorate	Total No. of cattle	No. of dairy cows	Percentage to All Dairy Farms
North	Irbid	12300	9102	18%
	Jerash	600	444	1%
	Mafraq	17000	12580	26%
	Ajloun	600	444	1%
Middle	Amman	7700	5698	11%
	Madaba	500	370	1%
	Zarqa	24400	18056	36%
	Balqa	2200	1628	3%
South	Karak	400	296	1%
	Tafeeleh	200	148	1%
	Maan	100	74	1%
	Aqaba	000	000	0%
Total	12	66000	48840	100%

Source: Prepared by the researcher based on MoA 2011 annual report.

Table 2. Distribution of the Sample according to governorate

Area	Governorate	No. of farmers interviewed
North	Irbid	18
	Jerash	1
	Mafraq	26
	Ajloun	1
Middle	Amman	11
	Madaba	1
	Zarqa	36
	Balqa	3
South	Karak	1
	Tafeeleh	1
	Maan	1
	Aqaba	0
Total	12	100

Source: Prepared by the researcher.

Table 3. Farm groups depending on the number of cows

Farm group	No. of cows	No. of sampled farms
1	0 - 9	19
2	10 - 19	23
3	20 - 29	27
4	30 - 39	18
5	40 - 49	8
6	≥ 50	5
Total		100

Source: Field Survey.

2.2 The Analytical Framework

Two approaches could be used to analyze the relationship between the firm specific attributes and the degree of production efficiency. One approach is a two-step procedure. It involves first estimating the efficiency scores, then regressing these scores against the firm specific attributes (Sharma et al., 1999). This two-step procedure is used in this study.

2.2.1 Technical Efficiency

Agricultural efficiency studies have been carried out in many developing countries (Squires, 1991; Rios & Shively, 2005; Shafiq & Rehman, 2000; Fletschner & Zepeda, 2002). Transforming given inputs into outputs is the main concern of the concept of efficiency. Three main types of efficiency were identified by economic theory. These include technical, allocative and economic efficiencies. Allocative efficiency refers to the choice of an optimum combination of inputs consistent with the relative factor prices. In developing agricultural economies efficiency is a very important factor of productivity growth due to weak resources and less opportunities for developing and adopting better technologies (Ali & Chaudhry, 1990).

The first theoretical treatment of production technical efficiency was developed by Farell (1957). The farm level production efficiency is measured by estimating a production frontier that envelope all the input/output data available for the analysis. The basic idea underlying the Farrell approach to efficiency measurement is illustrated in Figure 1.

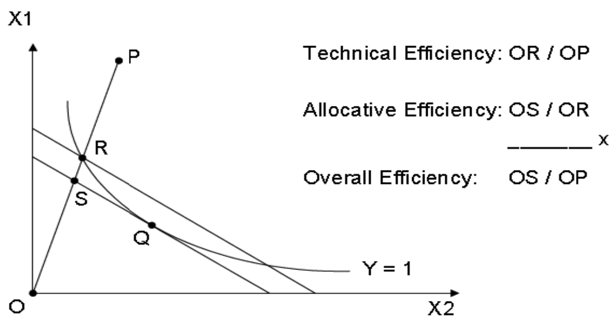

Figure 1. Farrell approach to efficiency measurement

(Source: Leibenstein, 1966).

Figure 1 shows the classic framework by Farrell which makes it possible to decompose overall efficiency into technical and allocative (price) efficiency. Consider the case of a simple output (Y) that is produced by using two inputs (X1, X2). Under the assumption that the production function Y= f(X1, X2) is linearly homogeneous, the efficient unit isoquant, Y = 1, shows all technically efficient combinations. In the figure (R) represents a farm that produces at Y = 1. The magnitude of the technical efficiency can be expressed as the ratio between optimal and actual resource use (OR/OP). By taking into account the iso cost line (representing relative factor prices), we can identify allocative efficiency. Any point on the line Y = 1 has technical efficiency, but only Q receives technical efficiency at minimum cost. Allocative (price) efficiency can be expressed as the ratio between minimum and actual cost (OS/OR), and overall efficiency is the product of technical and allocative efficiency. Technical efficiency (TE) takes a value between zero and one. Where a value of one indicates the farm is producing on the production frontier and is fully technically efficient, and hence provides an indicator of the degree of technical inefficiency of the farm. The smaller the technical efficiency values the greater inefficiency.

2.2.2 The Stochastic Production Frontier (SPF) Approach

The stochastic production frontier (SPF) methodology was applied in this study to measure farm-level economic efficiency. To achieve the goals of this study this methodology was applied to primary data from a survey of 100 dairy farms in Jordan**.**

Based on the Farell's (1957) seminal paper, there are two commonly-used procedures for measuring production efficiency. They are the Stochastic Production Frontier (SPF) procedure (Meeusen & van den Broeck, 1977), and the Data Envelopment Analysis (DEA) procedure (Charnes et al., 1978). The technical efficiency of a farm is measured relative to the input/output performance of all other farms in the sample (Fraser & Cordina, 1999). Coelli (1995) compared the two methods and concluded that the main strengths of the stochastic frontier approach are its ability to deal with stochastic noise and the incorporation of statistical hypothesis tests. He also concluded that the stochastic frontier approach is useful in determining the efficiency levels and policy formulation purposes, it is also useful to identify the sources of inefficiencies.

The technical efficiency of an individual farm is defined in terms of the ratio of the observed output to the corresponding frontier output given the available technology. A version of the traditional Stochastic Production Frontier (SPF) framework was implemented in this study to achieve its goals. The implemented stochastic production function is:

$$Y_i = f(X_{ij}\ \beta)\ \exp\ (V_i - U_j),\ = 1, 2, \ldots\ldots\ldots\ldots\ldots n,$$

Where:

Y_i is output of the i-th farm,

X_i is the vector of input quantities used by the i-th farm,

β is vector of unknown parameters to be estimated;

f represents an appropriate function (e.g. Cobb Douglas, translog, etc). V_i is a symmetric error which accounts for random variation in output due to factors beyond the control of the farmer e.g. weather, disease outbreaks, measurements errors, etc,

U_j is a non negative random variable representing inefficiency in production relative to the stochastic frontier.

Technical efficiency $(TE) = Y_i/Y_i^*$

$$= f(X_i, \beta)\ \exp\ (V_i - U_i) / f(X_i, \beta)\ \exp\ (V_i)$$

$$= (\exp)\ (-U_i)$$

Where:

Y_i = observed Output.

Y_i^* = Frontier Output.

Technical inefficiency relative to the stochastic production frontier is captured by the one-sided error component exp $(-U)$, $U \geq 0$. The condition $U \geq 0$ ensures that all observations lie below the stochastic production frontier (Anwarul & Arshad, 2010).

Frontier Analyst statistical package was used to obtain the TE scores. Frontier software was developed by Coelli (1996). Further information on the model can be found in Coelli et al. (2005).

2.2.3 The Econometric Model of Stochastic Frontier

The SPF analysis approach requires that a functional form be specified for the frontier production function. The production technology of dairy farms in this study is assumed to be specified by the Cobb Douglas frontier production function defined as follows:

$$\ln Y_i = \beta_o + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + V_i - U_i$$

Where:

Y_i = Value of milk produced.

X_1 = Herd size (number of milk producing cows).

X_2 = Feed quantities.

X_3 = Labor input (man-day's).

X_4 = Value of vet. Services, drugs and medicine.

X_5 = Fixed inputs and depreciation costs.

V_i = Random error.

U_i = Technical inefficiency.

B_o, B_1, B_2, …, B_5 are regression parameters to be estimated.

As in most frontier production analysis U_i is assumed to follow a half normal distribution.

2.2.4 Factors associated with Technical Efficiency

To examine the factors contributing to the observed technical efficiency in the Jordanian dairy farms the following regression model was used:

$$TE = \beta_o + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + e$$

The field survey results revealed that farmer's level of education (years) or X1, farmer's farming experience (years) or X2, farmer's contact with an extension services or X3 and herd size (heads) or X4 are the most obvious factors affecting the technical efficiency of dairy farms in Jordan, so our investigation in this model was limited to only these four factors. Here, TE is the farm technical efficiency score. B_o, B_1, … B_4 are regression parameters to be estimated.

3. Results and Discussion

The main characteristics of the sampled dairy farms average statistics are presented in Table 4. Table 5 shows the Maximum Likelihood (ML) estimates of the Cobb-Douglas production function for dairy farms in Jordan. Table 6 shows the distribution of the farm level measures of technical efficiency. Table 7 shows the Maximum Likelihood (ML) estimates of the Cobb-Douglas stochastic frontier production parameters for dairy farms associated with their technical efficiency.

Table 4. Average statistics of the main characteristics of sampled dairy farms

Variable	Mean	Standard deviation	Minimum	Maximum
Herd size (number)	13	8	2	76
Annual milk production (kg/cow)	3990	245	354	11240
Farmer age (years)	42	7	23	74
Farmer experience (years)	19	8	3	47
Farmer Education attainment (years)	5	2	1	17
Concentrated feed (kg/herd)	1670	433	217	3540
Roughage feed (kg/herd)	1637	875	46	5102
Household size (no.)	7	2	2	13
Labor (man-day's)	27	4	5	58

Source: Field survey.

Table 5. Maximum-likelihood estimates of the Cobb-Douglas production function of the sampled farms

Variable	Parameters	Coefficients	Standard Error	t-value
Constant	***Bo***	12.011	0.021	19.203**
Herd size (cow)	***B1***	3.139	0.368	7.128**
Feed intake (kg)	***B2***	1.671	0.235	7.773**
Labor (man-day's)	***B3***	0.899	0.119	9.065 **
Value of vet. Services, drugs and medicine	***B4***	0.408	0.193	0.899
Fixed inputs and depreciation costs	***B5***	- 0.098	0.101	- 0.917

**: Significant at 0.01 level.

Table 6. Distribution of the farm level measures of technical efficiency (TE)_

TE %	No. of Farms	% To total farms
20.0 - 29	37	37
30.0 - 39	14	14
40.0 - 49	16	16
50.0 - 59	15	15
60.0 - 69	9	9
70.0 - 79	5	5
80.0 - 89	3	3
90.0 - 99	1	1
Total	100	100% (Average of TE = 39.5%)

Table 7. Maximum-likelihood estimates of variables associated with technical efficiency

Variable	Parameters	Coefficients	Standard Error	t-value
Constant	***Bo***	4.325	0.428	8.724**
Education (years)	***B1***	1.036	0.635	5.003**
Experience (years)	***B2***	0.454	0.228	2.754 **
Contact with extension services (no.)	***B3***	-0.008	0.102	-0.597
Herd size (cow)	***B4***	0.149	0.068	3.823**

**: Significant at 0.01 level.

As Table 4 shows, on the average a typical dairy farmer in the sample was 42 years old with an average of 5 years of education and 19 years of experience. The table also shows that an average dairy producer farmer in Jordan employed 27 man-day's of labor and produced an output of 3990 kg of milk per annum. The annual average consumption of the herd from concentrates and roughages is 1670 and 1637 kg respectively. These results show that most of the producers, although they were with good experience and young, they are not well educated, not hiring enough labor power for their activity, providing less feed quantities than required for dairy activity and they were with large family size. These factors were the main reasons for the low level of fresh milk production of their farms (nearly 13 kg/day assuming 300 production days per a year).

Table 5 shows that herd size, feed intake and value of veterinary services including drugs and medicine costs coefficients are with positive signs and are statistically significant at 0.01 level showing direct relationship with milk production. This implies that any 1% increase in herd size, feed intake, labor unit and value of veterinary services including drugs and medicine costs would increase milk production by 3.139%, 1.671%, 0.899% and 0.408% for each of these variables respectively. The coefficient for fixed inputs and depreciation costs was with negative sign indicating indirect relationship or this variable with milk production. This implies that a 1% increase in fixed inputs and depreciation costs will lead to a 0.098% decrease in milk production.

The distribution of TE scores for the 100 sampled dairy farms is presented in table 6. As the table shows, 37% of the farms are with the TE score of less than 30%. The TE scores in the table shows that 67% of the sampled dairy farms are with TE less than 49%. Only 33% of the farms are with TE higher than 50%. This is an obvious indicator that dairy farms in Jordan exhibit a low degree of TE. This low TE may be attributed to many associated factors. The following paragraph will discuss the effect of these factors.

The field survey revealed that four main determinants were associated with TE in the sampled dairy farms. These include farmer's level of education; farmer’s farming experience, farmer's contact with an extension services and herd size. Table 7 shows that each 1% increase in the education level will lead to an increase of almost 1% in TE. Obviously, the well educated farmer will perform better and modern production practices than the less educated one. Education improves the skill and entrepreneurial ability of the farmer to organize inputs for the maximum efficiency. The table also shows that an increase by 1% of experience years of the farmer will lead to an increase by 0.454% in the technical efficiency of the farms reflecting that higher experience will end in higher TE due to more efficient use and allocation of resources by highly experienced farmers. The results of the analysis regarding the contact with extension services revealed unexpected indicators. The relationship between TE and the contact with extension services was with negative sign indicating that an increase in times of contact with extension services regardless its source will cause TE to be lowered. This result is important although the magnitude of the relation is small. The possible explanation for this result is that the type of contact is the reason for this negative relationship and not the duration of that contact, and could be also attributed to the bureaucratic inefficiency and the deficiency in extension programs design. The lack of a participatory approach may explain the insignificance of the extension programs on dairy farms efficiency in Jordan and in many other developing countries. Concerning the last variable which is the herd size, the estimated determinants of technical efficiency of the Jordanian dairy farms shows that as the herd size increase by 1% the technical efficiency will increase by 0.149%. This increase in TE due to farm size increase could be attributed to the economies of size which implies that as the farm size increase the lesser costs per production unit is attained and the better distribution of resources is achieved.

The average TE of the sampled farms is only 39.5% (computed from table 7). This result is not surprising because the studied farms are not specialized farms and depends on the traditional production procedures. This means that an average farm in the sample could in principle increase its level of milk production by 60.5% using the current input quantities. The result also implies that the dairy farms in Jordan are producing milk to only about 40% of the potential frontier production levels of this industry, implying that the production is about 60% below the frontier due to technical inefficiency.

4. Conclusions

Technical efficiency estimates were generated for 100 dairy farms in Jordan. The results of this study indicated that technical efficiency of milk production by most of dairy farms in Jordan is low. The mean technical efficiency was estimated to be only 39.5% for the sampled dairy farms. The results show that there is a substantial technical inefficiency on dairy farms in Jordan suggesting inefficient production. Farmer's level of education, farmer's farming experience, farmer's contact with an extension services and herd size are the main determinants associated with TE in the sampled dairy farms. Technical efficiency can be further improved through provision of education, training and orientation of the farmers toward dairy farming practices. More education will be crucial in increasing technical efficiency. There is need to improve farmers' access to extension services. The need to involve farmers more in the extension process itself should be encouraged.

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References

Ali, M., & Chaudhry, M. A. (1990). Interregional farm efficiency in Pakistan's Punjabi. A frontier production function study. *J. Agric. Econ., 41*, 62-73. Retrieved from http://www.blackwell-synergy.com/doi/abs/10.1111/j.1477- 9552.1990.tb00619.x

Alvarez, A., & Arias, C. (2004). Technical efficiency and farm size: A conditional analysis. *Agricultural Economics, 30*, 241-250. http:dx.doi.org/10.1111/j.1574-0862.2004.tb00192.x

Bauer, P. W., Berger, A. N., Ferrier, G. D., & Humphrey, D. B. (1998). Consistency conditions for regulatory analysis of financial institutions: a comparison of frontier efficiency models. *Journal of Economics and Business, 50*, 85-114. Florida State University, Tallahassee, Florida, USA. http://dx.doi.org/10.1016/S0148-6195(97)00072-6,

Binam, J. N., Tonye, N. W., Nyambi, G., & Akoa, M. (2004). Factors affecting the technical efficiency among smallholder farmers in the slash and burn agriculture zone of Cameroon. *Food Policy, 29*, 531-545. Retrieved from http://www.sciencedirect.com/science/article/B6VCB-4DD8HBY-4/2/4ef4a87db52cb8b1c6546ba8f1f1d2dd.

Bravo-Ureta, B. E., & Rieger, L. (1991). Dairy farm efficiency measurement using stochastic frontiers and neoclassical duality. *American Journal of Agricultural Economics, 73*, 421-428. http:dx.doi.org/10.2307/1242726

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring efficiency of decision making units. *European Journal of Operational Research, 2*, 429-444. http://dx.doi.org/10.1016/0377-2217(78)90138-8

Coelli, O. J. (1995). Recent development in frontier estimation and efficiency measurement. *Austr. J. Agric. Econ., 39*, 219-245. Retrieved from http://purl.umn.edu/22681

Coelli, T. J. (1996). *A Guide to Frontier Version 4.1: A computer program for stochastic frontier production and cost function estimation*. University of New England, Armidale, England. Retrieved from http://www.une.edu.au/econometrics/cepa.htm

Coelli, T. J., Prasada Rao, D. S., O'Donnell, C. J., & Battese, G. E. (2005). *An introduction to efficiency and productivity analysis* (2nd Edn). New York, USA: Springer.

Cooper, W. W., Seiford, L. M., & Tone, K. (2004). Data envelopment analysis: A comprehensive text with models, applications, references & DEA-solver software. USA: Kluwer Academic Publishers.

Dalton, T. J. (2004). Indivisibility and spatial components of dairy firm inefficiency. *American Agricultural Economics Associations Annual Meeting*, August 1-4, Denver, Colorado. USA.

Department of Statistics (DoS). (2011). Yearly Statistics.

Farrell, M. J. (1957). The measurement of productive efficiency. *Journal of Royal Statistics of Society, 120*, 253-290. http://www.jstor.org/stable/2343100

Fletschner, D. K., & Zepeda, L. (2002). Efficiency of small landholders in Eastern Paraguay. *Journal of Agricultural and Resource Economics, 27*(2), 554 - 572. Retrieved from http://purl.umn.edu/31134

Fraser, I., & Coridna, D. (1999). An application of data envelopment analysis to irrigated dairy farms in Northern Victoria, *Australia Agricultural Systems, 59*, 267-282. http://dx.doi.org/10.1016/S0308-521X(99)00009-8

Leibenstein, H. (1966). Allocative efficiency vs "X-efficiency." *The American Economic Review, 53*(3), 392-415.

Mbaga, D. M., Romain, R., Larue, B., & Lebel, L. (2003). Assessing technical efficiency of Quebec dairy farms. *Canadian Journal of Agricultural Economics, 51*, 121-137. http:dx.doi.org/10.1111/j.1744-7976.2003.tb00169.x

Meeusen, W., & Van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composite error. *International Economic Review, 18*, 435-444. http://dx.doi.org/10.2307/2525757

Ministry of Agriculture, Jordan, MoA. (2011). Annual Report.

Newbold, P. (1995). *Statistics for business and economists* (p. 867). Prentice-Hall International, Upper Saddle River, New Jersey.

Parikh, A., Ali, F., & Shah, M. K. (1995). Measurement of economic efficiency in Pakistani agriculture. *Amer. J. Agr. Econ., 77*, 675 - 85. http:dx.doi.org/10.2307/1243234.

Rios, A. R., & Shively, G. E. (2005). *Farm size and non parametric efficiency measurements for coffee farms in Vietnam*. Department of Agricultural Economics, Purdue University. USA.

Russell, N. P., & Young, T. (1983). Frontier production functions and the Measurement of technical efficiency. *J. Agr. Econ., 34*, 139-50. http:dx.doi.org/10.1111/j.1477-9552.1983.tb00984.x

Shafiq, M., & Rehman, T. (2000). The extent of resource use inefficiencies in cotton production in Pakistan's Punjab: An application of data envelopment analysis. *Agricultural Economics, 22*, 321-330. http:dx.doi.org/10.1111/j.1574-0862.2000.tb00078.x

Sharma, K. R., Leung, P., & Zaleski, H. M. (1999). Technical, allocative and economic efficiencies in swine production in Hawaii: a comparison of parametric and nonparametric approaches. *Agricultural Economics, 20*, 23-35. http://dx.doi.org/10.1016/S0169-5150(98)00072-3

Solís, D., Bravo-Ureta, B., & Quiroga, R. (2009). Technical efficiency among peasant farmers participating in natural resource management programs in Central America. *Journal of Agricultural Economics, 60*, 202-219. http://dx.doi.org/10.1111/j.1477-9552.2008.00173.x

Squires, D. S. (1991). Technical efficiency and future production gains in Indonesian agriculture. *Developing Economies, 24*(3), 258-70. http://dx.doi.org/10.1111/j.1746-1049.1991.tb00211.x