An Assessment of the Efficiency of Agribusiness Trucking Companies
A Data Envelopment Analysis Approach

Albert J. Allen
Department of Agricultural Economics
Mississippi State University
P.O. Box 5187
Mississippi State, MS 39762
Phone: (662) 325-2883
E-mail: allen@agecon.msstate.edu

Saleem Shaik
Department of Agricultural Economics
Mississippi State University
P.O. Box 5187
Mississippi State, MS 39762
Phone: (662) 325-7992
E-mail: shaik@agecon.msstate.edu

and

Joselito K. Estrada
Department of Business Administration
University of Texas at Brownsville
80 Fort Brown
Brownsville, TX 78520
Phone: (956) 983-7151
E-mail: jkestrada@utb.edu

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ABSTRACT

The purpose of this study is to investigate the issue of efficiency in the U.S. motor carrier industry using DEA and SFA. While both methods used the same variables, the resulting efficiency scores were significantly different. This leads to the question of which method is a better measure of efficiency.

INTRODUCTION

The motor carrier industry occupies an important position in the movement of goods and services. Given its advantages in the areas of accessibility to points of origin and final destination and the relatively low capital requirements for industry entry, motor carriers have overshadowed other transportation modes in terms of the market share, employment, and the number of firms.

In 2002, motor carrier employment accounted for 37 percent of the 3,581,013 persons employed in the overall transportation industry. In terms of payroll, this sector's share of the industry's $127 billion annual payroll was estimated at 35 percent. As far as market share was concerned, motor carriers accounted for roughly 57 percent of the 195,143 firms in the transportation industry (County Business Patterns, 2002).

In an era of rising fuel costs, transportation deregulation, and competition from foreign motor carrier operators, the issue of efficiency becomes important. Understanding the factors that allow firms to become efficient would be helpful in trying to alleviate the possibility of reduced domestic motor carrier transportation capability.

The purpose of this study is to investigate the issue of efficiency in the U.S. motor carrier industry. Specifically, the objective of this endeavor is to estimate the relative efficiency of U.S. agribusiness trucking firms using Data Envelopment Analysis (DEA). While the measurement of efficiency in the agribusiness trucking industry has been conducted previously (Allen, Fuentes, and Shaik, 2004), the present study differs with respect to how efficiency is estimated.

One appealing characteristic of DEA is the fact that there is no need to specify the functional form of the production function to be used (Pedraja-Chaparro, Salinas-Jimenez, and Smith, 1999). Despite its appeal, the question of whether the DEA model being used is correctly specified becomes an issue. DEA does not have any statistical tests for goodness-of-fit or misspecification that parametric statistical methods, such as regression, have (Van der Meer, Quigley, and Storbeck, 2004).

In order to avoid the problem of model misspecification, the present study follows the procedure established by Van der Meer, Quigley, and Storbeck (2004). To test their DEA model of operational efficiency among Coastguard coordination centers in the UK was correctly specified, the DEA efficiency scores were compared and ranked with efficiency scores from a stochastic frontier analysis (SFA) model that they developed for the same purpose. The results obtained in both models were similar.

This study compared efficiency scores from the DEA model with SFA efficiency scores. To test for similarities, correlation coefficients were estimated for both sets of efficiency scores.

The results of this study could present some interesting considerations for decision-makers who use DEA in their activities. Specification of the most appropriate variables to use in order to maximize/minimize a given objective is of importance. In a highly competitive industry, such as the U.S. motor carrier industry, this can spell the difference between choices that lead to the continuation or the cessation of a firm’s operations.

DATA AND METHODS

DEA is a mathematical technique that allows for the assessment of the operating efficiency of each firm, which is called a decision-making unit (DMU) in DEA, relative to other DMUs in the same industry. Using a set of inputs and outputs that are common to each DMU, a "virtual" DMU is generated and serves as the basis of comparison for each DMU in the industry. This "virtual" DMU embodies the most relatively efficient firm in terms of input use and output production. If a DMU's input use and output production are the same as that of the "virtual" DMU, that DMU is said to be efficient. DMUs that fall short of the "virtual" DMU in terms of input use and output production are deemed to be inefficient.

This non-parametric method for estimating frontier functions represents one of two principal methods. The other method, which is econometric in nature, is referred to as Stochastic Frontier Analysis or SFA (Coelli, 1996). A description of these two efficiency models is presented below.

EFFICIENCY MODELS

STOCHASTIC FRONTIER ANALYSIS [SFA]

The technology transforming input vector $X = (x_1 \ldots x_4)$ into output denoted by Y can be represented by Cobb-Douglas and the Translog stochastic production function as:

(1) $Y_i = x_i\beta + (V_i - U_i)$,i=1,...,N,

where Y_i is the production (or the logarithm of the production) of the i-th firm;

x_i is a k×1 vector of (transformations of the) input quantities of the i-th firm;[1]

β is a vector of unknown parameters;

[1]For example, if Y_i is the log of output and x_i contains the logs of the input quantities, then the Cobb-Douglas production function is obtained.

V_i are random variables which are assumed to be iid. $N(0,\sigma_V^2)$, and independent of the

U_i which are non-negative random variables which are assumed to account for technical inefficiency in production and are often assumed to be iid. $|N(0,\sigma_U^2)|$.

The term exp{- U_i } corresponds to the technical efficiency [TE] measure. In the case of the production function TE will take the value between zero and one. The unobservable U_i being predicated from the estimation is conditional upon the observed value of (V_i - U_i)

DATA ENVELOPMENT ANALYSIS [DEA]

The technology that transforms inputs x = (x_1.......x_I) 0 $|^I_+$ into outputs y_g = (y_1.......y_G) 0 $|^G$, can be represented by output, input and graph sets. These sets can be effectively utilized to compute efficiency measures.

Input oriented definition of efficiency is the multiple by which year *t* input can be decreased at a later point in time, producing the year *t* outputs. Following Fare, Grosskopf and Lovell (1994 pp 62-63), the input reference set satisfying constant return to scale and strong disposability of inputs can be defined as:

(2) $$L^T(y) = \{ x : \text{ y produced by x in year T}; \quad y \in \Re^J_+ \}$$

This concept can be represented by an input distance function evaluated for any year *t* using a reference production possibilities set *T*, as:

$$D_i^T(y^t, x^t)^{-1} = \min \{\lambda : \lambda \ y^t \in P^T(x^t) \}$$

or

(3) $$\begin{aligned} \min_{\lambda, z} \lambda \quad \text{s.t.} \quad & y^t \le Y z \\ & \lambda x^t \le X z \\ & z \ge 0 \end{aligned}$$

$$\text{where } X = (x^1, x^2, \ldots.., x^T)$$

Here, the second expression identifies the linear program that is used to calculate the distance function, with the *z*'s being a *Tx1* vector of intensity variables that identify the constant return to scale boundaries of the reference set.

This study used operational data for agricultural commodities and refrigerated food carriers, which was obtained from the Technical Transportation Services Blue Book of Trucking Companies, for the years 1994 to 2002. The input and output variables that were used in conducting the data envelopment analysis were the same variables utilized in a study conducted by Allen, Fuentes, and Shaik (2004).
Descriptions of these variables are presented in Table 1.

RESULTS

Estimated results of the DEA and SFA models for the refrigerated foods and agricultural commodities carriers are presented in Tables 3 and 4, respectively. Between 1994 and 2002, mean efficiency scores for both carrier sectors using the DEA and SFA models have been consistent, wherein the DEA mean scores exhibiting slightly values than the SFA scores.

A cursory inspection of the data may show that both measures of efficiency seem to produce similar results. When we tried to correlate the DEA and SFA scores for all firms in all years for each sector, a different picture emerged.

Table 4 shows us the correlation coefficients between the DEA and SFA efficiency scores for refrigerated foods and agricultural commodities carriers. In both types of carriers, the correlation coefficients were too close to zero to merit any distinct type of linear relationship.

SUMMARY AND CONCLUSIONS

This paper sought out to investigate the efficiency of several sectors within the U.S. trucking industry. Data envelopment analysis (DEA) was used as a means of testing the level of efficiency of these firms.

Since the DEA model does not necessarily call for the specification of the input and output variables in the model, we decided to use variables that were obtained from a prior efficiency study using stochastic frontier analysis (SFA). Given the fact that econometric models such as SFA have to specify the functional form of the model, it was assumed that this would give us a DEA model whose variables are appropriately specified. Essentially, the input and output variables in the SFA are the same as in the DEA model. Results from the DEA and SFA models illustrated that the efficiency scores from both models were significantly different from each other.

This allows us to raise an important issue regarding the measurement of efficiency. While we do not profess to know which efficiency estimation model or approach would be superior, does an approach or method exist for testing the accuracy of these estimation methods?

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Table 1: Input and Output Variables in the DEA and SFA Models.

Variable		Description
Input	Labor Variables	1. Number of drivers and helpers 2. Number of cargo handlers 3. Number of officers, supervisors, clerical and administrative staff 4. Total number of other laborers
	Capital Variables	1. Number of tractors owned 2. Number of trucks owned 3. Number of tractors leased 4. Number of trucks leased 5. Other equipment
	Operating Variable Costs	1. Fuel – gallons, oil, and lubricants 2. Total maintenance
	Operating Fixed Costs	1. Total operating taxes and licenses 2. Total insurance 3. Depreciation and amortization
Output		Total Ton-Miles

Source: Allen, Fuentes, and Shaik (2004).

Table 2: DEA and SFA Efficiency Scores for Refrigerated Food Carriers (1994-2002).

DMU	1994		1995		1996		1997		1998		1999		2000		2001		2002	
	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA
1	0.988	0.753	0.998	0.920	0.972	0.937	0.976	0.775	0.937	0.797	0.986	0.852	0.984	0.910	0.894	0.798	0.938	0.825
2	0.976	0.887	1	0.832	0.986	0.791	1	0.829	0.952	0.820	1	0.831	0.982	0.906	0.898	0.900	0.938	0.857
3	1	0.699	0.975	0.829	0.990	0.866	0.987	0.843	0.946	0.825	0.994	0.913	0.999	0.843	0.888	0.865	1	0.819
4	1	0.716	0.830	0.870	1	0.917	0.998	0.883	0.974	0.946	1	0.996	1	0.881	0.937	0.813	1	0.905
5	0.963	0.804	1	0.694	1	0.851	0.990	0.686	1	0.858	1	0.811	1	0.914	0.874	0.775	0.998	0.854
6	0.963	0.854	0.993	0.762	1	0.871	1	0.748	1	0.820	1	0.861	1	0.825	1	0.886	1	0.816
7	1	0.748	0.999	0.873	0.973	0.830	1	0.785	0.932	0.836	0.992	0.820	1	0.775	0.839	0.779	1	0.919
8	0.962	0.886	1	0.850	0.989	0.820	0.982	0.750	0.995	0.822	0.980	0.890	0.978	0.813	0.844	0.909	1	0.810
9	1	0.794	0.985	0.810	0.996	0.787	0.982	0.766	1	0.927	0.978	0.844	0.989	0.844	0.784	0.841	1	0.757
10	0.980	0.906	0.978	0.821	0.984	0.892	1	0.890	0.938	0.902	1	0.992	0.979	0.841	0.763	0.814	0.996	0.902
11	1	0.706	1	0.792	0.971	0.745	0.992	0.923	1	0.788	1	0.891	1	0.891	0.725	0.822	0.984	0.850
12	0.990	0.920	0.991	0.834	1	0.795	0.975	0.803	1	0.871	0.979	0.862	1	0.850	0.668	0.796	1	0.802
13	0.997	0.977	0.986	0.943	1	0.826	0.998	0.772	0.931	0.801	0.974	0.900	0.995	0.948	0.713	0.852	1	0.784
14	1	0.834	1	0.898	1	0.648	0.963	0.811	0.898	0.706	1	0.878	0.995	0.675	0.753	0.774	0.976	0.825
15	1	0.817	0.989	0.773	0.985	0.841	1	0.827	1	0.858	1	0.897	1	0.854	1	0.689	0.972	0.871
16	0.997	0.936	0.968	0.884	0.990	0.777	0.920	0.966	0.969	0.880	0.994	0.922	0.999	0.774	0.999	0.729	1	0.834
17											0.989	0.855	1	0.892	0.999	0.644	1	0.845
18											1	0.969	0.981	0.874	1	0.940	1	0.924
19											0.956	0.993	1	0.854	0.964	0.874	1	0.761
20											0.978	0.834	0.929	0.878	0.941	0.960	1	0.845
21															0.950	0.742	1	0.919
mean	0.989	0.827	0.981	0.837	0.990	0.825	0.985	0.816	0.967	0.841	0.990	0.891	0.991	0.852	0.878	0.819	0.991	0.844

Table 3: DEA and SFA Efficiency Scores for Agricultural Commodity Carriers (1994-2002).

DMU	1994		1995		1996		1997		1998		1999		2000		2001		2002	
	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA	DEA	SFA
1	1	0.870	1	0.790	0.999	0.731	0.983	0.829	1	0.856	0.966	0.805	0.969	0.906	0.983	0.694	0.929	0.898
2	1	0.898	0.989	0.726	1	0.822	0.979	0.763	1	0.924	0.982	0.945	1	0.706	0.974	0.762	1	0.773
3	1	0.716	1	0.823	0.997	0.793	1	0.857	0.987	0.874	0.986	0.778	1	0.920	0.973	0.874	0.911	0.885
4	1	0.849	1	0.8290	0.998	0.801	0.977	0.781	0.985	0.782	0.973	0.753	1	0.977	1	0.851	1	0.937
5	0.989	0.854	0.999	0.775	1	0.775	1	0.535	1	0.873	1	0.887	0.996	0.834	1	0.811	0.935	0.791
6	1	0.776	1	0.835	1	0.823	1	0.730	1	0.808	0.989	0.670	1	0.818	1	0.822	1	0.866
7	1	0.828	1	0.914	1	0.866	0.935	0.812	1	0.859	0.988	0.716	0.998	0.936	1	0.792	0.997	0.917
8	1	0.837	1	0.836	1	0.841	0.966	0.723	0.986	0.807	1	0.804	0.965	0.920	0.993	0.834	1	0.851
9	0.995	0.673	1	0.882	1	0.793	0.983	0.821	0.980	0.820	1	0.854	0.955	0.832	0.932	0.943	0.970	0.871
10											1	0.748	0.964	0.829				
11											0.967	0.886	0.962	0.870				
12											0.994	0.794						
mean	0.998	0.811	0.999	0.823	0.999	0.805	0.980	0.761	0.993	0.845	0.987	0.803	0.983	0.868	0.984	0.820	0.971	0.865

Table 4: Correlation Coefficients For DEA and SFA Models

Type of Carrier	Coefficient
Refrigerated Foods	0.040978
Agricultural Commodities	-0.126118

Data envelopment analysis (DEA) is a typical nonparametric method that measures relative efficiency by comparing it with the possible production frontiers of decision-making units (DMUs) with multiple inputs and outputs using linear programming (Farrell, 1957). From: The Strategies of China's Firms, 2015.Â In the stochastic frontier approach, the inefficiency and random error components of the composite error term are disentangled by making explicit assumptions about their distributions. The random error term, vi, is assumed to be two-sided (usually normally distributed), and the inefficiency term, ui, is assumed to be one-sided (usually half-normally distributed).