Stochastic Frontier Efficiency Analysis of Agribusiness Trucking Companies

by

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The purpose of this study is to evaluate the technical efficiency of trucking carriers on a national basis by commodity groups for the year 2001. In this analysis, the efficiency measures are estimated using stochastic frontier analysis. Results reveal efficiency measures of trucking carriers vary by the commodity transported but might not be statistically significant in this analysis.

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Introduction

Agribusiness trucking carriers play a vital role in the survival and successful operations of firms in the agribusiness system. Trucking carriers enable agribusiness firms to transact business by allowing them to sell their agricultural and food products at competitive prices, generate production and marketing opportunities, and ease the flow through the supply chain between food processing/manufacturing facilities, distribution centers, and retailers (Stephenson, 1987).

Efficient transportation firms have lower transportation costs and consequently offer lower transportation rates to shippers, enabling managers and owners of agribusiness firms to offer lower consumer prices or expand markets. Thus, the money saved by the managers due to the lower transportation rates can then be passed directly on to the customers of these agribusiness firms in form of lower prices, or spent on trucking carriers to haul the agribusiness agricultural and food products to more distant markets (Stephenson, 1987). Consequently, agribusiness trucking carriers not only play a vital role in agribusiness firms decisions making process, but they are also satisfy consumers wants and needs by supplying them with a wide variety of consumer goods at reasonable prices.

Additionally agribusiness-trucking companies also serve as competitors and as cooperators to complement the transportation services offered by other modes of transportation such as rail, barge, and air. This indicates that there should be a delicate balance between competition and integration of agribusiness truck carriers with other carriers of different modes of transportation, to provide shippers with a highly efficient, low-cost transportation system (Eriksen et al, 1998). Therefore, since technical efficiency is a perquisite to economic efficiency, evaluating the technical efficiency of agribusiness trucking carriers is vital to the economic success and efficiency of the entire agribusiness system to carry the inputs needed for the operation of agribusiness firms and the agricultural output or food and fiber products demanded by consumers, at reasonable prices.

Efficiency can be estimated as primal or dual measure through production function, cost minimization or revenue/profit maximization by one of the two alternative approaches (i) Stochastic frontier approach; and (ii) Nonparametric linear programming approach. In this paper we estimate the parametric efficiency measures using the Stochastic Frontier approach on a national and commodity basis.

After an extensive literature review on technical efficiency in transportation and technical efficiency in agricultural transportation, yielded no records of research activities on this subject in the transportation area. However several abstracts of research work that evaluate the technical efficiency of various modes of transportation and segments of the transportation industry were found. Most of the research work found in the literature review, focuses mainly to railroad cargo transportation, public passenger transportation and airline industry. None of these studies measured the technical efficiency of the for-hire cargo agribusiness trucking firms that haul agricultural commodities using stochastic efficiency frontier analysis. Therefore, it is expected that this study will bridge such information gap.

The paper by Ballis and Golias, 2002 evaluated technical and logistics developments that could lead to increased economic and technical efficiency of railroad transport terminals. In this study the main design parameters were identified and analyzed (length and utilization of transshipment tracks, train and truck arrival behavior/patterns, type and number of handling equipment, mean stacking height in the storage area, terminal access system and procedures). A comparative evaluation of selected conventional and advanced technologies was performed using an analytical tool that was developed for this purpose. This tool consists of three modules (an expert system, a simulation model and a cost calculation module). The overall outcome of the analysis is a number of cost-versus-volume curves for various terminal configurations. The paper concludes with two groups of results: (a) a comparative evaluation of conventional and advanced technologies that reveals similarities in terms of track numbers and the associated area requirements as well as differences in terms of layout flexibility, number of equipment, stacking policies and personnel requirements. Each design is proved effective for a certain cargo volume range. (b) A critical assessment of terminal capacity issues. It is identified that the capacity limitations are imposed mainly by the sidings/transshipment track sub-system rather than by the handling equipment.

A study by Vestergaard, 2003, measures technical efficiency in the Danish trawl fishery in the North Sea for the time period 1997-1998 with a stochastic production frontier model. This model allowed for both technical efficiency and a stochastic environment. The results show that the production frontier can be modeled by a translog function with time effects and a technical inefficiency function. The type of fishery (industrial or consumption) and size of vessel give a good explanation for the inefficiency of the fleet. The average technical efficiency is estimated to be 0.80. On average, industrial vessels have a higher technical efficiency than human consumption vessels, and smaller industrial vessels have higher technical efficiency than larger vessels. A trade-off exists between decommissioning the most technically efficient vessels to more directly reduce fishing capacity, and thereby, increase economic rents, and the social welfare lost from eliminating the most technically efficient vessels.

Coelli and Perelman (2000), measured and compared the performance of European railways. The authors also illustrated the usefulness of econometric distance functions in the analysis of production in multi-output industries, where behavioral assumptions such as cost minimization or profit maximization, are unlikely to be applicable. This study use annual data from 17 railways companies during 1988-93 period, and estimates multi-output distance functions using corrected ordinary least squares (COLS). The resulting technical efficiency estimates ranged from 0.980 for the Netherlands to 0.784 for Italy, with a mean of 0.863. The distance function results were also compared with those obtained from single-output production functions, where aggregate output measures were formed using either total revenue or a Tornqvist index. The results obtained indicate substantial differences in parameter estimates and technical efficiency rankings, casting significant doubt upon the reliability of these single-output models, particularly when a total revenue measure is used to proxy aggregate output.

Christopoulos et al, 2000 provide quantitative information on the magnitude of (time varying) input-specific inefficiency in the railway systems of ten countries in the European Union, as well as estimates of cost reductions that would be realized as a result of eliminating inefficiency due to each input separately. The researchers used a symmetric generalized McFadden flexible functional form to represent the cost structure. This form allows for global imposition of curvature conditions of neoclassical production theory. The authors found that production models based on the assumption of overall technical inefficiency can be rejected in favor of an input-specific technical inefficiency model. In addition the study examines the impact of railway technical characteristics on input-specific inefficiencies using maximum likelihood methods based on the beta distribution.

Cowie, 1999, examined the Swiss rail industry. In this study, the private and public ownership of the railroad industry was split on the basis of a 30 per cent private share holding. Data Envelopment Analysis (DEA) was used to estimate technical efficiency. Scale effects were found to be considerable, with most railways having increasing returns. Private railways were found to have significantly higher levels of technical, managerial, and organizational efficiencies, although organizational efficiency differences were less pronounced due to some variations in the results.

Cowie and Asenova, 1999 examined the organizational structure, scale effects and efficiency in the British bus industry. The researchers divided the British bus industry between privately and publicly owned companies, with the private sector further split into publicly listed owned subsidiaries and private companies. The authors also analyzed the change in ownership structure since privatization.

The researchers used Data Envelopment Analysis (DEA) to estimate the extent of returns to scale and technical efficiency, as defined by one output and three inputs. In this research work, technical efficiency is further divided into managerial and organizational components, and makes a comparison of median efficiency levels using a Mann Whitney statistical test. Results show that increasing returns to scale are found for smaller companies, but the size of such returns varies with the company type. A minimum efficiency scale is identified, with constant returns above this point. A high degree of technical inefficiency is found to be present in the industry, which may initially suggest a lack of competition and reflect the oligopolistic structure that has emerged since privatization. Privately owned companies are identified as more technically efficient, however this is due to significantly less organizational constraints, and considerable managerial inefficiency exists in this group. The authors concluded that the high level of inefficiency may not reflect ownership, but rather industry characteristics, and rather than a lack of competition may be indicative of wasteful competition. The researchers, therefore, suggested that there might be a need to make the market contestable rather than openly competitive.

A study by Chapin and Schmidt, 1999 examined the efficiency of the U.S. rail firms since deregulation using Data Envelopment Analysis (DEA). The authors also assessed whether mergers have improved efficiency in the rail industry. The researchers modeled production in two stages. In the first stage, firms produce a network of track as an output. In the second stage, firms use track to produce shipments of goods. Mergers increased technical efficiency in the first stage, but reduce scale efficiency. This result implies that many merged firms become larger and in the process sacrifice efficiency scale. Firms may merge to acquire market power from ownership of track. In the second stage, mergers have no effect on efficiency. This result reveals that efficiency has improved since deregulation, however this efficiency gains can not be attributed to mergers.

The article by Kerstens, 1999 determines the sources of observed technically inefficient behavior among French urban transit companies using non-parametric deterministic frontier specifications of technology. Decomposing overall technical efficiency yields component-wise efficiency measures reflecting scale, structural and technical inefficiencies. Also the effectiveness of urban transit is evaluated in a similar way. Moreover, the analysis investigates the effect of the selected orientation of measurement. The author states that this is the first study to control for the effect of outliers on the decomposition results. The empirical results indicate that technical inefficiency is the major source of poor performance, followed by inefficiencies due to inadequacies in scale. Congestion only plays a minor role.

In the paper by Mbangala and Perelman, 1997, the authors estimate technical efficiency for nine railways companies operating in the African Sub-Saharan countries using a nonparametric frontier approach: Data Envelope Analysis (DEA). Results show that over the 1975-90 period, some companies had major difficulties trying to improve, and even to maintain, their technical efficiency scores. Furthermore, the researchers used statistical analysis to identify some explanatory factors of technical efficiency. Among them, it appears that firms that favored passenger transportation over the last decades experienced also the best results.

McMullen uses Data Envelope Analysis (DEA) and a Malmquist Index to examine the sources of changes in U.S. motor carrier efficiency and productivity between 1977 and 1990 before and after the Motor Carrier Act (MCA) of 1980. The non-parametric approaches used by the author allow productivity changes to be decomposed into mutually exclusive categories: change caused by firms becoming more technically efficient with a given technology, and changes in technology. Contrary to expectations, results reveal that the DEA efficiency scores did not show that an increase in efficiency had occurred following deregulation. The Malmquist indices used by the author showed little overall change in productivity following the MCA of 1980. Using the Malmquist index, the author was able to decompose the overall change into efficiency and technical change. Malmquist results show that, as expected, firms did become efficient in the sense of moving closer to their relevant production frontier. The reason that the overall Malmquist productivity index shows little change is that efficiency gains were offset by technical regression in the post-MCA period.

Fethi M. et al (2001) developed an application of the stochastic DEA production frontierto study efficency across a panel of 17 European Airlines under the early stage of a market liberalization environment of the 1990's. The analysis was performed using the Land, Lovell and Thore model (1993) incorporating information on the covariance structure of input and output variables. Based on the analysis results, authors concluded that the airlines that were effficient on 1995, resembles those that were efficient in 1993, but not the ones in 1991. The airlines that were efficient in 1995, were the larger airlines companies.

In the present study efficiency measures are estimated for each trucking company by parametric stochastic frontier analysis using inputs and output data for the year 2001. The next section describes the parametric stochastic frontier analysis to estimate efficiency measures. The third section details the inputs and output data and construction. The empirical application and results are presented in the fourth section, followed by conclusions in the final section.

Stochastic Frontier Analysis

To represent efficiency in the primal approach for a firm i, $i = 1,........., I$, the basic form of the model can be represented as

(1) $y_i = f(x_i;\beta)\cdot\varepsilon_i$

where y denotes output produced from a vector of input, x and β the associated vector of parameters. Furthermore equation (1) can be utilized to estimate the efficiency measures by non-parametric or parametric approach. In this paper, we utilize the parametric stochastic frontier analysis approach.

Comprehensive literature reviews [Forsund, Lovell and Schmidt (1980), Schmidt (1986), Bauer (1990), Greene (1993), and Kumbhakar and Lovell (2000)] on the use of stochastic frontier analysis has been evolving since it was first proposed by Aigner, Lovell and Schmidt; Meeusen and van den Broeck; and Battese and Corra in the same year, 1977. The past decade has witnessed a surge in the extension of the parametric techniques to efficiency measurement. Furthermore within the primal framework, there has been progress made on the ability to handle multiple outputs and inputs via the distance functions, adjusting for time series properties, incorporating autocorrelation and heteroskedasticity, and finally the use of Bayesian techniques in the parametric efficiency measures.

The particular form considered here is the efficiency estimation from a primal production function. To formally represent this measure, equation (1) can be re-written to represent the parametric stochastic frontier analysis model with the decomposed error as:

(2) $y = f(x;\beta)\cdot v - u$

where v representing firm or time specific random error which are assumed to be identical and independently distributed and normally distributed variable with mean zero and variance σ_V^2; u represent the technical efficiency which must be positive hence absolutely normally distributed variable with mean zero and variance σ_U^2; and y, x and β as defined in equation (1).

With the paper by Jondrow, Lovell, Materov, and Schmidt in 1982, individual firm specific efficiency measures (u) conditional on ε can be represented as

$$(3) \qquad E\left(u \mid \varepsilon\right) = \frac{\sqrt{\sigma_{\mathrm{V}}^2 + \sigma_{\mathrm{U}}^2}\,\dfrac{\sigma_{\mathrm{U}}^2}{\sigma_{\mathrm{V}}^2}}{1 + \left(\dfrac{\sigma_{\mathrm{U}}^2}{\sigma_{\mathrm{V}}^2}\right)^2} \left[\frac{\phi(a_{it})}{1 - \Phi(a_{it})} - a_{it}\right]$$

where $a = \varepsilon \dfrac{\sqrt{\sigma_{\mathrm{V}}^2 + \sigma_{\mathrm{U}}^2}}{\sigma_{\mathrm{U}}^2 / \sigma_{\mathrm{V}}^2}$, and ϕ and Φ are the standard normal density and standard normal cumulative density function.

Data

The variables used to satisfy the objective of this paper are obtained from TTS Blue Book of Trucking Companies for the year 2001. The data for the input variables was divided into labor, capital, operating variable costs and operating fixed costs. The labor variables include (1) the number of drivers and helpers, (2) number of cargo handlers, (3) number of officers, supervisors, clerical and administrative staff, and (4) total number of other laborers. Capital variables include (1) number of tractors owned, (2) number of trucks owned, (3) number of tractors leased, (4) number of trucks leased, and (5) other equipment.

Operating variable costs include (1) fuel-gallons, oil, and lubricants and (2) total maintenance. The operating fixed cost category is composed of (1) total operating taxes and licenses; (2) total insurance; and (3) depreciation and amortization. The output variable consists of total ton-miles, which is the measurement most commonly used according to Caves et al (1980), McGeehan (1993) and Cantos et al. (1999), given that these demand related measure of output, allow an assessment of the level of user consumption and the value they place on the service. This ton-mile output measurement assumes little or no government control on the provision of the service, otherwise measures that isolate the government regulatory measures like truck-miles , which represents the degree of capacity or service level supplied by the trucking company, are more suitable for this type of analysis (Cantos, P. et al., 2000) The agribusiness trucking firms that this study analyzes to determine whether they are technically efficient are firms that haul agricultural commodities for hired.

Summary statistics for the U. S. trucking companies by commodity groups are shown in Table 1. Results indicate that agribusiness trucking carriers had a mean output value of 18.031 with a standard deviation of 1.132. The mean value of the agricultural commodity sector indicates these carriers ranked tenth in terms of ton-miles while the general freight container carriers had the highest mean value. The carriers that had the lowest mean value for the output component were the Less-than-truckload carriers. This group of carriers had a mean value of 16.565. The mean value of labor, 3.820, indicates that the agricultural commodity group had the lowest mean value among the U. S. trucking carriers. This value implies that the carriers in this category had the smallest number of employees during the study period.

Mean values of capital indicate that agricultural commodity carriers ranked 15 for ownership or lease of vehicular equipment among the carrier groups shown in Table 1.

These carriers as a group had a mean value of 4.914. This value implies that the carriers in this group did not invest heavily in the ownership or leasing of vehicular equipment to service its customers while most of the other carriers did.

The agricultural commodity carriers had 11th lowest operating variable costs in the United States in 2001. This value implies that this group did a fairly deceit job of keeping its operating variable costs low as possible so that they could serve their customers more efficiently than many of the carrier groups in the United States during the study period. The agricultural commodity carriers also had the 16th lowest operating fixed cost among the carrier groups in the United States in 2001. This group of carriers had a mean value of 13.569. This result implies that the carrier group was able to keep items such as insurance expenses low as possible to provide competitive services to their customers.

Results

Efficiency measures are estimated using 1961 trucking companies data for the year 2001. Specifically equation (2) is used to estimate the efficiency measures for each trucking company. Table 2 shows the means, standard deviations, and minimum and maximum values of efficiency measures by type of commodity carrier for the year 2001. Overall, mean values of the efficiency measures show that the 17 carrier groups were highly technically efficient in the year 2001. Mean values ranged from a high of 0.9619 for the refrigerated liquids carriers to a low of 0.8691 for the household goods carriers.

Efficiency measures show that the agricultural commodity group ranked eight among the 17 carrier groups in the United States for the year 2001. The mean value of the efficiency measure for the agricultural commodity group is 0.9462. Although the agricultural commodity carriers were not the best technically efficient group, these results do suggest that the agricultural commodity carriers as a whole did a very good technical job of providing the needed and wanted services for its customers in the study period.

As stated earlier in this paper, technical efficiency is a prerequisite for economical efficiency. Therefore the carriers should as a whole and individually strive to convert their technical efficiency advantages into economically efficiency advantages so that they will be able to provide their agribusiness customers with highly quality service at reasonable prices. This, in turn, will enable the agribusiness firms to purchase the required transportation services at reasonable rates so that they can continue to serve their customers at profitable levels. By enabling agribusiness firms to move agricultural commodities and products to their customers at reasonable rates will allow these firms to generate employment, tax revenues, output, and incomes to not only the agricultural commodity carriers serving them but also to their employees and the general public.

Summary and Conclusions

The purpose of this study was to evaluate the technical efficiency of agribusiness trucking carriers that haul agricultural and food products on a compensational basis. In this analysis, the parametric efficiency measures were estimated by decomposing them into technical efficiency and scale efficiency using the panel framework for differ carrier groups in the United States for the year 2001.

Results reveal that the trucking industry in general was highly technically efficient in 2001 with an overall mean value of 0.9368. Mean values of the technical efficiency measures ranged from a high of 0.9619 for refrigerated liquids truck carriers to a low of 0.8691 for household goods carriers. The agricultural commodity trucking companies had a mean value of 0.9462. This result implies that the agricultural commodity carriers as a whole in the United States performed very well from a technically efficient point of view. Therefore, the carriers in this category need to make sure that they transform this technical efficiency into an economically efficient process by combining their various external as well as internal resources into a service that provides economic value to their agribusiness customers in this highly competitive industry. This in turn will allow the agribusiness trucking companies in this segment to generate long-term profits by meeting the needs of their customers in the agribusiness sector.

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Table 1. Summary Statistics of Variables used in the Analysis

Commodity	Firms	Output	Labor	Capital	OVC	OFC
Mean						
General Freight, Less-than-truckload (LTL)	173	17.747	5.286	5.918	14.433	14.451
General Freight, Truck (TL)	822	18.482	4.337	5.328	14.205	13.989
Specialized Commodity Carrier, Heavy Machinery	59	17.908	4.155	5.189	13.778	13.952
Specialized Commodity Carrier, Petroleum Products (Tank Truck)	147	18.474	4.406	5.216	14.174	14.083
Specialized Commodity Carrier, Refrigerated Liquids (Tank Truck)	24	18.589	4.268	4.992	14.300	14.050
Specialized Commodity Carrier, Refrigerated Solids	162	18.681	4.251	5.094	14.354	14.009
Specialized Commodity Carrier, Dump Trucking	64	18.092	3.866	4.767	13.801	13.728
Specialized Commodity Carrier, Agricultural Commodities	62	18.031	3.820	4.914	13.807	13.569
Specialized Commodity Carrier, Motor Vehicles	25	18.318	4.604	5.072	14.049	14.494
Specialized Commodity Carrier, Building Materials	139	18.419	4.041	5.097	13.957	13.805
Specialized Commodity Carrier, Forest Products	22	17.959	4.111	4.938	14.087	13.796
Specialized Commodity Carrier, Retail Store Delivery Service	19	17.680	4.338	5.195	13.692	13.740
Specialized Commodity Carrier, Not Elsewhere Classified (NEC)	113	18.054	4.242	5.039	13.790	13.863
Household Goods Carrier	35	16.565	4.958	5.247	13.545	14.264
Specialized Commodity Carrier, Bulk Chemical	28	18.634	4.323	5.511	14.278	14.171
General Freight, Parcel	16	16.658	5.335	5.225	14.039	13.888
General Freight, Container	34	17.679	3.972	4.688	12.879	13.226
Standard deviation						
General Freight, Less-than-truckload (LTL)	173	1.869	1.678	1.727	1.589	1.702
General Freight, Truck (TL)	822	1.196	1.090	1.127	1.222	1.116
Specialized Commodity Carrier, Heavy Machinery	59	1.516	1.121	1.255	1.209	0.966
Specialized Commodity Carrier, Petroleum Products (Tank Truck)	147	1.210	1.222	1.164	1.223	1.061
Specialized Commodity Carrier, Refrigerated Liquids (Tank Truck)	24	0.984	0.946	1.005	0.923	0.912
Specialized Commodity Carrier, Refrigerated Solids	162	1.124	1.101	1.080	1.224	1.048
Specialized Commodity Carrier, Dump Trucking	64	0.818	0.822	0.854	0.908	0.876
Specialized Commodity Carrier, Agricultural Commodities	62	1.132	0.925	1.122	1.003	0.782
Specialized Commodity Carrier, Motor Vehicles	25	1.281	1.405	1.421	1.835	1.206
Specialized Commodity Carrier, Building Materials	139	1.022	0.987	0.902	1.085	0.962
Specialized Commodity Carrier, Forest Products	22	0.684	0.679	0.980	0.902	0.633
Specialized Commodity Carrier, Retail Store Delivery Service	19	1.279	1.175	1.211	1.493	1.275
Specialized Commodity Carrier, Not Elsewhere Classified (NEC)	113	1.218	1.091	1.041	1.507	1.001
Household Goods Carrier	35	2.209	1.020	1.002	0.955	1.383
Specialized Commodity Carrier, Bulk Chemical	28	1.265	1.308	0.996	1.078	1.162
General Freight, Parcel	16	2.089	2.111	1.981	1.896	1.954
General Freight, Container	34	1.448	0.902	0.921	1.187	0.835

Table 2. Mean and Standard deviation of the Efficiency measures

Commodity	Firms	Efficiency Measures			
		Mean	Std	Min	Max
General Freight, Less-than-truckload (LTL)	173	0.9090	0.0447	0.7574	0.9847
General Freight, Truck (TL)	822	0.9530	0.0301	0.6979	0.9936
Specialized Commodity Carrier, Heavy Machinery	59	0.9322	0.0470	0.7096	0.9915
Specialized Commodity Carrier, Petroleum Products (Tank Truck)	147	0.9533	0.0327	0.7573	0.9900
Specialized Commodity Carrier, Refrigerated Liquids (Tank Truck)	24	0.9619	0.0194	0.8902	0.9815
Specialized Commodity Carrier, Refrigerated Solids	162	0.9615	0.0244	0.8433	0.9941
Specialized Commodity Carrier, Dump Trucking	64	0.9492	0.0301	0.8513	0.9871
Specialized Commodity Carrier, Agricultural Commodities	62	0.9462	0.0362	0.8113	0.9884
Specialized Commodity Carrier, Motor Vehicles	25	0.9457	0.0301	0.8443	0.9824
Specialized Commodity Carrier, Building Materials	139	0.9566	0.0279	0.8158	0.9926
Specialized Commodity Carrier, Forest Products	22	0.9430	0.0230	0.8851	0.9713
Specialized Commodity Carrier, Retail Store Delivery Service	19	0.9288	0.0426	0.8227	0.9812
Specialized Commodity Carrier, Not Elsewhere Classified (NEC)	113	0.9423	0.0393	0.7666	0.9935
Household Goods Carrier	35	0.8691	0.0752	0.7094	0.9883
Specialized Commodity Carrier, Bulk Chemical	28	0.9535	0.0298	0.8776	0.9837
General Freight, Parcel	16	0.8786	0.0635	0.7682	0.9908
General Freight, Container	34	0.9419	0.0619	0.6796	0.9905