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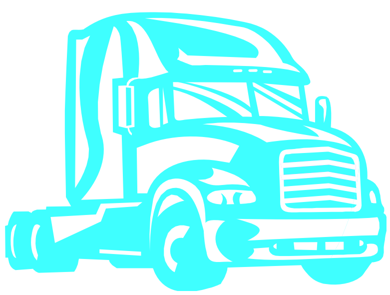

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Abstract

Stochastic frontier analysis, which is used to estimate the technical efficiency, is extended to examine the market structure, conduct and performance hypothesis for the U.S. trucking industry. The technical efficiency measure takes into account not only the relationship between inputs used in the production of output but also simultaneously examine the importance of market structure conduct factors on the performance of the firm. An empirical application to U.S. trucking carriers over the period 1994-2003 is examined. Results reveal that the variables average haul, average load, debt-to-equity and market concentration significantly affected technical efficiency. Capital, fixed and variable input variables were significant in the production function equation.

Market Structure Conduct Performance Hypothesis Revisited Using Stochastic Frontier Efficiency Analysis

Saleem Shaik[1], Albert J. Allen[2], Seanicaa Edwards, James Harris

Introduction

The market structure conduct and performance (SCP) framework was derived from the neo-classical analysis of markets. The structure conduct and performance paradigm was developed by the Harvard school of thought and popularized during 1940-60 with its empirical work involving the identification of correlations between industry structure and performance (Bain 1951). This structure conduct and performance hypothesis has led to the implementation of most anti-trust legislation. This was followed by the Chicago school of thought from 1960-80. They emphasized the rationale for firms becoming big, price theory and econometric estimation (Demsetz 1973; Peltzman 1976; Becker 1983). Schmalensee (1989) provides a comprehensive review of the SCP studies. During 1980-90 game theory took center stage with emphasis on strategic decision making and the Nash equilibrium concept (Triole 1988). After 1990, empirical industrial organization with the use of economic theory and econometrics led to complex empirical modeling of technological changes, merger analysis, entry-exit and identification of market power (Bresnahan 1982 and 1989).

The inverse relation between the degree of market concentration and degree of competition has been the underlying assumption of the market SCP hypothesis. This is because market concentration encourages firms to collude. More specifically, the standard SCP paradigm asserts that there is a direct relationship between the degree of market concentration and the degree of competition among firms. This hypothesis will be supported if there is a positive relationship between market concentration (measured by concentration ratio) and performance (measured by profits), regardless of efficiency (measured by market share) of the firm. Thus firms in more concentrated industries will earn higher profits than firms operating in less concentrated industries, irrespective of their efficiency.

A number of studies have examined the SCP hypotheses for various industries, commodities and products including Byeongyong and Weiss (2005), Smirlock et al.(1984), Alley (1993), Frech and Mobley (2000), and Allen and Shaik (2005). The general objective of these studies was to investigate the market structure and conduct factors affecting the performance using measures of profit/profit margin as the indicator of performance. Alternatively, the market SCP hypotheses can be examined by technical efficiency of the firm instead of profit/profit margin as the indicator of performance using primal production function framework.

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The technical efficiency concept introduced by Farrell (1957) is defined as the distance of the observation from the production frontier and measured by the observed output of a firm, state or country relative to realized output, i.e., output that could be produced if it were 100% efficient from a given set of inputs. In other words, technical efficiency of a firm can be defined as a measure of how well the firm transforms inputs into outputs given the technology and economic factors. Firms using the same set of inputs and technology may produce considerably different levels of output due to technical efficiency. Technical efficiency can be estimated by parametric stochastic frontier analysis or non-parametric linear programming approach.

Stochastic frontier analysis has become a popular tool to model the production relationship between input and output quantities and has been primarily used to estimate the technical efficiency of firms, states, and countries. Stochastic frontier analysis was first proposed by Aigner et al. (1977); and Meeusen and van den Broeck (1977). The past decade has witnessed a surge in the extension of parametric techniques to estimate technical change, efficiency change and productivity change measures using stochastic frontier analysis [for comprehensive literature reviews see Forsund et al. (1980), Greene (1993), and Kumbhakar and Lovell (2000)].

Efficiency and productivity measures of motor carrier firms have been estimated using parametric and non-parametric methods in the literature [McMullen, B. S. (1987), McMullen, B. S. and L R. Stanley (1988), McMullen, B. S. and H. Tanaka (1995), McMullen, B. S. and Man-Keung Lee (1999) and McMullen, B. S. and K. Okuyama (2000)] to examine the importance of regulation in the industry. Stochastic frontier analysis used to estimate technical efficiency is extended to examine the market structure, conduct and performance hypothesis for the U.S. trucking industry. Unlike the traditional two-stage procedure of computing the profit or profit margin, and then examining the factors affecting the performance of the firm, the proposed method is a single-stage procedure. The technical efficiency measure takes into account the relationship between inputs used in the production of output, and simultaneously examines the importance of market structure conduct factors on the performance of the firm. Specifically, a stochastic frontier production function equation and structure conduct performance equation is estimated with firm's output and technical efficiency, respectively as endogenous variables.

In this paper, the stochastic frontier production function technical efficiency measure is used as a measure to examine the market structure conduct performance hypotheses with an empirical application to U.S. trucking carriers by commodities over the period 1994-2003. In the following section, the theoretical model to jointly estimate the technical efficiency measure and structure conduct performance equation is presented. This discussion is followed by the data and construction of the variables to be used in the empirical model. The empirical application and results are presented in the next section followed by conclusions.

Stochastic Frontier Technical Efficiency and Performance Models

Following Allen and Shaik (2005), the market structure conduct performance hypotheses can be examined using profit or profit margin as an endogenous variable. This can be represented as:

(1) $$Performance\left(Y_1\right) = f\left(X_1\right)$$

where X_1 a vector of market structure and conduct variables and Y_1 is profit or profit margin, a measure of performance. The vector of X_1 variables include market concentration, market share, industry specific factors like average load and average haul, and risk factors like long term risk and financial ratio variables. The use of profit or profit margin as a measure of performance to examine market structure conduct performance hypotheses does take into account the production relationship between inputs used to produce output via the ex-post profits.

To account for the production relationship between output and input in examining the market structure conduct performance hypothesis, the technical efficiency, u of the firm estimated from stochastic frontier analysis is used as a measure of performance to examine market structure conduct performance hypotheses. To use technical efficiency, u as a measure of performance to examine market structure conduct performance hypotheses involves a two-step process.

The first step involves estimating the technical efficiency, u of a firm using stochastic frontier analysis of the production function. To represent technical efficiency in the primal (only quantities and not prices of output and input are used to examine the relationships) approach for a firm i, $i = 1,........,I$, the basic form of the production function model can be represented as:

(2) $$Output\left(Y_2\right) = f\left(X_2;\beta\right)\cdot v - u$$

where X_2 a vector of input variables affecting the output Y_2 , β is the input parameter coefficients; v represents firm or time specific random error which are assumed to be *iid (independent and identically distributed)* and normally distributed variable with mean zero and variance σ_V^2; and u represents the technical efficiency which must be positive hence absolutely normally distributed variable with mean zero and variance σ_U^2 .

The second step involves using technical efficiency, u , as a dependent variable to examine the market structure conduct performance hypotheses. To represent the second step, equation (1) can be re-written as

(3) $Performance(u) = f(X_1)$

where u is the technical efficiency a measure of performance, X_1 is a vector of variables including market concentration, market share, industry specific factors like average load and average haul, and risk and financial ratio variables.

The two-step process has been the subject of analysis by earlier researchers to examine the relationship between farm size, financial variables, organization, management and efficiency/productivity. However, the two-step process might be faced with bias due to omitted or left out variables (see Wang and Schmidt 2002) or heteroskedasticity (Greene 2004).

Hence, following Greene (2004) instead of a two-step process, a simultaneous equation model is used to examine the market structure conduct performance hypotheses. The simultaneous estimation of the stochastic frontier production function model and performance model with output and technical efficiency as endogenous variables to examine the structure conduct performance hypothesis can be represented as

$$\begin{aligned} &Performance(u) = f(X_1) \\ &Output(Y_2) = f(X_2;\beta)\cdot v - u \end{aligned} \qquad (4)$$

Where the variables are defined earlier under equation 2 and 3.

Equation 4 was also estimated with random error variance, σ_V^2 as a function of variables to account for heteroskedasticity. But none of the variables in the heteroskedasticity model were significant, hence equation 4 is the final model used in the estimation.

Empirical Results

To examine the structure conduct performance hypothesis using stochastic frontier analysis, equation (4) can be econometrically represented as:

$$\begin{aligned} Performance(u_{it}) = {} & \alpha_1 + \beta_{1,1}\, Mshare_{it} + \beta_{1,2}\, Mconc_{it} + \beta_{1,3}\, CAR_{it} + \beta_{1,4}\, LRisk_{it} + \\ & \beta_{1,5}\, Ahaul_{it} + \beta_{1,6}\, Aload_{it} + \varepsilon_{it} \\ Output(Y_{2,it}) = {} & \alpha_2 + \beta_{2,1}\, Labor_{it} + \beta_{2,2}\, Capital_{it} + \beta_{2,3}\, OVC_{it} + \beta_{2,4}\, OFC_{it} + v_{it} - u_{it} \end{aligned} \qquad (5)$$

where u is the technical efficiency estimated from the output Y_2 equation and used as the dependent variables in the performance equation, and i represents the number of firms and t represents the number of years. The construction and definition of the endogenous and exogenous variables presented in equation (5) is defined next.

Data and Construction of the Variables

The variables used to estimate equation (5) are obtained from *TTS Blue Book of Trucking Companies* for the period 1994-2003. The Technical Transportation Services, Inc. (TTS) is the company that publishes the Blue Book of Trucking Companies. The company has not published data beyond 2003 and hence the use of data up to 2003. The data for the input variable was divided into labor; capital, operating variable costs and operating fixed costs. The ***labor*** variable includes (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. The ***capital*** variable includes (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 (***OVC***) include (1) fuel, oil, and lubricants and (2) total maintenance. The operating fixed cost (***OFC***) category is composed of (1) total operating taxes and licenses; (2) total insurance; and (3) depreciation and amortization. Both ***OVC*** and ***OFC*** were deflated by implicit gross domestic product price deflator to obtain implicit quantity index of ***OVC*** and ***OFC*** in 1000 dollars. The output variable consists of total ton-miles, which is the measurement most commonly used according to Caves et al. (1980) and Cantos et al. (1999). Since these input variables are used in the estimation of Hicks-neutral (Hicks-neutral assumes the technology is indifferent or similar across the inputs used in the production of output) stochastic frontier production function it is expected to be positively related to output. The sign on technology or time trend variable could be positive or negative.

The market structure conduct efficiency equation variables include market share (***mshare***). It is the share of firm *i* in time period *t* or the proportion of the market that the firm is able to capture and can measure the firm's performance relative to its competitors. Market share is computed for each commodity. Market share is often positively associated with profitability and thus many firms seek to increase their sales relative to competitors (QuickMBA 2009). Even though market share is expected to be positively related to profitability, its relationship to efficiency of the firm might be negative if there are too many firms leading to overall reduction in the industry production efficiency, that is, relatively higher cost structures. Alternatively, due to intense competition among firms in the industry, the overall industry production efficiency might actually be positively related to market share. This is because market concentration emerges from competition where firms with low cost structures increase profits by reducing prices and expanding market share. As a result, firms that are more efficient would perform better. This result would support the efficient structure hypothesis which holds that performance of the firms would be positively related to their efficiency (market share in this case), regardless of the degree of concentration in the market (Molyneux and Forbes 1995).

The market concentration[1] (***mconc***) of firms is the percentage of market share owned by the largest *m* firms in an industry, where *m* is a specified number of firms. The concentration ratio can be expressed as: $CR_m = s_1 + s_2 + s_3 + \ldots .. + s_m$, where s_i = market share of the i^{th} firm. In this study the 4-firm concentration ratio is used. Once again the market concentration is computed for each commodity. The market concentration is expected to be positively related to production efficiency due to the traditional SCP hypothesis of increased collusive or monopolistic activities by larger farms or firms (Page 1984). The long-term Debt-to-Equity (***LRisk***) variable is obtained by dividing long-term liabilities by total equity and represents long term risk. This variable measures the indebtedness of a company relative to invested capital (TTS). CAR is total equity divided by total assets which are financed by the owner's capital rather than through debt, and therefore indicates financial position. The debt-to-equity variable is expected to be negatively related to production efficiency, while the equity-to-asset ratio is expected to be positively related to production efficiency. The higher the ratio of debt to equity, the higher is the financial risk faced by the business because of the operation of the principle of increasing risk. Thus financial risk exacerbates business risk (Malcolm et al. 2005). The higher the ratio of equity to assets, the more equity the owner has put into the operation of the firm and less by creditors.

Average length of haul (***Ahaul***) is obtained by dividing total ton-miles by total tons. This variable shows how far the unit travels (one way) each time it is dispatched. Average load (***Aload***) is obtained by dividing ton-miles-highway service by total highway miles operated. This variable is an index of the use of productive capacity. In addition, this index indicates the number of tons transported by each unit dispatched (TTS). Average length of haul is negatively related to production efficiency due to economies of scale. This can occur when motor carriers serving longer distance markets experience a decrease in average total cost as the fixed costs associated with terminal and handling expenses are distributed over more units of output. Thus, total cost increases at a decreasing rate as the distant markets are served. The average load is expected to be negatively related to the production efficiency due to the principle of diminishing marginal returns. Table 1 defines the summary of the variables used in the analysis, description of each variable, and expected signs in the regression analysis for the study period. Table 2 presents the number of observations and the means of the variables used in the stochastic frontier production function equation by commodity carriers. Both were estimated by LIMDEP (Greene 2007). The importance of carriers in the freight commodities industry during the study period is revealed. Less-than truckload (LTL) carriers of general freight commodities had the largest mean values of the variables used in estimating the stochastic frontier production function relative to other commodity carriers. For example, the LTL carriers had mean values of almost 520,409 ton-miles; 2,626 employees; 914 units of capital equipment; 6,233 implicit quantity index in thousand dollars; and 16,840 implicit quantity index in thousand dollars for output, labor, capital, operating variable costs, and operating fixed costs, respectively.

The truckload (TL) carriers of general freight commodities had the second largest mean output value of almost 343,810 ton-miles and operating variable costs of almost 3,174 implicit quantity index in thousand dollars relative to other commodity carriers. The carriers of motor vehicles had the second largest mean values of almost 311 workers, 268 units of capital equipment, and operating fixed costs of almost 5,857 implicit quantity index in thousand dollars relative to other commodity carriers during the analysis.

Table 2 also represents the number of observations and means of the market structure conduct and performance equation variables by commodity. Carriers of vehicles had the largest average market share of almost 7% relative to other carriers. This result, in general, indicates that trucking carriers had relatively small mean market shares during the study period. Market share is used by businesses to determine their competitive strength in a sector as compared to other companies in the same sector. It also allows the accurate assessment of a company's performance from year to year (wiseGEEK 2009).

The results also show that the carriers of motor vehicles had the largest 4-firm concentration ratio of 22% which shows that the overall trucking industry was highly competitive during the study period. Further motor vehicle carriers had the largest standard deviation for the market share variable used in the market structure conduct and performance variables.

Table 1. Summary of Variables, Description and Expected Signs for the Study Period

	Description	**Expected Signs (+/-)**
Stochastic Frontier Production Function Equation Variables		
Labor	Number of Employees	Positive
Capital	Units of Equipment	Positive
OVC	Operating Variable Costs	Positive
OFC	Operating Fixed Costs	Positive
Time	Represents technology changes	Positive/Negative
Market Structure, Conduct, Performance Equation Variables		
Mshare	Market Share=Firm's Gross Revenue/Total Gross Revenue for each Commodity Sector	Positive/Negative
Mconc	4-Firm Concentration Ratio=Sum of market shares for top firms in each commodity sector	Positive
CAR	Total equity/Total assets	Positive
LRisk	Long-term liabilities/Total equity	Negative
Ahaul	Total ton-miles/Total tons	Negative
Aload	Ton-miles-highway service/ Total highway miles operated	Negative
Time	Represents technology changes	Positive/Negative

Table 2. Means of Production Function Variables by Commodity

	N	Output (Ton miles)	Labor (Number)	Capital (Number)	OVC (Dollars)	OFC (Dollars)
Gen. Freight, LTL	883	520,408.9	2,625.6	914.2	6,233.0	16,839.6
Gen. Freight, TL	3660	343,809.8	263.4	193.1	3,173.8	3,951.4
Heavy Machinery	233	160,164.8	186.8	161.3	1,308.6	2,282.1
Petroleum Products	734	286,859.5	207.8	168.1	1,592.6	3,196.4
Refrigerated Solids	806	321,350.9	173.2	151.9	2,801.6	2,880.2
Dump Trucking	291	130,078.0	81.3	73.4	1,058.0	1,461.2
Agricultural Commodities	315	120,765.8	74.6	62.3	1,069.2	1,249.4
Motor Vehicles	134	219,780.9	310.8	267.5	2,526.2	5,856.7
Building Materials	574	200,378.1	121.0	115.6	1,594.0	2,178.4
Others	997	210,942.9	208.1	165.0	1,804.3	2,773.8

	Mshare (%)	Mconc (%)	CAR (Ratio)	LRisk (Ratio)	Ahaul (Miles)	Aload (Tons)
Gen. Freight, LTL	0.0113	0.1588	0.410	2.018	0.449	9.265
Gen. Freight, TL	0.0023	0.0273	0.353	5.487	0.652	16.142
Heavy Machinery	0.0364	0.0787	0.440	2.898	0.504	15.430
Petroleum Products	0.0129	0.0311	0.413	2.876	0.261	20.957
Refrigerated Solids	0.0104	0.0417	0.333	3.643	0.790	17.212
Dump Trucking	0.0325	0.0276	0.382	1.820	0.232	20.163
Agricultural Commodities	0.0290	0.0250	0.430	2.357	0.631	19.154
Motor Vehicles	0.0696	0.2238	0.376	1.433	0.540	15.294
Building Materials	0.0156	0.0403	0.396	2.530	0.517	18.818
Others	0.0094	0.0829	0.424	2.118	0.465	16.406

Results

To examine the market structure conduct performance hypotheses of U.S. trucking carriers using technical efficiency as a measure of performance, equation (5) is estimated for each of the 10 category groups. The output equation is estimated using the logs of the variables and the market structure conduct performance equation is estimated in levels as the efficiency measure is in levels. Stochastic frontier analysis of a production function and the performance equations was estimated following Greene (2007). Table 3 presents the mean, standard deviation, minimum and maximum efficiency scores estimated from the stochastic frontier output equation by commodity. Parameter coefficients and the significant variables indicated by bold font are presented in Table 4.

Mean efficiency score estimates presented in Table 3 by commodity carriers show that other commodity carriers had the highest efficiency score of .74, followed by heavy machinery carriers of almost .72. These results, in general, indicate that the trucking carriers were 28% inefficient in their operations during the study. Thus, managers and owners of the carriers need to do a better job of improving their operations in the future than they did in the study period. This is not true for some carriers. For example, LTL and TL carriers of general freight commodities, refrigerated solid carriers, petroleum products carriers, and carriers of building materials had firms with maximum efficiency scores of 1.00 indicating that these firms reached the highest level of efficiency in their respective commodity areas during the study period. However, the managers and owners of these carriers need to continue to do everything in their power to maintain this level of efficiency in the future as they most likely will be challenged by other carriers to enhance the efficiency of their operations. Overall the standard deviation of the efficiency scores across commodity groups are within the range of 22-28%.

Table 3. Summary Statistics of Efficiency Scores by Commodity

Commodity	N	Mean	Standard Deviation	Minimum	Maximum
Gen. Freight, LTL	883	0.615	0.276	0.045	1.000
Gen. Freight, TL	3660	0.623	0.237	0.099	1.000
Heavy Machinery	233	0.715	0.276	0.023	0.998
Petroleum Products	734	0.689	0.239	0.088	1.000
Refrigerated Solids	806	0.698	0.243	0.098	1.000
Dump Trucking	291	0.474	0.231	0.088	0.962
Agricultural Commodities	315	0.627	0.223	0.136	0.993
Motor Vehicles	134	0.559	0.246	0.243	0.963
Building Materials	574	0.705	0.234	0.121	1.000
Others	997	0.743	0.221	0.030	0.990

Table 4. Parameter Coefficient of the Production Function - SCP Equation by Commodity

	Stochastic Frontier Production Function Equation					
	Intercept	**Labor**	**Capital**	**OVC**	**OFC**	**Time**
Gen. Freight, LTL	**68.200**	**-0.199**	**0.331**	**0.173**	**0.653**	**-0.032**
Gen. Freight, TL	-0.626	**0.099**	**0.410**	**0.027**	**0.343**	0.004
Heavy Machinery	45.934	0.040	**0.704**	**0.194**	0.094	-0.020
Petroleum Products	**-40.305**	**0.182**	**0.354**	**0.047**	**0.211**	**0.024**
Refrigerated Solids	**-34.728**	**0.107**	**0.244**	**-0.079**	**0.523**	**0.021**
Dump Trucking	44.545	-0.052	**0.225**	**0.124**	**0.282**	-0.018
Agricultural Commodities	4.429	0.020	**0.272**	**0.056**	**0.247**	0.002
Motor Vehicles	43.562	-0.020	**0.668**	0.055	0.093	-0.018
Building Materials	**-46.433**	**0.144**	**0.446**	**-0.066**	**0.290**	**0.027**
Others	-24.618	**0.135**	**0.390**	-0.007	**0.428**	0.016

	Market Structure, Conduct, Performance Equation							
	Intercept	**Mshare**	**Mconc**	**CAR**	**LRisk**	**Ahaul**	**Aload**	**Time**
Gen. Freight, LTL	**2.829**	1.312	1.772	-0.221	0.001	**-4.187**	**-0.328**	0.012
Gen. Freight, TL	**3.140**	**-121.284**	-3.299	**0.705**	0.000	**-1.388**	**-0.200**	**-0.038**
Heavy Machinery	**5.154**	-3.153	0.932	0.748	0.027	-1.319	**-0.400**	-0.292
Petroleum Products	**5.208**	**-181.047**	-1.973	**-1.817**	-0.006	**-1.453**	**-0.207**	-0.062
Refrigerated Solids	**4.241**	**-278.382**	3.546	0.132	-0.019	**-0.973**	**-0.227**	-0.008
Dump Trucking	**3.945**	**-28.986**	**12.917**	**-1.746**	-0.028	**-1.514**	**-0.091**	-0.087
Agricultural Commodities	**5.096**	**-45.702**	-8.883	**0.874**	0.000	**-1.453**	**-0.173**	**-0.285**
Motor Vehicles	**2.163**	-4.317	1.169	-0.161	**0.209**	**-1.116**	**-0.191**	0.082
Building Materials	**4.606**	**-74.916**	-1.352	**0.388**	0.004	**-4.095**	**-0.184**	-0.105
Others	**2.357**	1.175	**5.257**	0.940	-0.002	**-1.217**	**-0.305**	-0.062

Note: Values with bold font indicate significant at 0.05 % level of significances.

Parameter estimates from the stochastic frontier output equation are expected to be positively related to output due to the assumptions of the production function. In general, all the variables were positively related with output and consistent with the theory of the production function with few exceptions. The labor variable with a positive and significant sign indicates with more labor-truck drivers and cargo handlers more output-ton mile is realized for general freight TL, petroleum products, refrigerated solids, building materials and other categories. The coefficient was highest for petroleum products (0.182) followed by building materials (0.144), others (0.135), refrigerated products (0.107) and general freight TL (0.099). Since the variables are in logarithms, the parameters can be interpreted as elasticities. For example, a 1% increase in labor for petroleum products would lead to 0.182% increase in the output. The exception was general freight LTL category with a negative and significant sign. LTL freight carriers generally consolidate and carry multiple shipments to multiple destinations, typically through a hub-and-spoke system (Nickerson and Silverman 2003). Using this type of system requires timely coordination of truck arrivals and departures at break-bulk facilities, large warehouses in which freight must be rapidly unloaded, sorted, and reloaded. One late arrival at one of these facilities may lead to a reduction in output to the carrier's entire system and thus reducing efficiency. Also, due to large number of times freight is handled in this industry, there could be an increase in damage to freight thus reducing output. In many instances, these carriers outsource drivers (Nickerson and Silverman 2003). To increase the output, the LTL companies may want to use their own drivers rather than outsourcing. In this way, the carriers will have greater control over the handling process. Other input categories had positive and negative labor coefficients but were not significant.

Capital with positive and significant signs indicates with more capital more output-ton mile is realized for all the categories. The coefficient of capital was 0.704 (heavy machinery) and 0.668 (motor vehicles) at the higher end, and 0.225 (dump trucks) and 0.244 (refrigerated solids) at the lower end. For refrigerated solids and heavy machinery, for example a 1% increase in capital would lead to 0.244 and 0.704% increase in output, respectively.

Like capital, the operating fixed cost (OFC) with positive signs indicates that with more OFC more output-ton mile is realized for all the categories. It is significant for all the motor carrier categories with the exception of heavy machinery and motor vehicles. The coefficient of OFC was highest (0.653) for general freight LTL and lowest (0.211) for petroleum products. Operating variable cost (OVC) was positive and significantly related to output with the exception of the refrigerated products and building materials categories. The time trend variable was positively related to output with the exception of general freight LTL. Heavy machinery and dump trucking had negative coefficients but were not significant.

Results of the market structure and conduct variables on performance, i.e., the technical efficiency measure are reported in Table 4. The parameter coefficients cannot be interpreted as elasticities as the endogenous and exogenous variables are not in logarithms. Market share with negative and significant signs indicates that with increased market share lower efficiency is realized for most of the categories with few exceptions. These exceptions however were statistically insignificant. The magnitude of market shares was -278.4 (refrigerated solids) and -181.1 (petroleum products) at the higher end, and -28.9 (dump trucks) and -45.7 (agricultural commodities) at the lower end. Market concentration had mixed signs but was positive and significant for dump trucking and other categories. The positive sign indicates a highly concentrated industry would lead to higher production efficiency and thus higher profits due to efficient use of inputs to produce output.

The significantly positive concentration ratios estimated for the dump trucking and other categories industry support the traditional interpretation of the structure-conduct-performance (SCP) paradigm that is based on the proposition that market concentration fosters collusion among firms in an industry. Thus, firms in more concentrated industries will earn higher profits through collusive or monopolistic activities than firms operating in less concentrated industries, irrespective of the efficiency of the firms. This hypothesis is not supported for the remaining categories of firms in this study.

Average load and average haul with negative and significant signs indicate that with increased load per trip and length of the haul per trip, lower efficiency is realized for all the categories. The negative sign leading to lower production efficiency of the trucks with higher average load and hauling over greater distance might be due to the principle of diminishing marginal returns.

The long-term risk variable is positive and significant only for the motor vehicles category indicating firms in this category with higher indebtedness are motivated to be more efficient in the production of the output. Firms with more of its own equity invested in the operation tend to be positively (negatively) related to production efficiency of general freight TL, agricultural commodities and building materials (petroleum products and dump trucking).

Summary and Conclusions

The stochastic frontier analysis used to estimate technical efficiency is extended to examine the market structure, conduct and performance hypothesis for the U.S. trucking industry. This research is the first that proposes and estimates a stochastic frontier production function equation and structure conduct performance equation with firm's output and technical efficiency, respectively as endogenous variables to examine market SCP hypothesis. Traditional capital, labor, fixed and variable cost input variables were included in the estimation of stochastic frontier production function equation. The market structure and conduct variables and additional risk variables were included in the technical efficiency equation to examine the performance hypothesis. Unlike the traditional analysis of market SCP hypothesis, the results are mixed when using pure technical efficiency as a measure of performance of the US trucking industry for the period 1994-2003.

The parameter coefficients show that labor, capital, operating variable cost, and operating fixed cost were mostly positively and significantly related to the stochastic frontier production function that was developed for this analysis for several motor carrier commodity categories. For example, the labor results indicate that with more labor-truck drivers and cargo handlers, more output per ton mile can be realized for general freight TL, petroleum products, refrigerated solids, building materials and other commodity categories under the assumption of Hicks-neutral technical change. The results imply, in general, that firms in these commodity categories might want to look closely at the feasibility of adding more workers to their firms and yet be efficient with output production.

The impact of the market structure and conduct variables on performance, i.e., the technical efficiency measure, reveals that market share, which is often associated with profitability, was negatively and significantly related to technical efficiency for the following commodity categories: (1) refrigerated solids; (2) petroleum products; (3) dump trucks; and (4) agricultural commodities. These results imply that the firms in these commodity categories needed to reduce their market share to become more technically efficient during the study period. In this case, the firms need to identify those customers that are unprofitable and drop them. This will allow the firms to lose market share while improving profitability (or technical efficiency).

In the future, this analysis will be extended by using economic and technical efficiency with cost functions. Also, additional data beyond the study period (1994-2003) are needed to more completely evaluate changes that might have occurred since that firm-level data set was published in 2003. Nevertheless, this analysis offers insight into the factors affecting the market conduct structure performance of the trucking industry during the study period.

Endnotes

[1]The market concentration and market share computation is computed for each commodity group to truly capture the market structure and conduct variables of the trucking industry. We did not use the Herfindahl-Hirschman Index (HHI) because we felt that the 4-firm concentration ratio was appropriate for our analysis. Although the HHI is considered a better indicator of industry concentration by many than the 4-firm concentration ratio that we used in our analysis because it uses information about each firm in the industry, it is not without a few problems (AmosWeb.com 2009). According to AmosWeb.com, the HHI has three major problems when you use it for estimating market concentration values. The first problem is to find meaning in the numbers that you calculate. For example, if you calculate a 4-firm concentration ratio of 62.25 percent, this value means that the top four firms account for 62.25 percent of the total industry sales. However, if you calculate an HHI value of 1177, there is no obvious intuitive meaning to the Herfindahl-Hirschman Index value of 1177. Another problem with the HHI is the choice of squaring the market shares. There is no particular reason, theoretical or otherwise, to square the market shares of each firm. Although it is obvious that squaring each firm market share would give more importance or weight to the larger firms than the smaller firms for the industry, the market shares could have been calculated by cubing each share and so forth. The final problem with the HHI is that it requires a substantial amount of information than the 4-firm concentration ratio that we used in our analysis. With the 4-firm concentration ratio that we used, the only information that is required is the market shares of the top four firms. However, with the HHI, the market share of each firm is needed and then you have to square each share, and then sum all these squared market shares to get the HHI value.

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