these hypotheses, a more detailed analysis of the limits to mass cycling and motor vehicle mixing in the communities that have been isolated is recommended.

REFERENCES

1. K. Moran; Mountain Bicyclists' Association, Inc. Bicycle Transportation for Energy Conservation. U.S. Department of Transportation, April 1980.
2. M.D. Everett. Marketing Bicycle Transportation: A Critique of the National Comprehensive Bicycle Transportation Program. TRB, Transportation Research Record 851, 1982, pp. 37-40.
3. The College Blue Book: Tabular Data. MacMillan, New York, 1981.
4. Patterson's American Education. Education Directories, Inc., Mount Prospect, IL, 1980.
5. Selected Characteristics of Travel to Work in 21 Metropolitan Areas, 1977. Bureau of the Census, U.S. Department of Commerce, Current Population Reports, Series P-23, No. 105, Jan. 1981.
6. De Leuw, Cather and Company. Bikeway Design Evaluation. District of Columbia Department of Transportation, Washington, DC, 1979.
7. C.A. Buckley. Bicycle Traffic Volumes. TRB, Transportation Research Record 847, 1982, pp. 93-102.
8. F.O. Robinson, J.L. Edwards, and C.E. Ohrn. Strategies for Increasing Levels of Walking and Bicycling for Utilitarian Purposes. TRB, Transportation Research Record 743, 1980, pp. 38-48.
9. W. Hyman and others. Development of Wisconsin Urban Work Trip Models for Forecasting Modal Choice. Wisconsin Department of Transportation, Madison, 1982.
10. Cycling as a Mode of Transportation. Transport and Road Research Laboratory, Crowthorne, Berkshire, England, 1980.
11. D.F. Lott, T.J. Tardiff, and D.Y. Lott. Evaluation by Experienced Riders of a New Bicycle Lane in an Established Bikeway System. TRB, Transportation Research Record 683, 1978, pp. 40-46.
12. S.G. Lipton. Evaluation of the Eugene, Oregon, Greenway Bicycle Bridge. TRB, Transportation Research Record 739, 1979, pp. 29-37.
13. Transportation Choices for Urban Passengers: Measures and Models. Organization for Economic Cooperation and Development, Paris, France, 1980.
14. M. Everett. Commuter Demand for Bicycle Transportation. Traffic Quarterly, Vol. 28, No. 4, Oct. 1974, pp. 585-602.
15. M. Everett. Bicycle Safety and Ethics. Presented to TRB Committee on Bicycling and Bicycle Facilities, Summer Meeting, San Diego, 1979.
16. V.S. Darago. Regional Workshops on Bicycle Safety, Final Report. NHTSA, U.S. Department of Transportation, Rept. DOT HS-803 658, Sept. 1978.
17. J. Kaplan. Characteristics of the Regular Adult Bicycle User. FHWA, Rept. HNG-25, July 2, 1976.
18. P.L. Wheatley and K.D. Cross. Causal Factors of Non-Motor-Vehicle-Related Bicycle Accidents. TRB, Transportation Research Record 743, 1980, pp. 20-30.
19. K. Cross; Anacapa Sciences, Inc. Bicycle Safety Education: Facts and Issues. American Automobile Association Foundation for Traffic Safety, Falls Church, VA, 1978.
20. Bikeway Planning Criteria and Guidelines. Institute of Transportation and Traffic Engineering, Univ. of California, Los Angeles, 1972.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.

Statistical Cost Analysis of the Regulated Household-Goods Trucking Industry

WILKIE W. CHAFFIN AND WAYNE K. TALLEY

An investigation of whether the household-goods (HG) trucking industry, which is regulated by the Interstate Commerce Commission, will become concentrated (i.e., fewer HG truck carriers controlling a larger percentage of the industry's market) during the current deregulatory environment is presented. The likelihood of concentration is investigated by alternatively investigating the existence of economies of scale in the industry. It is concluded that the HG trucking industry exhibits economies of scale and therefore will likely become concentrated during the current deregulatory environment.

In July 1980 President Carter signed into law the Motor Carrier Act of 1980. This Act provided for deregulation of the Interstate Commerce Commission (ICC) regulated trucking industry. For example, the Act increased opportunities for new carriers to enter the trucking industry, established a zone of rate freedom, and expanded the number of commodities to be exempt from ICC regulation. One type of ICC truck carrier that was excluded from the Act was the household-goods (HG) carrier. Given the unique nature of HG carriers, regulatory reform for these carriers was considered by Congress apart from the Motor Carrier Act of 1980. In fall 1980 the Household Goods Transportation Act of 1980 was passed by Congress. This Act reduced unnecessary government regulation of HG truck carriers and furnished additional pricing options for the carriers and their customers.

An investigation of whether the deregulated HG trucking industry will become concentrated (i.e., fewer HG truck carriers controlling a larger percentage of the industry's market) during the current deregulatory environment is presented. The likelihood of concentration occurring in a deregulated industry has traditionally been investigated by alternatively investigating whether there exist economies of scale in the industry; this is the approach adopted in this paper. Economies of scale refer to a less-than-proportional increase in cost when all inputs are increased equiproportionally. The likelihood of concentration occurring in the HG trucking industry is an important issue because the occurrence of concentration will be contrary to an objective of regulatory reform, i.e., to promote a competitive HG trucking industry.

Although numerous studies have investigated the existence of economies of scale for general-freight trucking firms or a combination of general-freight and HG trucking firms, no study (to our knowledge) has investigated separately the existence of economies of scale for HG carriers. The general conclusion of previous studies has been mixed. By using statistical cost analyses, Nelson (1) and Roberts (2), in separate studies, conclude that economies of scale do not exist in the U.S. trucking industry. By using a statistical production-function approach, Ladenson and Stoga (3) conclude that economies of scale do exist. This conclusion is also supported by Dicer (4), Johnson (5), and Rakowski (6). However, Spady and Friedlaender (7) conclude that economies of scale disappear when shipment characteristics such as lengths of haul and types of loads are taken into account.

Although HG carriers share many characteristics with general-freight carriers, the peculiar nature of the demand facing HG carriers has made their operations distinct from those of general-freight carriers. The origins and destinations for HG shippers are geographically dispersed. With shipper demands being nonrepetitive in nature, HG carriers are also prevented from providing scheduled service over regular routes. By comparison, general-freight carriers transport freight between a limited number of origin and destination points on a regular basis.

Because of the irregular, nonrepetitive nature of demand for HG carriers, the probability of an empty backhaul is great. As a result, nationwide and large regional HG carriers have established solicitation agents in local communities to serve geographically scattered shippers in order to minimize empty backhauls. Also, the carrier's fleet of vans is used to provide irregular route, nonscheduled moving service throughout a territory without respect to a home base of operations. The routes taken by moving vans are determined by a central dispatcher who attempts to match shipments booked by local agents with the available capacity of vans. Alternatively, local carriers who have no representation at potential destination points are thus limited to shorter-haul outbound shipments that can be handled profitably under backhaul conditions.

Due to the distinctive nature of HG carriers, it is therefore reasonable to investigate separately the existence of economies of scale for HG carriers and that of general-freight carriers. An investigation of the existence of economies of scale for HG carriers by means of a statistical cost analysis is conducted. In addition, cost elasticity estimates for various characteristics (such as weight and length of haul) of HG shipments are obtained. Furthermore, the results are analyzed and compared with that of previous research.

This investigation is conducted as follows. First, the specification of the cost function to be estimated is developed. Then the statistical cost results, along with a comparison of previous research, are presented and analyzed. Finally, conclusions are presented.

SPECIFICATION OF COST FUNCTION

In return for its operating certificate, an HG carrier is obligated to carry forthcoming traffic at established ICC rates (8). With HG carriers being under legal and economic pressure to abide by this obligation, the level of output produced by an HG carrier, at least in principle, is taken out of the control of the firm and placed in the hands of its customers. Thus, profit-maximizing HG carriers seek a combination of inputs that minimize the cost of transporting an exogenously determined volume of freight.

Assume that the cost (C) to be incurred for inputs (X_1, X_2, ..., X_n) by a given HG carrier may be expressed as

$$C = P_1X_1 + P_2X_2 + \ldots + P_nX_n \quad (1)$$

where P_i is the price of the ith input (i = 1, 2, ..., n). Further assume that the above inputs can be combined efficiently to transport Q volume of freight, or

$$Q = f(X_1, X_2, \ldots, X_n) \quad (2)$$

Thus, from the above discussion, a profit-maximizing HG carrier will seek those amounts of inputs that will minimize cost in Equation 1 that are subject to an exogenously determined volume of freight Q. In solving such a problem, a cost function that represents the minimum cost to be incurred in transporting Q volume of freight can be derived; i.e.,

$$C = C(P_1, P_2, \ldots, P_n, Q) \quad (3)$$

In attempting to estimate the parameters of Equation 3, a problem arises, as it does in all empirical studies in transportation: how to measure output. The measurement used most often for freight output is the ton-mile. This measurement, however, has been criticized, because it considers a shipment of 1 ton transported 1000 miles as being equivalent to a shipment of 1000 tons transported 1 mile. These shipments are not equivalent because "a firm with heavy loads and long hauls is able to produce a ton-mile more cheaply than its light-load, short-haul counterpart" (9, p. 58).

Warner (10, p. 15) states: "It is clear that if all shipments were alike, there would be no difficulty in the choice of an output variable. The variable, number of shipments, would itself be a natural measure of output. A firm whose shipments were twice those of another would clearly have twice the output of the other." However, shipments differ due to weight, length of trip, time in transit, pickup time, delivery time, and so on. If Q in Equation 3 were defined as shipments, and if these shipments differ according to the above characteristics, then the cost equation (Equation 3) for an HG carrier may be rewritten as

$$C = g(P_1, P_2, \ldots, P_n, Q, S_1, S_2, \ldots, S_m) \quad (4)$$

where S_k is the kth characteristic of a given shipment (k = 1, 2, ..., m).

If shipments are used as a measure of output, then ideally all distinguishing characteristics of nonhomogenous shipments (or the S_k's) should be considered in the estimation of a HG carrier's costs. Although such data are not ordinarily available, some aggregate measures are available that partly reflect the composition of shipments transported by HG carriers. Following Warner (10), we shall consider the following aggregate characteristics: average weight per shipment and average length of haul per ton. Assuming further that HG carriers pay the same prices for given inputs, the general stochastic version of Equation 4 that will be estimated by using HG carrier data thus becomes

$$C_j = h(Q_j, W_j, H_j, \epsilon_j) \quad (5)$$

where

- C_j = cost incurred by the jth HG carrier in transporting Q_j shipments,
- Q_j = number of shipments transported by the jth HG carrier,
- W_j = average weight (total tons/total number of shipments) per shipment transported by the jth HG carrier,
- H_j = average length of haul (total ton-miles/total tons) per ton transported by the jth HG carrier, and
- ϵ_j = stochastic error term for the jth HG carrier.

EMPIRICAL RESULTS

In order to investigate the existence of economies of scale for HG carriers, Equation 5 was estimated by assuming linear and logarithmic functions. Because the statistical fit for the logarithmic cost function was superior to that of the linear function, only the results of the logarithmic estimation will be reported here. Although it would be desirable to estimate a translog cost function so as to take advantage of all the relevant information it offers, the available data base does not permit this degree of cost disaggregation. The translog cost function would require a better data base, one that had expenditure information on each factor input in the production process. Estimation of a translog cost function, for example, appears in Spady and Friedlaender (7).

The data used in the estimations were based on a 1975 cross-sectional sample of 32 HG carriers and were taken from the Trinc's Bluebook (11). The average number of shipments per carrier (in the sample) was 24 000 shipments with an average weight of slightly more than 4 tons/shipment.

The logarithmic formulation of Equation 5 that was estimated is

$$C_j = Q_j^{\beta_1} W_j^{\beta_2} H_j^{\beta_3} D_j^{\beta_4} e^{\epsilon_j} \quad (6)$$

where D_j is a dummy variable and e is the base of natural logarithms.

In an analysis of a linear cost function, a constant term (α) would be included, because the presence of economies of scale could be inferred by an estimate of α that is significantly greater than zero. However, in the logarithmic function analysis, the presence of economies of scale is inferred by the estimates of the β_1 coefficients being significantly less than 1. Thus, the inclusion of a constant term is not warranted in terms of detecting economies of scale. The α value, if included, would reflect the influence of all omitted factors on cost during the period of study. It is believed that all costs are variable in the true model. If there are variable costs that have not been included in this model, then the effect of these costs would still be reflected by the dummy variable coefficient (β_4). In addition, an estimated constant term [as concluded by Warner (10)] would be biased upward. Because any information reflected by the constant term would be of secondary interest and would be suspect because of estimation bias, no constant term is included in Equation 6.

The dummy variable is included in Equation 6 as a proxy for those characteristics of shipments not otherwise considered. It is assumed that the characteristics for class 1 HG carriers are distinguishable from those of class 2 carriers. Hence, we assign a 1 to the dummy variable of a class 1 carrier and a 0 for a class 2 carrier.

The parameters β_1, β_2, and β_3 in Equation 6 can be interpreted as cost elasticity coefficients; i.e., they represent the percentage change in cost with respect to a percentage change in the corresponding explanatory variable. Parameter β_1 is of particular interest to this study, because if its value is less than 1 (but positive), it can be concluded that economies of scale exist among HG carriers. This conclusion follows because a given percentage change in shipments will result in a lesser percentage change in costs if β_1 is positive as well as less than 1.

In Table 1, estimates of the parameters of Equation 6 are presented. Estimates were found by using total cost as the dependent variable as well as various components of total cost. By using various cost components, Equation 6 was estimated to investigate the impact of the explanatory variables on these costs.

HG carriers' total costs are broken down into administrative salaries and wages, general operating costs, depreciation and amortization, insurance, communication, and purchased labor and transportation costs. Purchased labor and transportation include the cost of leased vehicles and the cost of temporary help at the destination for unloading and at the warehouse for periods of abnormal demand.

Heteroscedasticity is frequently present in cross-sectional studies of this type. By using each of the cost components, Equation 6 was tested for heteroscedasticity with respect to each of the explanatory variables. Based on the Goldfeld-Quandt test (12, pp. 104-106), the equation for administrative costs and the equation for operating costs were both found to be heteroscedastic with respect to average length of haul. No other equation was found to be heteroscedastic with respect to any explanatory variable.

The administrative costs and operating costs equations were reestimated by using transformed data in order to correct for the heteroscedasticity; i.e., data were obtained by dividing each firm's observations by its average length of haul. Based on the Goldfeld-Quandt test, the corrected equations were found to be free of any significant heteroscedasticity. The results of the regression analysis on these two corrected equations, as well as the equations for the other cost components, are given in Table 1. In this table the t-statistics test for nonzero coefficients for the explanatory variables, and b_1, b_2, b_3, and b_4 represent estimates of the parameters β_1, β_2, β_3, and β_4, respectively.

For the total-cost equation, the presence of economies of scale is suggested because the coefficient of the shipment variable Q is less than 1 and almost identical to the 0.947 value obtained by Warner (10, p. 21) by using general-freight carrier data. The estimated standard error for b_1 was

Table 1. Regression results when estimating Equation 6.

		b_1 (Q)		b_2 (W)		b_3 (H)		b_4 (D)	
Cost Component	R^2	Estimated Regression Coefficient	t-Statistic	Estimated Regression Coefficient	t-Statistic	Estimated Regression Coefficient	t-Statistic	Estimated Regression Coefficient	t-Statistic
Administrative	0.4795	0.6781	3.755[a]	-1.073	2.411[a]	0.9764	10.84[a]	-0.329	0.544
Purchased labor and transportation	0.6183	0.8042	2.412[a]	0.5255	0.6395	0.7141	4.295[a]	0.597 1	0.5464
General operating	0.7020	0.8993	6.144[a]	-0.8327	2.302[a]	0.7947	10.887[a]	-0.890 2	1.856
Salaries and wages	0.3910	0.8490	5.659[a]	-0.9444	2.554[a]	1.062	14.206[a]	-1.535	3.122[a]
Depreciation	0.5671	0.734	4.838[a]	-0.216	0.5780	0.568	7.496[a]	-0.922 2	1.855
Insurance	0.8816	0.9364	8.245[a]	-1.214	4.339[a]	0.7186	12.687[a]	-0.005 95	0.0158
Communication	0.8050	0.9267	6.174[a]	-0.782	2.299[a]	0.5647	8.202[a]	-0.225 9	0.4995
Total cost	0.7168	0.9464	6.189[a]	-0.9104	2.416[a]	1.2456	16.334[a]	-0.920 8	1.838

[a]Significant at the 0.05 level.

Table 2. Regression results when average weight variable is omitted.

		b_1 (Q)		b_3 (H)		b_4 (D)	
Cost Component	R^2	Estimated Regression Coefficient	t-Statistic	Estimated Regression Coefficient	t-Statistic	Estimated Regression Coefficient	t-Statistic
Administrative	0.3715	0.6912	3.547[a]	0.7849	17.114[a]	-0.6942	1.125
Purchased labor and transportation	0.6124	0.7977	2.418[a]	0.8079	10.406[a]	0.7795	0.7466
General operating	0.6453	0.9095	5.799[a]	0.6461	17.503[a]	-1.1792	2.376[a]
Salaries and wages	0.2419	0.8606	5.2599[a]	0.8940	23.216[a]	-1.862	3.5965[a]
Depreciation	0.5619	0.7367	4.194[a]	0.5286	14.982[a]	-0.9972	2.101[a]
Insurance	0.8020	0.9513	6.595[a]	0.5019	14.782[a]	-0.4277	0.9362
Communication	0.7682	0.9364	6.335[a]	0.4251	12.220[a]	-0.4974	1.063
Total cost	0.6577	0.9575	5.800[a]	1.083	27.874[a]	-1.237	2.367[a]

[a]Significant at the 0.05 level.

0.1529, which yields a t-statistic of -0.3506 for testing the hypothesis H_0: $\beta_1 > 1$ versus H_1: $\beta_1 < 1$. This t-value corresponds to a level of significance of approximately 0.365. Although not statistically significant at the more commonly chosen values for level of significance, this t-value does indicate some statistical evidence of economies of scale.

In addition, note that the estimated value for β_1 is greater for the total-cost equation than for any of the cost-component equations. This may indicate some aggregation bias, which suggests that the true value of β_1 is actually somewhat less than 0.947. Furthermore, the conclusion of economies of scale for HG carriers is also supported by the fact that the cost elasticities (i.e., the estimates of β_1) are less than 1 in each of the cost-component equations.

The estimated coefficients for average weight, with the exception of the purchased labor and transportation equation, were found to be negative. Although weight should not have a large effect on costs, an increase in weight should not cause a decline in costs. The problem may well be one of multicollinearity. Average weight was defined as total tons per number of shipments, which is obviously related to the shipments variable. Because length of haul is the total ton-miles per total tons, weight and distance may also be collinear.

In order to determine if multicollinearity is the source of the problem, another regression set was estimated without the average weight variable in order to examine the effect on the standard errors of the coefficients. The estimated standard error of the average length of haul variable declined substantially, thus indicating that a relation between average length of haul and average shipment weight may have existed. The t-statistics for length of haul also greatly increased, and the R^2 values declined only slightly (see Table 2).

With the weight variable being deleted, the b_1 value for the total-cost equation in Table 2 still indicates the presence of economies of scale for HG carriers (because it is less than 1). Furthermore, the cost elasticities with respect to the shipment variable are less than 1 in each of the cost estimations. None of these individual cost elasticities is significantly less than 1 in a statistical sense. However, the fact that all seven cost-component coefficients and the total-cost coefficient are less than 1 does provide substantial evidence that economies of scale for HG carriers do exist. Thus, if shipments increase by a certain percentage, we would expect the cost to be incurred by HG carriers to increase by a smaller percentage.

Because the coefficients on the dummy variables are negative for every cost estimation except for purchased labor and transportation costs, it is concluded that, for these cost estimations, class 1 HG carriers are expected to experience lower costs than class 2 carriers (other things remaining the same). With the dummy coefficient being positive for purchased labor and transportation costs, it further appears that class 1 HG carriers are expected to experience higher costs for this category than class 2 carriers.

The major difference between our cost analysis, which used HG carriers, and that of Warner's, which used general-freight trucking firms, is in the estimated value of the coefficient on length of haul. Warner (10, p. 21) obtains a value of 0.321 for this coefficient in his total-cost equation as opposed to our value of 1.083. Thus, Warner (10) concluded that if length of haul increased for general-freight carriers, total cost would increase by a smaller percentage.

Based solely on the size of our estimate (1.083), we conclude that cost will increase at a faster rate than length of haul. In fact, the null hypothesis that the length-of-haul coefficient for total cost <1 can be rejected at the 0.05 level by using the HG data. However, the length-of-haul coefficient is less than 1 for each of the cost-component equations and considerably less than 1 for most of these cost-component equations. This indicates that the length-of-haul parameter (β_3) for total cost is overestimated because of aggregation bias. Thus, conclusions about economies of scale for length of haul must be based on cost-component coefficients.

Based on these coefficients, it can be concluded that economies of scale do exist for length of haul. Still, with the length-of-haul coefficients for the cost-component equations being substantially greater than Warner's (10) coefficient of 0.321, a proper conclusion would be that a percentage increase in length of haul for HG carriers would be expected to result in a greater percentage increase in costs for these carriers than for general-freight carriers.

CONCLUSIONS

The purpose of this paper has been to investigate the existence of economies of scale for HG carriers by means of a statistical cost analysis. The general conclusion is that economies of scale do exist for HG carriers. Also, the extent of economies is almost identical to that found by Warner (10) for general-freight carriers. Hence the irregular, nonrepetitive nature of demand for HG carriers does not appear to be a hindrance to economies of scale for these carriers. Our analysis also suggests that HG carriers receive substantially less economies from length of haul than that found by Warner (10) for general-freight carriers.

From our analysis of various cost categories, it is further concluded that class 1 HG carriers are expected to experience lower costs for these categories than class 2 carriers (other things remaining the same). One exception was purchased labor and transportation costs. This conclusion is reasonable because larger carriers are more likely to purchase labor and transportation services than smaller carriers.

Because our analysis supports the existence of economies of scale in the HG trucking industry, we can further infer that concentration (i.e., fewer HG truck carriers controlling a larger percentage of the industry's market) will likely occur during the current deregulatory environment. Existing HG carriers will be seeking to increase their market share and size in order to take advantage of the lower unit costs attributed to the existence of economies of scale.

ACKNOWLEDGMENT

We wish to thank James D. Voorhies for help rendered in the statistical analysis.

REFERENCES

1. R.A. Nelson. The Economic Structure of the Highway Carrier Industry in New England. Presented at New England Governors' Conference on Public Transportation, Boston, 1957.
2. M.J. Roberts. Some Aspects of Motor Carrier Costs: Firm Size, Efficiency, and Financial Health. Land Economics, Aug. 1956, pp. 228-238.
3. M.L. Ladenson and A.J. Stoga. Returns to Scale in the U.S. Trucking Industry. Southern Economic Journal, Jan. 1974, pp. 390-396.
4. G.N. Dicer. Economies of Scale and Motor Carrier Optimum Size. Quarterly Review of Economics and Business, Spring 1971, pp. 31-37.
5. J.C. Johnson. Trucking Mergers: A Regulatory Viewpoint. Heath, Lexington, MA, 1973.
6. J.P. Rakowski. Economies of Scale in U.S. Trucking. Journal of Economics and Business, Spring/Summer 1978, pp. 166-176.
7. R.A. Spady and A.F. Friedlaender. Hedonic Cost Functions for the Regulated Trucking Industry. Bell Journal of Economics, Spring 1978, pp. 159-179.
8. D.A. Breen. The Monopoly Value of Household-Goods Carrier Operating Certificates. Journal of Law and Economics, April 1977, pp. 153-185.
9. R. Koenker. Optimal Scale and the Size Distribution of American Trucking Firms. Journal of Transport Economics and Policy, Jan. 1977, pp. 54-67.
10. S.L. Warner. Cost Models, Measurement Errors, and Economies of Scale in Trucking. In The Cost of Trucking: Econometric Analysis (M.L. Burstein and others, eds.), William C. Brown Co., Dubuque, IA, 1965, pp. 1-46.
11. Trinc's Bluebook of the Trucking Industry. Trinc Transportation Consultants, Washington, DC, 1977.
12. R.S. Pindyck and D.L. Rubinfeld. Econometric Models and Economic Forecasts. McGraw-Hill, New York, 1976.

Publication of this paper sponsored by Committee on Application of Economic Analysis to Transportation Problems.