An Econometric Analysis of Differences Between Motor Carriers: Implications for Market Structure

B. Starr McMullen*
Oregon State University

Hiroshi Tanaka
Oregon State University

Despite repeated findings of constant returns to scale in trucking, there have been increases in motor carrier industry concentration following the Motor Carrier Act of 1980. This study uses a translog cost function to examine differences between large (Instruction 27) and small (Instruction 28A) motor carriers. Results show significant structural differences between large and small carriers, supporting the hypothesis that larger firms offer a different, possibly higher quality, service by using an extensive network system. Significant economies associated with increasing average load, average length of haul, and average shipment size are found for large firms. Smaller firms appear already to have taken advantage of these economies and therefore have no incentive to grow in size. These findings suggest that increases in industry concentration will continue as large firms try to take advantage of unexploited, network-related economies.

INTRODUCTION

The increase in U.S. motor carrier industry concentration following the Motor Carrier Act of 1980 has been a topic of great concern to industry observers (Kling, 1990; Enis and Morash, 1987; Rakowski, 1988,1990). While there is little dispute that the industry has become more concentrated, there is debate about whether this represents a problem.

The growth in firm size may be attributable to anticompetitive activities that result in the exercise of monopoly power. If firms are expanding to take advantage of size-related economies and the cost savings are passed to customers, however, there is no rationale for government intervention via antitrust laws or regulation.

This paper utilizes industry cost functions to help explain the observed increases in concentration. Existing econometric evidence indicates no evidence of technological economies of scale in the trucking industry.[1] The absence of economies of scale suggests no cost-based reason for the increase in concentration.

Keeler (1989), however, refers to *economies of integration* or *network economies* that may be associated with size. Traditional econometric studies of industry cost focus on a single measure, the elasticity of cost with respect to output, and do not consider these network economies. Network economies result from the efficient use of a network system to increase load factors and reduce the shipper's wait time.

---

[1] Previous studies indicating no evidence of increasing returns to scale include Grimm, Corsi, and Jarrell (1989), McMullen and Stanley (1988), Winston, Corsi, Grimm, and Evans (1990), Daughety and Nelson (1988), and Harmatuck (1991). Daughety and Nelson (1988) do not mention scale economy results in the text of their paper, but their reported econometric results indicate constant or somewhat decreasing returns to scale.

0747-5535/95/1500-0016 $02.50

Carriers may serve different markets, providing different levels of service quality. One carrier type may serve shippers that prefer faster or more frequent service, resulting in lower equipment utilization and greater service frequency. Carriers operating in such a market are able to reduce per unit costs by increasing route density; more customers spread the fixed cost of a trip over more units of output. Another type of carrier may provide less frequent service—the resulting higher load factors and lower unit costs do not provide a cost-based incentive for further expansion.

Accordingly, a carrier with a small network and dense routes may have no motivation to expand, whereas a carrier with a large network system consisting of thin routes may be able to attain significantly lower unit costs by increasing system-wide traffic. There is no reason to believe that both kinds of firms cannot co-exist in an unregulated environment because they operate in different types of markets. We hypothesize that firms that are increasing in size may be taking advantage of network-related size economies that are not relevant to other firms.

Network economies are thought to be most important for less-than-truckload (LTL) carriers that require consolidation and coordination activities. Precise empirical definition of a less-than-truckload carrier, however, is elusive. The formal Interstate Commerce Commission (ICC) definition of an LTL shipment is one that weighs less than 10,000 pounds, while a truckload (TL) shipment is one that weighs more than 10,000 pounds. The ICC does not categorize firms as TL or LTL; only shipments are categorized.

ICC-certified carriers of general freight must file information with the ICC by identifying themselves as either Instruction 27 or Instruction 28A carriers. Instruction 27 carriers derive at least 75 percent of their revenues from interstate traffic over the most recent three year period, whereas Instruction 28A carriers derive less than 75 percent of their traffic from interstate commerce.

ICC-certified Instruction 27 carriers conventionally have been considered less-than-truckload carriers and Instruction 28A have been designated as truckload carriers.[2] It has become more difficult, however, to make a clear empirical distinction between these two categories according to their participation in LTL or TL activities. Virtual freedom of entry has encouraged large scale entry into less-than-truckload markets, resulting in an increase in the relative importance of less-than-truckload traffic to all carriers.

For instance, the percentage of general freight shipments that were less-than-truckload rose from approximately 68 percent in 1980 to 88 percent in 1987 (Grimm, Corsi, and Jarrell, 1989). As of 1988, 67 percent of those carriers reporting as Instruction 27 (and usually referred to as LTL carriers) derived at least 30 percent of their tonnage from less-than-truckload traffic. Fifty-five percent of the Instruction 28A carriers, however, also obtained at least 30 percent of their tonnage from less-than-truckload freight movements.

Thus, it does not appear appropriate to refer to one group as less-than-truckload and the other as truckload, as both Instruction 27 and 28A carriers engage in a considerable amount of less-than-truckload traffic.

[2] Thus, the simple definition of Instruction 27 and 28A carriers suggests that the two groups service different sorts of markets: Instruction 27 carriers may be expected to serve a more extensive network as indicated by their greater participation in intercity transportation.

Studies documenting the observed increase in industry concentration have used Instruction 27 data (Kling, 1990; Enis and Morash, 1987; Rakowski, 1988,1990). Further, Emerson, Grimm, and Corsi (1992) find that Instruction 27 carriers have experienced greater increases in market share than the Instruction 28A carriers. These studies suggest that there is still a reason to distinguish between the two types of carriers. Of particular interest is why the two groups appear to have different tendencies toward concentration.

Grimm, Corsi, and Jarrell (1989) find evidence of constant returns to scale for both Instruction 27 and 28A firms. Their study, however, does not include network-related attributes that could account for large increases in concentration in the Instruction 27 carriers relative to the Instruction 28A carriers. This study includes network attributes in the cost specification to explain the observed divergence in concentration tendencies between Instruction 27 and 28A carriers.

METHOD

We use duality theory to estimate translog cost functions for the two segments of the motor carrier industry to compare the production structures of Instruction 27 and 28A general freight commodity carriers.

The cost function is written in general terms as:

$$(1)\ C = C(p, y, a)$$

where:

C = Long-run costs;
y = Output;
p = A vector of input prices; and
a = A vector of firm attributes.

The translog cost function provides a second order approximation to (1) and is written as:[3]

$$\begin{aligned}(2)\ \ln C(p, y, a) = {} & \alpha_0 + \Sigma_i\, \alpha_i \ln p_i + \alpha_y \ln y + \Sigma_j\, \beta_j \ln a_j + .5\Sigma_i\Sigma_k\, \alpha_{ik} \ln p_i \ln p_k \\ & + .5\alpha_{yy}(\ln y)^2 + .5\Sigma_j\Sigma_l\, \beta_{jl} \ln a_j \ln a_l + \Sigma_i\, \alpha_{iy} \ln p_i \ln y \\ & + \Sigma_i\Sigma_j\, \rho_{ij} \ln p_i \ln a_j + \Sigma_j\, \beta_{yj} \ln y \ln p_j + \varepsilon,\end{aligned}$$

where:

ε = A normally distributed disturbance term, and each variable represents the deviation from its sample mean.

[3]The translog cost function has become a standard for estimating motor carrier cost functions. Other specifications have been tried in the past (McMullen, 1987); however, the basic results remain similar.

Symmetry and homogeneity of degree one are imposed on the parameters, and factor share equations are estimated simultaneously with the cost function to increase efficiency. Because cost shares sum to one, one of the share equations is dropped. (Barten (1969) has shown that the results are invariant to the equation dropped.) Additive disturbances are appended to the cost equation and the remaining factor share equations.

Within our system of equations, however, there is likely to be correlation between the random errors in the different equations because the error terms may reflect some common unmeasurable or omitted factors. We jointly consider the equations and account for correlation between disturbances by using Zellner's seemingly unrelated regression procedure. The added information derived from viewing the equations as a system rather than unrelated equations to be estimated separately results in efficiency gains in the estimation of parameters.

One benefit of using a translog cost function is the ease in calculating elasticities of substitution between inputs once the cost function coefficients have been estimated. The Allen-Uzawa partial elasticities of substitution between inputs i and j are calculated as:

(3) $$\sigma_{ij} = \frac{\alpha_{ij} + S_i S_j}{S_i S_j} \qquad \text{i not equal to j}$$

$$\sigma_{ii} = \frac{\alpha_{ii} + S_i(S_i - 1)}{S_1^2}$$

where:

S_i = The fitted value of the cost share of the ith input.

The own price elasticity of demand is defined as:

(4) $E_{ii} = S_i \sigma_{ii}$.

As Aw and Roberts (1985) explain, the Allen-Uzawa elasticities measure the change in the quantity of the ith factor input in response to a change in the price of the jth factor (holding other prices and output fixed, but allowing other inputs to adjust to new optimal levels). A positive (negative) sign indicates that the two inputs are substitutes (complements). In this study, estimates of input elasticities are evaluated at their means.

The dependent variable is total cost (TC), defined to include a 12 percent return to capital:

TC = TOE + .12 (NOPE + WC)

where:

TOE = Total operating expense;
NOPE = Net operating property and equipment; and

WC = Net current assets or working capital.

We obtained a real value for net operating property by deflating the 1988 dollar values using a ten year average of the producer's durable equipment implicit price deflator for trucks. The use of a 12 percent return on investment to calculate the cost of capital follows previous researchers (McMullen, 1987; McMullen and Stanley, 1988; Ying, 1990; and others).

We measure output as revenue ton-miles (TONMILE). Attributes of output are average length of haul (ALH), average load (AL), average shipment size (AS), and insurance per ton-mile (INS). Average length of haul, average load, and average shipment size all reflect characteristics of the carrier's network.[4]

Output attributes are included in motor carrier cost functions because the output measure, tonmiles, does not capture the heterogeneity of motor carrier output. The average length of haul is defined as tonmiles divided by tons. Carriers serving longer distances experience a decrease in unit costs as the fixed costs associated with terminal and handling expenses are distributed over more units of output. Accordingly, we hypothesize that the coefficient on ALH is negative.

The average load is defined as tonmiles divided by miles. We included average load to capture economies of equipment utilization; unit costs should be lower when a truck is loaded more fully. A carrier may have a low average load because it operates on less dense routes or because it offers more frequent service. Service frequency is a major indicator of service quality. In either case, the coefficient on average load is expected to be negative.

Average shipment size is tons divided by the number of shipments. This measure attempts to capture the lower transactions and handling costs associated with handling a few large shipments rather than many small ones. Average size also serves as an indication of a firm's participation in LTL versus TL traffic: firms with more TL traffic will have higher average shipment sizes. A higher AS indicates that the firm is engaging more in TL activity which has lower per unit costs. Accordingly, the expected sign of AS is negative.

Insurance per tonmile reflects differences in the value of commodities transported by a carrier; higher valued commodities require both more insurance against loss and damage and possibly more handling costs. McMullen (1987), McMullen and Stanley (1988), Daughety, Nelson, and Vigdor (1985), and Friedlaender and Spady (1981) all find this coefficient to be positive, reflecting the higher costs associated with higher valued commodities. If high valued commodities require higher quality service, this may cause higher costs.

Factor prices include the price of labor, capital, purchased transportation, and fuel. See the appendix for definitions used for cost and factor prices. All data are from the *1988 Motor Carrier Annual Report* published by the American Trucking Association.

Table 1 shows definitions and sample means for output (tonmiles) and attributes of both Instruction 27 and 28A carriers. Instruction 28A carriers have lower average output, but they have higher average loads, shipment size, and average length of haul than

---

[4] These attributes are standard ones used in previous studies including McMullen (1987), McMullen and Stanley (1988), and Grimm, Corsi, and Jarrell, (1989).

Table 1—Sample Means for Instruction 27 and 28A, Carrier Output and Attributes, 1988

	Instruction 27		Instruction 28A	
	Mean	Standard Deviation	Mean	Standard Deviation
Tonmiles	313206	1109060	144085	235078
Average Load	9.41	4.79	13.20	6.67
Average Length of Haul	347.44	330.89	485.54	474.23
Average Shipment Size	3.9716.53	16.65	20.31	
Insurance per Tonmile	.016	.017	.015	.036
Number of Firms	207	89		

Source: All figures derived from data in American Trucking Association: *1988 Motor Carrier Annual Report*

Variable Definitions:
Average Load (AL): Tonmiles/ Miles
Average Length of Haul (ALH): Tonmiles/Tons
Average Shipment Size (AS): Tons/Shipments
Insurance per tonmile (INS): Insurance Expense/Tonmiles

Instruction 27 carriers. Higher shipment size usually is associated with the provision of more TL service. Higher average loads indicate either denser routes or less frequent service. This information is consistent with the hypothesis that Instruction 27 and 28A carriers provide different sorts of service and serve different markets.

EMPIRICAL RESULTS

We present first order results from the estimation of equation (2) in Table 2, with Instruction 27 estimates in column 1 and Instruction 28A results in column 2. (Complete results are shown in Table 2a.) The estimated coefficient for tonmiles (TONMILE) does not differ significantly from one for either group, indicating constant returns to scale.[5]

We test the hypothesis that Instruction 27 and 28A firms are sampled from the same underlying population by using a likelihood ratio test. We calculate a χ^2 statistic where χ^2 is equal to $-2(L_1 - L_2)$; L_1 is the logarithm of the likelihood function obtained when pooling firms into one data set and L_2 is the sum of the logarithms of the likelihood functions obtained by estimating equation (2) separately for the two groups of firms.

[5] The Instruction 28A carriers have a smaller sample size (89) compared to the Instruction 27 carriers (207). This obviously is a reason for the higher standard errors and lower overall levels of statistical significance in the instruction 28A results. The adjusted R^2 is .967 for the Instruction 27 carries and only .911 for the Instruction 28A carriers. These adjusted R^2s still indicate a high level of explanatory power for both regressions. Note that although the estimates may not be efficient due to the small sample size, they are still unbiased.

It would be ideal to have a larger sample set. Instruction 28A carriers, however, are not required to provide the ICC with as much data as are the Instruction 27 carriers. Thus, fewer Instruction 28A carriers report enough information to provide a complete data set. (Apparently some instruction 28A carriers provide more information than the minimum required by the ICC).

Note that similar data constraints have been experienced by others, including McMullen and Stanley (1988) who studied a small sample of specialized commodity carriers and report translog cost estimation results based on less than 80 observations.

Table 2—Estimates of First Order Coefficients From Equation (2) (Dependent Variable—Total Cost)

Variable	Large Firms Instruction 27	Small Firms Instruction 28A
Tonmiles	1.0092****	.85435****
(TONMILE)	(.073)	(.362)
Price of Capital (PK)	.3367***	.3475***
	(.027)	(.068)
Price of Rented Capital (PR)	.1994***	.2984**
	(.038)	(.142)
Price of Fuel (PF)	.0478***	.0610**
	(.006)	(.028)
Price of Labor (PL)	.4160***	.2931***
	(.038)	(.082)
Average Load (AL)	-.8076***	-.0962
	(.182)	(.782)
Average Length of Haul (ALH)	-.5494***	.0696
	(.128)	(.527)
Average Shipment Size (AS)	-.2533***	.0670
	(.084)	(.431)
Insurance per Tonmile (INS)	.0695	.6811
	(.177)	(.618)
Adjusted R^2	.967	.911
Number of Observations	207	89

All variables are expressed in logarithmic form

The statistic in parentheses below each estimate is its standard error

** Significantly different from zero at the .05 level
*** Significantly different from zero at the .01 level
**** Not significantly different from one at the .01 level, indicating constant returns to scale

The hypothesis that Instruction 27 and 28A firm data come from the same underlying population is rejected at the .005 level of significance, with a χ^2 equal to 217.89: the two types of firms have significantly different cost (and thus production) structures. This means that it is inappropriate to pool Instruction 27 and 28A carriers when estimating cost functions.

Although the estimated coefficients for factor prices are positive (as expected) and statistically significant for both groups, network attribute coefficients differ widely. This finding is not surprising, given the observed differences in average network attribute levels shown in Table 1. The coefficient on the insurance variable (INS) is not significantly different from zero for either group. Thus, cost differences between the two groups of firms seem to arise from the network structure variables: average load, average length of haul, and average shipment size.

Average load, average shipment size, and average length of haul for the Instruction 27 carriers all show the expected negative and statistically significant coefficients. Negative coefficients indicate that these firms can achieve lower costs by increasing average load, average shipment size, and average length of haul. These carriers thus have cost-based incentives to expand their operations despite constant technological returns to scale.

Table 2a—Coefficient Estimates For Equation (2) (Dependent Variable—Total Cost)

Variable	Large Firms Instruction 27	Small Firms Instruction 28A
Constant	11.218*** (.160)	10.381*** (.531)
Tonmiles (TONMILE)	1.0092**** (.073)	.85435**** (.362)
Tonmiles^2 (TONMILE)^2	.0070 (.029)	-.0318 (.264)
Tonmiles × Price of Capital (TONMILE*PK)	-.0056 (.008)	.0154 (.029)
Tonmiles × Price of Rented Capital (TONMILE*PR)	.0035 (.009)	.0068 (.005)
Tonmiles × Price of Fuel (TONMILE*PF)	-.0039* (.002)	-.0045 (.009)
Tonmiles × Price of Labor (TONMILE*PL)	.0060 (.009)	-.0177 (.039)
Tonmiles × Average Load (TONMILE*AL)	.0047 (.058)	-.2188 (.319)
Tonmiles × Average Length of Haul (TONMILE*ALH)	-.0134 (.042)	-.5544 (.282)
Tonmiles × Insurance per Tonmile (TONMILE*INS)	.0105 (.045)	-.126 (.208)
Tonmiles × Average Shipment Size (TONMILE*AS)	-.0371* (.023)	.0934 (.142)
Price of Capital (PK)	.3367*** (.027)	.3475*** (.068)
(Price of Capital)^2 (PK)^2	.0194** (.010)	-.104 (.022)
Price of Capital × Price of Rented Capital; (PK*PR)	.0121 (.012)	.0397 (.038)
Price of Capital × Price of Fuel (PK*PF)	-.0077** (.003)	-.0100 (.010)
Price of Capital × Price of Labor (PK*PL)	-.0238** (.010)	-.0156 (.025)
Price of Capital × Average Load (PK*AL)	.0039 (.027)	.0350 (.067)
Price of Capital × Average Length of Haul (PK*ALH)	.0249 (.016)	-.0047 (.031)
Price of Capital × Insurance per Tonmile (PK*INS)	.0313 (.022)	.0465 (.043)
Price of Capital × Average Shipment Size (PK*AS)	.0209** (.009)	-.0061 (.033)
Price of Rented Capital (PR)	.1994*** (.038)	.2984** (.142)
Price of Capital^2 (PK)^2	.0306 (.029)	.0580 (.111)
Price of Rented Capital × Price of Fuel (PR*PF)	.0028 (.003)	-.0246 (.236)
Price of Rented Capital × Price of Labor (PR*PL)	-.0455*** (.017)	-.0731 (.064)

Table 2a—Coefficient Estimates For Equation (2) (continued)

Variable	Large Firms Instruction 27	Small Firms Instruction 28A
Price of Rented Capital × Average Load (PR*AL)	-.0600 (.045)	-.0149 (.112)
Price of Rented Capital × Average Length of Haul (PR*ALH)	.0363 (.029)	.0122 (.052)
Price of Capital × Insurance per Tonmile (PR*INS)	-.0303 (.029)	-.0860 (.089)
Price of Rented Capital × Average Shipment Size (PR*AS)	.0500*** (.013)	.0112 (.055)
Price of Fuel (PF)	.0478*** (.006)	.0610** (.028)
Price of Fuel² $(PF)^2$	.0243*** (.004)	.0420*** (.012)
Price of Fuel × Price of Labor (PF*PL)	-.0193*** (.004)	-.0074 (.014)
Price of Fuel × Average Load (PF*AL)	-.0171** (.008)	-.0123 (.023)
Price of Fuel × Average Length of Haul (PF*ALH)	.0164*** (.005)	.0080 (.014)
Price of Fuel × Insurance per Tonmile (PF*INS)	-.0043 (.005)	.0033 (.018)
Price of Fuel × Average Shipment Size (PF*AS)	.0017*** (.002)	.0106 (.013)
Price of Labor (PL)	.4160*** (.038)	.2931*** (.082)
Price of Labor² $(PL)^2$	.0089*** (.013)	.0962** (.047)
Price of Labor × Average Load (PL*AL)	.0732** (.036)	-.0077 (.059)
Price of Labor × Average Length of Haul (PL*ALH)	-.078*** (.026)	-.0155 (.046)
Price of Labor × Insurance per Tonmile (PL*INS)	.0034 (.028)	.0361 (.056)
Price of Labor × Average Shipment Size (PL*AS)	-.0826*** (.013)	-.0157 (.025)
Average Load (AL)	-.8076*** (.182)	-.0962 (.782)
Average Load² $(AL)^2$	-.0615 (.203)	.9923 (.786)
Average Load × Average Length of Haul (AL*ALH)	-.324*** (.102)	.0677 (.574)
Average Load × Insurance per Tonmile (AL*INS)	-.1214 (.113)	.5109 (.417)
Average Load × Average Shipment Size (AL*AS)	-.2627*** (.060)	.111 (.302)
Average Length of Haul (ALH)	-.5494*** (.128)	.0696 (.527)
Average Length of Haul² $(ALH)^2$	-.0408 (.106)	.1095 (.436)
Average Length of Haul × Insurance per Tonmile (AL*INS)	-.2475** (.103)	.0653 (.397)

Table 2a—Coefficient Estimates For Equation (2) (continued)

Variable	Large Firms Instruction 27	Small Firms Instruction 28A
Average Length of Haul × Average Shipment Size (ALH*AS)	.0669 (.045)	-.0554 (.292)
Insurance per Tonmile (INS)	.0695 (.177)	.6811 (.618)
Insurance per Tonmile^2	-.0849	.3010
Insurance per Tonmile × Average Shipment Size (INS*AS)	-.0688 (.060)	.1678 (.205)
Average Shipment Size (AS)	-.2533*** (.084)	.0670 (.431)
Average Shipment Size^2 (AS^2)	.1296*** (.047)	-.0148 (.219)
Adjusted R^2	.967	.911
Number of Observations	207	89

All variables are expressed in logarithmic form

The statistic in parentheses below each estimate is its standard error

* Significantly different from zero at the .1 level
** Significantly different from zero at the .05 level
*** Significantly different from zero at the .001 level
**** Not significantly different from one at the .01 level, indicating constant returns to scale

None of the estimated attribute coefficients for the Instruction 28A carriers differ significantly from zero. This means that increases in average shipment size, average load, and average length of haul do not have a significant impact on cost. Accordingly, these carriers have no incentive to expand the size of their operations; they already have achieved any economies available. This result is consistent with the evidence presented in Table 1 which shows that Instruction 28A carriers have higher mean average load and average shipment size than the larger Instruction 27 carriers. Firms with higher load factors have less to gain through increased equipment utilization.

Table 3 presents elasticity estimates and cost shares for Instruction 27 and 28A firms. The biggest difference in cost share arises because the larger Instruction 27 firms spend a greater percentage on labor and less on rented transportation services than do Instruction 28A carriers. Purchased transportation is a larger percentage of total cost for Instruction 28A firms, suggesting they may use their own capital fully and rent transportation services to meet unexpected demand. The larger Instruction 27 firms that rely more on owned capital may be more susceptible to the problems of excess capacity.

These findings provide support for Keeler's (1989) hypothesis that larger firms provide a higher quality service by having a more extensive network system. Higher quality service may be associated with lower average loads as carriers try to provide more frequent service (service frequency being a major component of service quality). Thus, the Instruction 27 carriers are able to lower unit costs by growing in size and obtaining more traffic, thus increasing average load.

Table 3—Allen-Uzawa Elasticities of Substitution and Cost Shares

Panel A: Large Firms, Instruction 27 Carriers	Capital	Labor	Rented Capital	Fuel
Labor	.83000			
Rented Capital	1.18064	.45157		
Fuel	.52181	.02741	1.29083	
Own Price Elasticity	-.60567	-.37088	-.64717	-.44455
Cost Share	.30647	.50866	.14098	.04389

Panel B: Small Firms, Instruction 28A Carriers	Capital	Labor	Rented Capital	Fuel
Labor	.84689			
Rented Capital	1.38249	.16408		
Fuel	.52705	.58377	-.35060	
Own Price Elasticity	-.699295	-.37884	-.24961	-.50711
Cost Share	.31124	.31273	.31173	.06429

This line of reasoning also is suggested by Wang-Chiang and Friedlaender (1985), who argue that excess capacity in networks gives larger firms the incentive to expand business because they can lower unit costs simply by increasing equipment utilization.

CONCLUSIONS AND POLICY IMPLICATIONS

This study reaffirms earlier findings of constant returns to scale in motor carriage for both Instruction 27 and Instruction 28A firms. Empirical results indicate statistically different overall cost (and thus production) structures, however, between the two groups of carriers. One explanation for this result is the conventional wisdom that Instruction 27 carriers engage in more LTL traffic than Instruction 28A carriers. It generally is acknowledged that the extensive network and terminal system required of an LTL carrier entails a different production structure than that of a carrier which that in primarily TL traffic.

Empirical evidence indicates that the larger Instruction 27 firms have not yet exhausted economies associated with increasing their average length of haul, average load, and average shipment size. This may be because these firms are operating with a more extensive network system, resulting in excess capacity and underutilization of equipment. Thus, these firms are able to reduce unit costs by expanding their operations over their network systems. This helps explain the observed increase in concentration among the largest Instruction 27 motor carriers despite repeated finding of constant returns to scale.

The smaller Instruction 28A firms appear to have exhausted any economies associated with shipment size, average load, and average length of haul. These firms have no further incentive to grow. Given the large cost share these firms devote to rented transportation services, it is likely that these firms choose to meet unexpected demand by purchasing transportation services rather than expanding the size of their own operation. Renting transportation reduces the excess capacity problem in times of low demand.

The results of this study suggest that the observed tendency toward increased concentration in U.S. trucking will continue into the future as the large Instruction 27 firms strive to take advantage of unexploited network economies. Whether the increased concentration should be of concern to policy makers depends on how the large firms behave in the post-MCA market environment.

If large firms expand to take advantage of lower unit costs and these savings are passed to the consumer, there is no reason to be disturbed by size alone. Keeler (1989) refers to the experience with deregulated trucking in Australia where long haul trucking is controlled by only four firms and truck rates approximate long-run costs. If large firms are able to exploit their position and earn excess economic profit, however, then policy makers may need to intervene. This remains a topic for future study.

REFERENCES

1. *1988 Motor Carrier Annual Report* (Alexandria, Virginia: American Trucking Associations, 1989).

2. Aw, B.Y., and M.J. Roberts, "The Role of Imports From the Newly Industrialized Countries in U.S. Production," *Review of Economics and Statistics*, 65, no. 1 (February 1985), pp. 108-117.

3. Barten, A.P., "Maximum Likelihood Estimation of a Complete System of Demand Equations," *European Economic Review* (Fall 1969), pp. 7-73.

4. Daughety, A.F., F.D. Nelson, and W.R. Vigdor, "An Econometric Analysis of the Cost and Production Structure of the Trucking Industry," in A.F. Daughety (ed.), *Analytical Studies in Transport Economics* (Cambridge: Cambridge University Press, 1985), pp. 65-95.

5. Daughety, A.F., and F.D. Nelson, "An Econometric Analysis of Changes in the Cost and Production Structure of the Trucking Industry, 1953-82," *Review of Economics and Statistics*, 70, no. 1 (February 1988), pp. 67-75.

6. Emerson, C.J., C.M. Grimm, and T.M. Corsi, "The Advantage of Size in the U.S. Trucking Industry: An Application of the Survivor Technique," *Journal of the Transportation Research Forum*, 32, no. 2 (1992), pp. 369-378.

7. Enis, C.R., and E.A. Morash, "Some Aspects of Motor Carrier Size, Concentration Tendencies, and Performance After Deregulation," *Akron Business and Economic Review*, 18, no. 1 (Spring 1987), pp. 82-94.

8. Friedlaender, A.F., and R.H. Spady, *Freight Transportation Regulation* (Cambridge, MA: MIT Press, 1981).

9. Grimm, C.M., T.M. Corsi, and J.L. Jarrell, "U.S. Motor Carrier Cost Structure Under Deregulation," *Logistics and Transportation Review*, 25, no. 3 (Fall 1989), pp. 231-249.

10. Harmatuck, D.J., "Economies of Scale and Scope in the Motor Carrier Industry," *Journal of Transport Economics and Policy*, 25, no. 2 (May 1991), pp. 135-151.

11. Harrington, L.H., "Getting Employees to Measure Up," *Traffic Management*, 26 (June 1987), pp. 60-62.

12. Keeler, T.E., "Deregulation and Scale Economies in the U.S. Trucking Industry: An Econometric Extension of the Survivor Principle," *Journal of Law and Economics*, 32, no. 2 (October 1989), pp. 229-253.

13. Kling, R.W., "Deregulation and Structural Change in the LTL Motor Freight Industry," *Transportation Journal*, 29, no. 3 (Spring 1990), pp. 47-53.

14. McMullen, B.S., "The Impact of Regulatory Reform on U.S. Motor Carrier Costs," *Journal of Transport Economics and Policy*, 26, no. 3 (September 1987), pp. 307-319.

15. McMullen, B.S., and L.R. Stanley, "The Impact of Deregulation on the Production Structure of the Motor Carrier Industry," *Economic Inquiry*, 26, no. 2 (April 1988), pp. 299-316.

16. McMullen, B.S., "Motor Carrier Costs Revisited," working paper no. 90-M-9, Department of Economics, Oregon State University (1990).

17. McMullen, B.S., "Purchased Transportation and LTL Motor Carrier Costs: Possible Implications for Market Structure," *Journal of the Transportation Research Forum*, 38, no. 2 (Spring 1991), pp. 433-439.

18. Rakowski, J.P., "Marketing Economies and the Results of Trucking Deregulation in the Less-Than-Truckload Sector," *Transportation Journal*, 27, no. 3 (Spring 1988), pp. 11-22.

19. Rakowski, J.P., "The Failure in LTL Trucking: What Hath Deregulation Brought?" *Transportation Practitioners' Journal*, 56 (Fall 1990), pp. 33-43.

20. Thomas, J.M., and S.J. Callan, "Constant Returns to Scale in the Post-Deregulatory Period: The Case of Specialized Motor Carriers," *Logistics and Transportation Review*, 25, no. 3 (September 1989), pp. 271-288.

21. Wang Chiang, J.S., and A.F. Friedlaender, "Truck Technology and Efficient Market Structure," *Review of Economics and Statistics*, 67, no. 2 (May 1985), pp. 250-258.

22. Winston, C., T.M. Corsi, C.M. Grimm, and C.A. Evans, *The Economic Effects of Surface Freight Deregulation* (Washington, D.C.: Brookings Institution, 1990).

23. Ying, J.S., "Regulatory Reform and Technical Change: New Evidence of Scale Economies in Trucking," *Southern Economic Journal*, 56, no. 4 (April 1990), pp. 996-1009.

APPENDIX 1—DATA

All data for the computation of cost and factor prices are from the *1988 Motor Carrier Annual Report.* Total cost (C) is calculated to include a 12 percent return to capital

$$C = TOE + .12\ (NOPE + WC),$$

where:

TOE	=	Total operating expense;
NOPE	=	Net operating property and equipment; and
WC	=	Net current assets or working capital.

A real value for net operating property and equipment is obtained by deflating the 1988 dollar values using a ten year average of the producer's durable equipment implicit price deflator for trucks.

The price of labor (PL) is the firm's total employee compensation divided by the total number of employees. The price of rented capital (PR) is total expenditures on purchased transportation divided by the total number of rented vehicle miles. The price of capital (PK) is computed by dividing residual expenses (obtained by subtracting total fuel, labor, and purchased capital expenditures from total cost) by net operating property and equipment plus working capital.

Finally, the price of fuel (PF) is calculated as total fuel and oil expense divided by an estimate of the number of gallons of fuel used. We assume that trucks get an average of five miles per gallon (conversations with truckers and individuals at the American Trucking Association indicate that four to six miles per gallon is a reasonable estimate of fleet fuel efficiency.) We get an estimate of gallons by dividing total vehicle miles by five. For those firms not reporting purchased transportation or fuel expenses, regional averages are used as proxies for their PF and PR. Firms are assigned to regions according to the state in which the firm is located.