PROCEEDINGS —

Nineteenth Annual Meeting

Theme:

"Theory, Reality, and Promise:
Transportation Faces Tomorrow"

October 24-25-26, 1978
Biltmore Hotel
New York, New York

Volume XIX • Number 1 1978

TRF

TRANSPORTATION RESEARCH FORUM

The Status of Economies of Scale in Regulated Trucking: A Review of the Evidence and Future Directions

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INTRODUCTION

1977 WAS A BANNER YEAR for empirical work on the issue of economies of scale (EOS) in trucking. The results of three empirical studies by Chow, Friedlaender, and Klem respectively were presented at the Workshop on Motor Carrier Economic Regulation (April, 1977) and the results of a fourth study by Koenker were published earlier in the year.[1]

Despite this abundance of evidence, it is the contention of this paper that the controversy over the existence of EOS in trucking remains. This paper reviews the studies cited. It seeks answers to the following questions.

(1) What differences in methodologies exist?
(2) What conclusions on the issue of EOS can reasonably be made from this evidence?
(3) What are the strengths and weaknesses of each work?
(4) What improvements can be made by future work in this area of study?

METHODOLOGICAL APPROACHES

The major studies on EOS in trucking presented in 1977 are summarized in Table 1.[2] All of the studies seek to estimate the long run cost function through multiple regression techniques. Log transformations are generally utilized to linearize the regression functions. Care is taken to reduce the heterogeneity of the carriers studied by focusing on intercity general freight carriers. Finally, each study sought to account for differences in costs due to traffic characteristics rather than size of the firm.

The Chow and Klem studies are extensions of the log linear model used by Warner and subsequently by Lawrence.[3] The coefficients associated with each independent or explanatory variable are interpreted as elasticities. The regression coefficient (B_1) associated with the scale or output variable is the elasticity of total cost to output. A one percent increase in scale, holding the effect of other independent variables constant, results in a B_1 percent increase in total cost. If B_1 is statistically less than one, statistically significant EOS exist; if B_1 equals one, constant returns to scale are implied: and if B_1 is greater than one, diseconomies of scale are implied.

A major difference between the earlier work of Warner and the recent extensions is that Warner utilized a time series of cross-section data (i.e., data for a given set of carriers for a given number of years) while the recent studies relied on single year's cross-section. This resulted in a much larger set of carriers being available for analysis in the Chow and Klem studies.

The major innovations of the Chow work is the exploration of non-scale variables affecting cost and the emphasis on segmenting the trucking industry into more homogeneous groups. In addition to accounting for the effect of the size of shipment and length of haul on costs as pioneered by Warner, the effects of the following factors were also modeled and tested:

(1) the amount of single line (versus interline) traffic,
(2) differences in pickup and delivery conditions,
(3) differences in the use of rented and owned equipment,
(4) percentage of traffic moved by owner operators,
(5) the effect of peddle operations,
(6) geographic differences in congestion, terrain and input costs.

Many persons familiar with trucking readily recognize that the trucking industry is an amalgamation of many different types of carriers. The legal distinction between common and contract, general freight and special commodity, or regular versus irregular route carriers initially comes to mind. It is further asserted that the distinction between long haul and short haul (and possibly regional) carriers, between Less than Truckload (LTL) and Truckload (TL) carriers, and between limited cov-

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SUMMARY OF RECENT ECONOMIC STUDIES OF ECONOMIES OF SCALE IN INTERCITY TRUCKING

	Type of Study					Explanatory Variables				
Author	Dependent Variable	Functional Form	Data Used	Additional Homogeneity Properties	Measure of Scale and Approximate Size of Carriers	Quality Measures	Operating Conditions Measures	Utilization Measures	Input Prices	Conclusions
Chow	Estimate of total cost function	Double Log Transformation	1973 cross-section of 538 Class I intercity general freight carriers. Carriers with missing data or obvious errors deleted.	Carriers segmented simultaneously by shipment class (TL versus LTL), haul class (long and short haul), geographic coverage class (high versus low).	Number of shipments, Largest and smallest Class I carriers.	Average shipment weight, Average haul, Peddle service.	Regional dummy variables, % Interline, Other variables.	None	None	"economies of scale are present in the LTL segment of general freight... economies of scale were found to be strongest in the short and medium haul groups and weakest on the long haul groups...the results of under-specifying the cost model results in bias against economies of scale, particularly for long haul carriers."
Friedlaender	Estimate of total cost function	Translog Approximation of Cost jointly estimated with translog approximation of factor shares	1972 cross-section of 171 Class I and II intercity general freight carriers in Central States East, Central States West, Middle Atlantic, North Middle Atlantic and New England Regions as defined in TRINCS. Carriers with missing data, obvious errors, and outlier values in independent variables deleted.	None	Ton-Miles, Largest-180,215,000 ton-miles. Smallest-not indicated, probably small Class II.	Average shipment weight, % LTL tons. Average haul.	None	Average load.	Firm specific price of labor, firm specific price of capital, regional price of fuel, regional price of purchased transportation.	"...any economies that exist are economies of-haul or of service, not economies of scale of output *per se*... Because average costs at large output levels are substantially greater than minimum average costs, in the absence of the economies of regulation, large firms find themselves at a competitive disadvantage."
Klem	Estimate of total cost function	Double Log Transformation with second order output term.	1971 cross-section of 518 Class I intercity general freight carriers.	LTL carriers identified	Number of shipments, largest and smallest Class I carriers.	Average shipment weight, Average haul.	Regional dummy variables, % Interline.	None	None	"It appears that the cost structure of the trucking industry exhibits economies of scale only at the size range which corresponds to the smallest Class I carriers,...Diseconomies of scale are evident for firms with revenues more than approximately $10 million."
Koenker	Estimate of total cost (minus capital input) function.	Double Log Transformation with second order output term and dynamic lag adjustment.	1948-1972 time series of a cross-section of 25 interstate general freight carriers headquartered in Ill., In., Mi., Oh., Wisc.	None	Ton-Miles, Largest-319,705,000 ton-miles in 1972. Smallest - approximately 4,700,000 ton-miles in 1972	Average haul	Year to year output differences	Average load	None	"The average cost curve declines sharply to an output level of 6-8 million ton-miles per annum and rises gradually beyond this output level, holding average load and average haul factors constant."

TABLE 1

erage and broad coverage carriers are important.[4] On the demand side, these classifications represent completely different types of service. On the supply side, these classifications potentially represent different operating techniques, terminal and fleet configurations, and cost characteristics because different services are being produced. These nonrevelations have two implications. First, the results of a study of a set of carriers residing primarily in one classification of carriers cannot be easily extrapolated to apply to another group. Second, a study should seek homogeneity in the carriers under study through segmentation of carriers or the appropriate inclusion of explanatory variables in the estimating functions.

In the Chow study, the segmentation approach was used. The industry was initially segmented into TL and LTL groups, further classified by length of haul class, and finally divided into high and low coverage groups.

Klem's extension of the Warner model also involves exploring additional non-scale effects on cost, limited industry segmentation, and the testing of a variable elasticity model. The additional variables used by Klem represented interlining and geographic cost differences.[5] Segmentation involved the analysis of a separate group of LTL carriers. The testing of a variable elasticity model represents the greatest departure in the Klem analysis. It has been hypothesized that the extent of EOS (or diseconomies of scale) may be different depending on the size of the firm.[6] That is, the true elasticity of cost to output could change for different levels of output. Klem concludes that the inclusion of a second order term is the best way to allow EOS to vary with firm size.

The Friedlaender study differs substantially from the two preceding studies in three respects. First, a different functional form, the translog approximation, is used to estimate the cost function. Second, factor share equations are estimated simultaneously with the cost function. Third, factor prices are explicitly included in the model. The value of the translog approximation is that it permits the evaluation of a wide range of hypotheses concerning the structure of technology through its second order terms. Like the Klem model, the translog approximation allows for changes in elasticity of cost to output as output levels change. In addition, hypothesis about the separability of the cost function can be tested by coefficients representing the interaction between output and price of specific factors of production.

The inclusion of factor prices, i.e., the price of labor, capital, purchased transportation and fuel, is a methodology used to isolate the technological as opposed to pecuniary economies of scale. Technological EOS arise from production relationships only; that is, trucking has EOS if a carrier can double its output of shipments or ton-miles (haul and shipment weight held constant) without having to double the number of employees, number of trucks, gallons of fuel and other inputs needed to produce service. Pecuniary EOS arises when a large carrier can buy inputs (i.e., trucks or fuel) more cheaply than smaller carriers because of their bargaining strength, quantity discounts and lower transaction costs.[7]

The major innovation of the Koenker study is the inclusion of a distributed lag mechanism. Management does not always forecast demand accurately so that actual costs are actually a function of a planned level of activity and the unanticipated deviation from that planned level. The lag variables allow for the effect of unanticipated year to year increases or decreases in demand. To compute the output differences, Koenker's study utilizes a time series of a given cross-section of carriers. As with Warner, this sets some limitations on the maximum number of carriers that have complete data. Koenker also includes a second order output variable to allow EOS to vary with firm size.

VARIABLES USED

Each study sought to isolate the effect of scale on cost through the inclusion of non-scale variables as explanatory factors. Such variables can be classified into three types; output or service quality variables, utilization variables, and operating condition variables.

Most observers of trucking operations have found that a long haul ton-mile or a TL ton-mile is considerably cheaper to produce than a short haul or LTL ton-mile. Average length of haul is consistently included as a non-scale variable. A variable representing the effect of shipment size on cost is less consistently used. Chow, Klem, and Friedlaender utilize average shipment weight and the latter also utilizes the percentage of tons shipped in LTL lots. Both Chow and Klem recognize that the degree of interlining can seriously affect the total cost incurred by a firm and Chow tests several additional "traffic" quality variables.

Both the Friedlaender and Koenker analysis included average vehicle load as an explanatory variable in their models. The inclusion of a capacity utilization variable in such analysis is inappropriate because such measures do not represent a product dimension nor operating condition that is exogenous to the firm. If one supposes that better utilization is achieved because of size per se, then the inclusion of such factors serves to hide the benefits of size.[8] The opposite view is that average load does represent an exogenous characteristic of a carrier's traffic because it represents the effect of entry regulation for which the carrier has little short run control over. The view deserves a more critical look.

Friedlaender asserts that ". . . it is generally believed that size and diversity of operating rights permit large firms to enjoy high load factors, . . ."[9] Friedlaender's own empirical research shows a positive relationship between the average load and average length of haul. Indeed. any inspection of carrier statistics indicates that long haul carriers exhibit heavier loads. However, there is no reason to believe that longer hauls per se cause heavier loads. It is a basic tenet of location theory that the flow of products decreases with distance since distance related transport costs and transfer costs mitigate differences in relative prices for a commodity between two points. Consequently, it is more difficult to build heavier loads between two specific points that are farther apart than between two points that are closer together, all other factors equal. However, all other factors are not equal; many larger carriers are also broad coverage carriers who serve numerous origin-destination pairs over a large network of terminals and take advantage of consolidation and reconsolidation opportunities to achieve maximum vehicle loads.

Herein lies the real controversy. A variable accounting for the effect of increased geographic coverage is lacking in all of the analyses. What would the potential effect on cost and firm size of the inclusion of such a variable be? It may mean higher average loads but it also suggests increasing the minimum size of the carrier as well since a minimum amount of traffic would be necessary to efficiently serve any particular point especially if the traffic is primarily LTL. One must question the feasibility of a small carrier serving more origins and destinations and decreasing their costs without increasing the amount of traffic moved. Carrier growth cannot be attributed to capturing a larger share of the market in its present route structure alone, it also involves to a significant degree expanding that route structure.[10] The consequence is greater minimum carrier size, somewhat different operating techniques and essentially a different or higher quality service than their smaller counterparts.

The inclusion of factor input prices serve to eliminate interfirm cost differences due to differences in the cost of labor, capital, purchased transportation, and fuel in the Friedlaender analysis. In the Chow and Klem analysis, dummy variables representing spatial variations in cost and operating conditions between ICC defined regions were used. Koenker's study sample was limited to Central States carriers so that the same control of regional cost differences is achieved. It is duly recognized that even within ICC defined regions labor cost will vary, particularly wages for hourly employees in different cities. A possible solution would be the use of finer geographic definitions, perhaps the format defined in TRINCS. Consequently, Friedlaender's underlying assumption is that the prices of inputs faced by each carrier may differ within a region while the other studies assume input prices are competitively determined, exogeneous, and identical for all firms within a geographic region. The latter assumption is not completely true. Short haul carriers have to cope with more hourly and guaranteed compensation plans (i.e., minimum pay for a turnaround) while long haul carriers pay more on mileage basis. However, if this is true, the effect on cost should be captured by the variable representing length of haul and the same principle would apply for other wage differences due to the type of service provided. A reasonable a priori assumption is that region-wide Teamster contracts apply to all carriers insuring that all carriers are paying uniform wages for the type of work performed in each region.

Friedlaender's work weakly suggests that wages do vary.[11] There are, however, potential explanations for these contradictions. The firm specific price of labor is measured by total labor compensation divided by average number of employees. Such a measure reflects both the contracted prices (i.e., mileage or hourly rates) and the productivity of the carrier. If productivity were associated with the increasing (decreasing) size of the carrier, one would expect that the larger (smaller) carrier could produce a larger (smaller) output with a propotionately smaller workforce and smaller total labor cost. This may not be the case in trucking where the workforce represents many individuals who are paid according to output as measured by hours worked or miles driven. A carrier can simply utilize its labor force more or less intensively rather than change the size of its workforce, leading to variations in annual wages. A related explanation is the substantial correlation between types of carriers and wages. Synthetic cost studies suggest that potential vehicle and driver utilization (annual miles per year) increases with the length of haul characteristic of carrier service.[12] Line haul drivers, paid the same mileage rates, can thus earn higher annual wages by driving more miles. These contentions need to be explored further.

The rationale for assuming that the cost of capital and cost of fuel are competitively determined and uniform for all carriers in a region rests on shakier grounds. Larger carriers may be able to obtain lower prices for trucks because of their bargaining power or through quantity discounts. Capital may be obtained more cheaply by larger carriers because of reduced transaction costs and their exposure to the investing public. Larger carriers potentially have a stronger ability to hedge against fuel shortages and increased prices through long term contracts for fuel and direct bulk purchases of fuel. These possibilities mean that observed EOS may reflect pecuniary as well as technological EOS unless explicit recognition of these price differences is made.

The view that only technological sources of EOS are relevant is severely questioned on public policy grounds. One of the ultimate questions for EOS research is directed to whether larger carriers will have a significant cost advantage over its smaller competitors. One should not ignore any source of EOS that would continue to persist whether regulation continues or not. Finally, some of the pecuniary EOS may truly represent production economies to society. For example, the quantity discounts available for large fleet purchases may reflect the production economies resulting from longer production runs of a specific vehicle type.

Few would question the contention that the cost models used to date remain underspecified. The quality of truck service has many dimensions beyond size of shipment and length of haul. What is necessary is the collection and use of data measuring carrier performance with regards to:

(1) Loss and damage,
(2) Transit time,
(3) Variability of transit time,
(4) Availability of equipment,
(5) Tracing and other information or advisory services,
(6) Geographic coverage,
(7) Special equipment and services.

The bias resulting from exclusion of some of these quality characteristics can be deduced. With regards to geographic coverage, a higher level of coverage is afforded by larger carriers and extra cost is expended in increasing coverage. Consequently, a cost model without a coverage variable tends to understate EOS. The availability of equipment can be analyzed in a similar manner. The vehicle fleet can be viewed as an inventory held to meet uncertain demand. A larger carrier would require less reserve equipment to guard against equipment shortages because the random peaks and valleys of each individual customer's demand tend to cancel out as carriers serve a larger number of shippers. On one hand, the larger carrier could reduce costs for a given level of equipment availability by holding a smaller fleet than its smaller counterparts. However, as Lawrence suggests, many carriers have opted for a high quality of service strategy whereby a larger fleet could be maintained to provide a greater availability of equipment. The appearance of constant returns (or even diseconomies of scale) may simply reflect the higher quality levels provided by larger carriers.[13]

For other quality of service characteristics, the bias is less clear because it is not at all evident that the quality of service is positively correlated with carrier size though many observers have supported the contention that there are economies of service.[14]

The data required to measure these additional service dimensions will not be easily obtained. True measures of carrier performance are reflected in shipper satisfaction. This means that a degree of openness and cooperation in developing satisfactory quality of service data is necessary from both shippers and carriers. Shippers and carriers differ a great deal in their perceptions as to what constitutes good service and neither party can develop such information without cost.[15] Nonetheless, some data on loss and damage performance and coverage is presently available. Route miles are available from the carrier's annual report to the ICC and terminal information is available from a variety of carrier guides and these may provide rough measures of a carrier's coverage. Loss and damage information is likewise reported to the ICC.

Finally, a word should be said about improving the quality of the measurement variables now used. Whereas Chow and Klem used number of shipments as a measure of scale, Friedlaender and Koenker used ton-miles. Both shipments and ton-miles are closely correlated particularly when the effects of average shipment size and length of haul are taken out. However, one is inclined to choose the number of shipments over ton-miles because the shipment measure is an exact number resulting from the aggregation of bill of lading statistics while ton-miles are generally estimated.[16] Consequently, the measurement errors associated with the most important explanatory variable are reduced if shipments are used. Secondly, we cannot continue to depend on time honored definitions of the variables consistently used in econometric studies. Average shipment weight and average haul are what they are averages. One might consider the average weight of TL shipments and LTL shipments separately or use a weighting scheme to account for the distribution of traffic by weight groups. Much of the problem lies in the reliance on easily available data but part of it rests on the lack of clever methods of data manipulation.

THE INTERPRETATION OF THE EMPIRICAL RESULTS

The studies by Klem, Koenker and Friedlaender all suggest that the optimal size of the general freight motor carrier is quite small. To properly interpret these quantitative assessments, it is important to consider the size of the transport market and the quality of service variables not considered explicitly in their analysis.

EOS are not significant if the output level at which declining costs are fully exploited is small relative to the size of the market. In such a case, many sellers can achieve minimum cost and many carriers can successfully compete for the traffic. The problem is that the definition of the relevant market is vague. If the market is the demand for transport services between two specific points, there are many markets where the volume of traffic would support a large number of carriers of the size envisioned by the studies cited. However, at the same time, there are many point to point markets that do not satisfy this criterion. In a Department of Transportation sponsored study, surveys conducted in the nine state Rocky Mountain region by the Federation of Rocky Mountain States and separate surveys by the Wyoming and North Dakota Public Service Commissions indicate that:

(1) a significant number of carriers did not serve towns that they were authorized to serve,

(2) the quality of service particularly in terms of schedules per week is low,

(3) the number of carriers serving 25 percent of the locations in the region is two or less. Sparse population and scarce traffic are cited as contributing factors.[17]

The existence of pooling agreements also suggests the existence of geographic freight markets that cannot support a competitive number of carriers. One successful pooling agreement began in 1971 when Graves Truck Lines asked to act as pooling agent for P.I.E., Consolidated Freightways, and Eastern Express by picking up and delivering LTL shipments for these companies to and from 107 communities in Kansas.[18]

Abstracting from the issue of market demand, what type of service can a carrier of the optimal size (determined in quantitative studies) produce? We have already indicated that the models are underspecified so that one really does not know what quality of service the optimal carrier provides. However, one can develop clues by synthetic analysis. Koenker's optimal size firm is used as a starting point. In Table 2, various assumptions about length of haul, average load and number of days that the carrier operates per year are combined to determine the average number of vehicle trips taken per day by the optimal size firm defined as one that moves 6,691,000 ton-miles per year. Focusing on a specific length of haul of 750 miles, such a carrier would move 595 loads a year or about 2.3 loads a day assuming 260 days worked in a year. This example assumes daily service is provided. In this case, balanced movements would allow the production of 1.15 round trips per day.[19] Clearly this size carrier cannot serve more than one origin-destination pair given the level of service parameters indicated.

If the carrier provides service to additional geographic destinations, it cannot remain at the size indicated given the frequency of service, length of haul, average load, and lane balance assumptions. Instead, it must increase by almost a multiple of the optimal firm size, the multiple being equal to the number of new lanes the carrier wishes to serve (i.e., each new lane requires 1,500 miles per round trip $\times$ 15 tons per load $\times$ 260 trips per year $=$ 5,850,000 ton-miles per year).

One can conclude that increasing the coverage dimension of service increases the minimum size of a carrier. Similarly, the coverage aspect of a carrier can be held constant and another aspect of service can be varied. It is easy to deduce that holding other factors constant:

(1) an increase in the frequency of service (i.e., daily as opposed to twice a week) increases minimum scale and vice versa,

TABLE 2

POTENTIAL CHARACTERISTICS OF OPTIMAL SIZE MOTOR CARRIER[1]

Optimal Size Ton-Miles Per Year	Average Haul Miles[1]	Average Load Tons	Tons Per Year	Number of Truckloads (TL) Moved Per Year	TL's Per Day[2]	Potential Origin-[3] Destination Pairs Served Per Day
(1)	(2)	(3)	(4)	(5)	(6)	(7)
			(1)÷(2)	(4)÷(3)	(5)÷260	(6)÷2
6,691,000	150	8	44606.6	5575.8	21.4	10.70
6,691,000	200	10	33455.0	3345.5	12.9	6.45
6,691,000	350	15	19117.0	1274.5	4.9	2.45
6,691,000	750	15	8921.3	594.8	2.3	1.15
6,691,000	1,000	15	6691.0	446.0	1.7	.85

1 From Koenker, p. 62 for 150-350 miles; assumed for other haul groups.
2 Assumes 260 working days a year.
3 Assumes daily service and balanced loads.

(2) an increase in the length of haul increases minimum size and vice versa.

This exercise highlights the dangers of extrapolation. The small optimal size determined in some studies may be applicable to carriers providing one type of service but not for another type of service. It appears that the carriers observed by Friedlaender and Koenker are principally small and regional so that any inferences of their results to larger and longer haul carriers are to be made with caution.[20]

CONCLUSIONS: SOME STRENGTHS AND WEAKNESSES OF CURRENT APPROACHES

The studies reviewed in this paper present a variety of approaches to estimating the relationship between carrier size and long run costs. The strengths and weaknesses of each provide valuable lessons for future research and interpretation of the results. The principal lessons appear to be:

(1) Segmentation of the industry into more homogeneous service groups reflects the view that the industry is really a number of subindustries with significantly different features. The lack of such segmentation may produce results that do not really reflect the true cost structure of the subindustries. Extrapolation of empirical results from one subindustry to another should be taken with great caution.

(2) The inclusion of second order terms in the output variable, to allow for variable elasticity of cost to output is necessary in order to estimate at what level of output all economies of scale are exhausted.

(3) The inclusion of utilization variables such as average load is a potentially serious mis-specification of the cost model.

(4) The use of a distributed lag mechanism reduces the bias potentially produced by unexpected changes in quantity demand in a regulated environment.

(5) Variables measuring differences in operating conditions (such as spatial differences in input costs, congestion, etc.) are appropriate non-scale variables and should be included if they are accurate measures of what is supposed to be measured.

(6) Number of shipments rather than ton-miles is a superior measure of scale when potential measurement errors are considered.

(7) The inclusion of input prices may or may not be necessary depending on one's viewpoint. Their inclusion in econometric studies of cost has a number of precedents.[21] They also allow the testing of additional hypotheses about the underlying technology of trucking. The accuracy of measuring these prices adequately, however, is questionable. Furthermore, it was argued that pecuniary economies of scale are never the less an important competitive factor in the real world. If the objective of the research is to measure the extent of declining costs, the inclusion of input prices could potentially disguise actual competitive advantage.

(8) Further work is needed in developing measures for quality of service characteristics in order to properly specify a true cost model.

It is clear from these lessons that no single study in 1977 is faultless. The weak and strong points of each study can be appraised from Table 1. One can only make guarded conclusions from such analyses.

A great amount of new and original evidence on the issue of EOS in trucking was presented in 1977. These studies have brought the state of the art in measuring long run trucking costs a great deal forward but not to the end of the road. Future studies on the subject should recognize the strengths and weaknesses of these studies such as those listed in this section. It should also be noted that differences in data as well as approaches are probably responsible for the different results of each study. An important benefit of publicly funded research should be to disseminate a common set of data that is available to all interested parties. In this manner, the variance in the statistical results of different research efforts will be reduced and we will find ourselves a bit further down the road to consensus on the issue of EOS in trucking.

FOOTNOTES

1 Garland Chow, "The Cost of Trucking Revisited," in **Proceedings of a Workshop on Motor Carrier Economic Regulation** (Washington, D.C.: National Academy of Sciences, 1978): 57-98; Ann F. Friedlaender, "Hedonic Costs and Economies of Scale in the Regulated Trucking Industry," in **Proceedings**: 33-56; Richard Klem, "The Cost Structure of the Regulated Trucking Industry," in Proceedings: 141-162; and Roger Koenker, "Optimal Scale and the Size Distribution of American Trucking Firms," **Journal of Transport Economics and Policy** 11 (Jan. 1977): 54-67.

2 For a critical analysis of empirical work on EOS in trucking prior to 1977, see Chow, pp. 58-65.

3 Stanley L. Warner, "Cost Models, Measurement Errors, and Economies of Scale in Trucking," in **The Cost of Trucking: Econometric Analysis**, M. L. Burstein, et al. (Dubuque: Wm. C. Brown Co., 1965): 1-46; Michael L. Lawrence, "Economies of Scale in the General Freight Motor Common Carrier Industry: Additional Evidence," **Proceedings—Seventeenth Annual Meeting of the Transportation Research Forum** (Oxford, IN.: Richard B. Cross Co., 1976): 169-176.

4 See for example J. H. Fleas, "The Regional Common Motor Carrier, Today and Tomorrow," **Transportation Journal** 7 (Winter 1967): 27-31; Lawrence, Ibid.; F. A. Saleh, J. F. Robeson and J. R. Grabner, **Creative Selling and the Systems Concept** (Washington, D.C.: American Trucking Associations, Inc., 1970); J. C. Spychalski, "Criticisms of Regulated Freight Transport: Do Economists' Perceptions Conform With Institutional Realities," **Transportation Journal** 14 (Spring 1975): 5-7; and D. D. Wyckoff, "Factors Promoting Concentration of Motor Carriers Under Deregulation," **Proceedings — Fifteenth Annual Meeting of the Transportation Research Forum** (Oxford, IN.: Richard B. Cross, Inc., 1974): 1-6.

5 Klem's interline measure weights the percent of single line tons by two (one pickup and one delivery), weights the percent of interline tons either terminated or originated by one, and weights the percent of bridge traffic by zero. Chow simply uses the percent of single line tons.

6 See Gary N. Dicer, "Economies of Scale and Motor Carrier Optimum Size," **Quarterly Review of Economics and Business** 11 (Spring 1971): 33-34.

7 Some economists have used the phrase "economies of size" to distinguish pecuniary economies of scale from the purely physical relationship between inputs and outputs implied by "economies of scale." See I. M. Grossack and D. D. Martin, **Managerial Economics: Microtheory and the Firm's Decisions** (Boston: Little, Brown and Co., 1973): 406-412.

8 The opposite case is possible as well, i.e., larger carrier size results in worse utilization. In this case, the inclusion of utilization variables may hide the diseconomies of size.

9 Friedlaender, p. 49.

10 As Harrison points out, "To expand means, primarily, to expand geographically, for, even in a given centre, demand for transport in any particular direction is only a fraction of the total demand originating in that centre, so it may be easier for a firm to expand away from its base rather than by winning the whole of the market where it is based, . . . " A. J. Harrison, "Economies of Scale and the Structure of the Road Haulage Industry," **Oxford Economic Papers** 15 (November 1963): 300.

11 Koenker notes, "Unfortunately, especially in a simple cross section, and even with several cross sections, factor price variation is slight and much of what is attributed to factor price variation in Professor Friedlaender's work may instead be variation in the composition of labor and capital inputs within her aggregates." R. Koenker, "Discussants Comments" in **Proceedings of a Workshop on Motor Carrier Economic Regulation**: 167.

12 For example, see U.S. Department of Agriculture, Economic Research Service, **Cost of Operating Trucks for Livestock Transportation**, by Patrick P. Boles, Marketing Research Report No. 982 (Washington, D.C., 1973): 3, 7, 8.

13 Lawrence, "Economies of Scale," pp. 170-171.

14 See for example George W. Wilson, "The Nature of Competition in the Motor Freight Industry," **Land Economics** 36 (Nov. 1960): 387-391; and D. Phillip Locklin, **Economics of Transportation**, 7th ed. (Homewood, Ill.: Richard D. Irwin, Inc., 1972): 648-649.

15 For example, see R. E. Evans and W. R. Southard, "Motor Carriers' and Shippers' Perceptions of the Carrier Choice Decision," **The Logistics and Transportation Review** 10 (1974): 147.

16 See Interstate Commerce Commission, Bureau of Accounts **Preparation and Submission of Motor Carrier of Property Annual Report Forms M-1 and M-2 For 1974** (Washington, D.C., 1975): 13-14. The publishers of TRINCs note for ton-miles, "This statistic, used as a base for ratios on Lines 85, 86 and 87 is perhaps the least reliable provided by the carriers in their annual reports. Smaller carriers especially, sometimes furnish rough estimates, or simply obtain a ton-mile figure by multiplying tons by vehicle miles . . . . Extreme care should be exercised in using these ton-mile data without critical reference and evaluation with related data filed by the particular carriers." See **TRINC's Blue Book of the Trucking Industry 1972 Edition** (Washington, D.C., 1972) VI.

17 Federation of Rocky Mountain States, Inc., **Motor Common Carrier Freight Rate Study** (Washington, D.C.: Department of Transportation, 1975):44-45, 60.

18 See Ray Lippe, "Graves Truck Line-Salina, Kansas," **Terminal Operator** (May 1975):11-15. For a description of the rationale behind pooling and ICC pooling policy, see John M. Records, "Pooling by Interstate Freight Common Carriers," **The Transportation Law Journal** 6 (July, 1974): 125-138.

19 This implicitly assumes that it is economical to provide daily service to and from a location that only generates one load a day. Economies

associated with multiple pickup and delivery operations may increase the minimum.

20 Friedlaender chose TRINC region for which traffic is predominantly short haul, as opposed to long haul regions such as Eastern-Central, East-Midwest, etc. See TRINCS, p. IX for definitions. The largest carrier studied has a size of 180,215,000 ton-miles whereas the average size of all Class I General Freight carriers is 115,-859,320 ton-miles. Koenker also examined predominately small and short haul carriers. His carriers are listed in Roger Koenker, **The Estimation of Input Demand Functions and the Relative Economic Efficiency of Regulated Trucking Firms** (Unpublished Ph.D. dissertation, University of Michigan, 1974):117.

21 For example see Marc Nerlove, "Returns to Scale in Electricity Supply," in C. Crist, et al., **Measurement in Economics** (Stanford: Stanford Univ. Press, 1963):167-198.