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Economies of Scale in the General Freight Motor Common Carrier Industry: Additional Evidence[1]

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I. INTRODUCTION

AMONG THE MANY unresolved issues relative to transportation deregulation, the question concerning the presence or absence of economies of scale in the motor carrier industry is perhaps the most misunderstood. Proponents of regulatory reform argue that there are none or that if there are economies of scale they are not significant. Therefore, they argue that large carriers are not inherently more cost efficient and that free competition in the trucking industry would not lead to industry concentration in the long run.

It is likely that there are segments of the motor carrier industry which are characterized by high degrees of divisibility in assets, operations and markets and that therefore are not subject to pronounced economies of scale.

However, there is a major portion of the industry, the LTL (less-than-truckload) segment, in which a high degree of indivisibility exists. The economic value of an efficiently run system of LTL terminals and break-bulk (reship) centers is significantly greater than the sum of the values of its individual parts. The interactive effects among the components of an LTL system (both operations and market components) are complex, and carrier executives are continually refining their management methods which rely heavily on the systems approach. Carrier executives charged with the responsibility of running these complex systems strongly believe that there are pronounced economies of scale in the LTL general freight industry.

The general freight carriers accounted for 65% of all Class I and II motor common carrier inter-city revenues in 1973; and 62% of general freight intercity revenues were from LTL shipments. Obviously, if there are pronounced economies of scale in the LTL general freight business, the argument that free competition will not lead to significant concentration in the motor carrier industry requires much closer examination.

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II. RATIONALIZATION OF ECONOMIES OF SCALE IN THE GENERAL FREIGHT INDUSTRY

Economies of scale exist, according to Ferguson,[2] when, after all inputs having been optimally adjusted in proportion to one another, the long run unit cost of production can be reduced by increasing the "size of plant." Size of plant in this context refers to both the amount of capital and the amount of labor employed in an operation.

In discussing the "technological" factors which contribute to economies of scale, Ferguson[3] states: "If several different machines, each with a different rate of output are required in a production process, the operation may have to be quite sizeable to permit proper meshing of equipment." It is extremely important to note that "plant" in a general freight trucking operation is a network of terminals, each supported by its own local operations, and connected with one another through intercity movements of men and equipment. It is equally important to note that "size of plant" does not refer to the size of the individual movement units nor to the size of the individual terminals. Rather, it is the "meshing" of terminals. men, and movement units that gives rise to economies of scale in the general freight industry.

For example, all long haul LTL carriers find it necessary to operate "break-bulk" terminals for the purposes of consolidating shipments from several lanes[4] in order to build efficient size trailer loads, avoid having freight collecting at terminals, and meet minimum service requirements. Intra-company profit analysis indicates that the percent of LTL shipments that must be reshipped (rehandled at break-bulk terminals) is one of the two or three most important determinants of operating costs on a lane by lane basis. Undoubtedly, the carriers which have the largest market share on a particular lane can achieve the lowest percent bills reshipped if they so desire.

Increased volume on a single lane can often improve the cost efficiencies of many other lanes in a carrier's system by increasing load averages and equipment utilization for segments of lanes (legs)[5] into and out of break-bulk facilities. This same "systems" effect and others also apply to increased volume associated with the opening of new terminals.

The existence of economies of scale is also quite prevalent in local operations, as can be seen in the productivity of the city pick-up and delivery drivers and equipment.[6] In a typical suburban operation, a city driver (and unit) averages 1.2 shipments per stop (either pick up or delivery) and 1.5-3.0 miles between stops. Increasing the shipments per stop is highy remunerative (since the incremental cost of additional shipments per stop is minimal) and the probability of receiving multiple shipments per stop increases as the number of terminals to which a carrier offers single line service (extensiveness of coverage) increases. Reducing the distance between stops is also highly productive, and carriers can realize these efficiencies by increasing penetration of each individual market. Admittedly, the opportunity for increased penetration of individual local markets is available to "small" and "large" firms alike, but a firm's marketing ability to capitalize on this opportunity is greatly enhanced as the size of a carrier increases.

The marketing advantages accruing to large firms from extensiveness of coverage should be obvious. However, the greatest marketing advantages of size probably accrue from frequency and consistency of line-haul trips on ·ny given lane. Speed and consistency f transport service are so conducive to ·icient industrial distribution manage- ·nt that shippers are generally will- to pay substantial premiums to ob- ·it.[7] The probability of designing an ·ion with high frequency and con- v of service on most lanes is con- v enhanced by the overall size ·rrier.

·cussion of the advantages of be extended almost indefi- example, general adminis- selling expenses, including g and telecommunications, y lower as a percent of a per shipment basis, ·s than they are for other things equal. ·hat many observers familiar with the i-terminal, multi- · general freight that there are ' scale in the

III. ESTIMATION PROBLEMS IN PREVIOUS ECONOMIC RESEARCH

It is discomforting, therefore, that so much of the scholarly literature has concluded that there are no significant economies of scale in the trucking industry. However, there are at least three major reasons to re-examine the scientific evidence.

First, the major research on this subject was conducted ten to twenty years ago. Studies by Nelson, Roberts, Adams, and Meyer et al., were conducted in the mid 1950's and are still quoted as authoritative research on this subject.[8, 9, 10, 11] The largest general freight carrier in 1956, Associated Transport, had revenues of $48 MM and less than 50 terminals. In 1975 Roadway reported revenues of almost $600 MM from operations at over 300 terminals. In the 50's extensive industrial engineering, computerized operations control and many other modern management techniques were still many years away from successful application in the motor carrier industry. In short, the studies cited above were based on a different industry than that which exists today.

Second, previous econometric studies were based on sample groups which consisted predominantly of small carriers. The technical complications associated with this sampling procedure are discussed in Section IV.

Finally the validity of econometric tests of the existence of economies of scale hinges on the ability to isolate the effects which scale has on the factors of production or on average cost per unit of output. That is to say, the effects of all other factors must be held constant. There are at least three critical determinants of general freight operating costs per unit, which vary widely in their effects between firms, and which the published research has failed to control (or to discuss). These items are: quality of service, extent of operations in dense metropolitan areas, and intensiveness of market penetration (as distinguished from extensiveness of market penetration).

Quality of Service. Given the option of choosing between the combination of minimum operating cost and minimum service quality or high service at moderate (competitive) cost, most carrier executives would opt for the high service level. If the largest carriers can operate at a lower per unit cost than can smaller carriers at the same level of service, a logical explanation for the cost-service relationship among carriers of different size is shown in Exhibit 1.

SIZE VERSUS SERVICE AND OPERATING COST

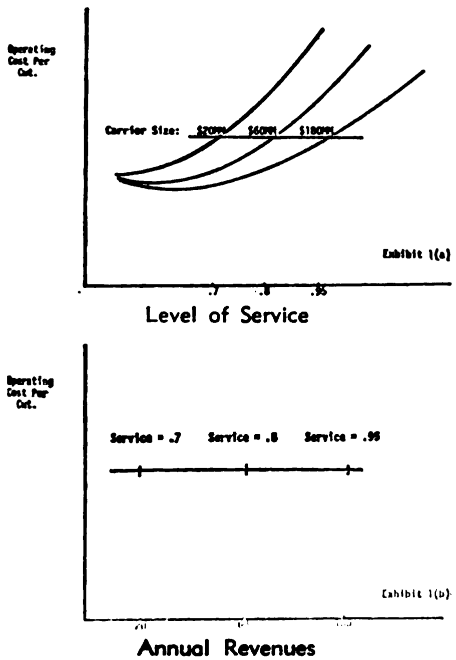

EXHIBIT 1

Each carrier offers the level of service he can afford, as shown in Exhibit 1 (a). The result is that each carrier operates at a competitive cost per unit, with the largest carriers providing higher quality service. However, as shown in Exhibit 1 (b) if operating costs per unit are plotted versus size of company without showing the influence of service quality on costs, the large carriers appear to have no cost advantage.

The implication of this analysis is that the marginal revenue from improving service is greater than the marginal cost of providing the service. Thus, the advantage of size, which the largest carriers have opted to apply to quality of service rather than realizing maximum cost efficiency, will be reflected in a profit versus size analysis, but will not necessarily appear in a cost versus size analysis unless some method for controlling the service quality factor is employed. To this point, the published economic research has not presented a method for controlling the quality of service variable.

High Cost Metropolitan Centers. Per unit operating costs in the largest metropolitan areas are significantly higher than in smaller cities. The proportion of total business with a large metropolitan center as the origin and/or destination terminal is significantly higher for the largest carriers than for smaller carriers, and it varies widely among large carriers. Failure to control this variable in econometric estimations of the shape of long run cost curves will cause the higher operating costs associated with large metropolitan centers to "load up," at least in part, on the regression coefficient for size (output).

Market Intensiveness and Market Extensiveness. The share of market that a carrier has in a given geographical territory is referred to as market intensiveness, or density. Market extensiveness is the geographical dispersion of point coverage. Although both extensiveness and intensiveness can give rise to economies of scale in operations, intensiveness is the more important of the two.[12] However, extensiveness is widely believed to be a major determinant of intensiveness. That is, extensiveness of point coverage is a major determinant of demand for a firm's LTL services at all points in its system.

The existing situation within the long haul LTL industry is that a few carriers have achieved both significant intensiveness and extensiveness (Roadway, Yellow, and Consolidated, to name three); and that the other large long haul LTL carriers seem split between those that are stagnating and those that are providing extensiveness in the hope of building intensiveness.

To further complicate the problem, many carriers with substantially more market extensiveness than intensiveness are operating with significant "excess capacity." Excess capacity in this context doesn't necessarily mean empty or idle equipment or excess dock space; but rather there is "excess capacity" in the Chamberlin sense that the resources employed to produce the service are underutilized relative to their productive potential.[13] These referenced carriers are getting fewer shipments per PUD stop, running longer distances between PUD stops, and re-handling a higher percentage of shipments at breakbulk facilities than would be true if their market extensiveness and intensiveness were better balanced. In most respects, $10MM Carrier A with limited extensiveness but with intense penetration is operating at a much larger scale than is $100 MM Carrier B with many thin markets spread over an extensive number of terminals. The fact that the per unit operating cost of Carrier A is significantly lower than that of Carrier B is the result of a combination of factors including the economies of scale achieved by Carrier A from intensive but limited market penetration and the under-utilization of capacity (in the Chamberlin sense) experienced by Carrier B. Unfortunately, previous econometric research employs total tons, ton miles, shipments, or revenues as the measure of scale and therefore interprets the foregoing example as evidence of diseconomies of scale in the trucking industry.

It is important to note that carriers with over-developed extensiveness (in relation to their intensiveness) have done so consciously in order to stimulate demand and total revenues, which to some extent offsets the cost sub-optimization involved. Thus, econometric estimation of the industry profit function is probably less distorted by this factor than is estimation of the cost function.

IV. ECONOMETRIC EVIDENCE

One serious mistake made in previous research on this subject is that the effects of carrier size (output) on the cost curve have been analyzed with the smallest carriers and largest carriers in the same data sample. Operating characteristics are widely diverse among the smallest carriers, all of which bear little comparability to the large, long distance carriers. A related, and also serious, error is that in previous research the sample data have been disproportionately weighted with the smallest carriers. Therefore, for the purposes of this analysis, the Class 1 general freight industry was divided into five distinct but at times intersecting groups. The original sample was designed so that each basic group would have 50 observations or the total number of firms in that segment of the industry, whichever was largest. During the analysis several observations were eliminated from each group, because of missing data. The original firms in each group were randomly selected.

The five groups and the number of firms without missing data in each group are as follows:

Group	# of Firms	Description
1	38	Revenues less than $10 MM
2	42	Revenues greater than $10 MM, but less than $50 MM
3	44	Revenues greater than $50 MM
4	26	Revenues greater than $50 MM, average haul greater than 500 miles
5	86	Revenues greater than $10 MM

Group 5 is the combination of Groups 2 and 3 and Group 4 is a sub-set of Group 3. The reasons for studying Group 4 are twofold:

(1) There are significant differences in the operating characteristics of long haul and short haul LTL carriers.

(2) Measures of the large city cost effect, market extensiveness and market intensiveness were available for this group. (Unfortunately, development of an appropriate measure of quality of service was not possible within the time and resource constraints of this project.)

Multiple regression models were developed for the profit, revenue, and expense functions for each of the five groups based on a cross-sectional analysis of carrier data for 1973. The methodology is similar to that employed in previous research. All regressions were in log form so that the regression coefficients of each explanatory variable reflect the percentage change in the study variable (profits, revenues, or expenses) for a 1% change in the respective explanatory variable assuming the other explanatory variables unchanged. For Groups 1, 2, 3, and 5 the explanatory variables are total tonnage, average length of haul, average load per trailer, the ratio LTL tonnage/total tonnage, and average tons per LTL shipment. For Group 4, the five explanatory variables listed above were included in the analysis in addition to surrogates for the large city cost effect, market intensiveness and market extensiveness. The surrogate for the large city cost effect is the ratio: total population of those of the 20 largest U.S. metropolitan areas in which a carrier has at least one terminal divided by the total population of all metropolitan areas (or cities) in which the carrier has at least one terminal. The surrogate for market intensiveness is average revenue per terminal divided by the average metropolitan population per terminal. The surrogate for market extensiveness is number of terminals operated by each carrier.

In preliminary experimentation the three surrogate measures for the large city cost effect, market extensiveness, and market intensiveness behaved as expected in the models for Group 4. Market intensiveness was the most important variable in models explaining operating ratios (not reported here) and ranked second behind total tonnage in explaining total profits. Both extensiveness and intensiveness added to the explanatory power of the expense model. Unfortunately, there is substantial multicollinearity when any two of total tonnage, market intensiveness and market extensiveness are included in the same regression model. Therefore, although research is continuing on the scale-intensiveness-extensiveness problem, it was necessary to omit measures of intensiveness and extensiveness from the models for the purpose of this report. The large city effect, however, was included for Group 4 and contributed to the explanatory power of the models.

The results of the profit model are the most definitive of the three models. Unfortunately, space does not allow reporting the regression results for all variables and models, but such are available upon request. The item of interest to the subject of economies of scale, of course, is the regression coefficient for tonnage. A coefficient of 1.0 for the tonnage variable means that a 10% change in tonnage, all other factors equal, results in a 10% change in total profits. A coefficient less than 1.0 implies that profitability rises less than proportionately as tonnage grows and a coefficient greater than 1.0 means profitability grows faster than tonnage. The regression results for tonnage for the five groups of companies are:

Group	Size Range (Revenues)	Regression Coefficient	Standard Deviation	Implied Increase in Profits for a 10% Increase in Tonnage
1	1 MM - 10 MM	1.075	.248	10.75%
2	10 MM - 50 MM	1.170	.289	11.70%
3	Over 50 MM	1.525	.290	15.25%
4	Over 50 MM (Distance 500 Miles)	1.352	.272	13.52%
5	Over 10 MM	1.253	.150	12.53%

The results indicate that profitability increases as firms grow larger, in all categories of size and distance studied. More significantly, size is relatively more important among the larger carriers. This observation coincides with suggestions by Dicer,[14] Wycoff,[15] and others that technical, managerial, and financial barriers to growth among small carriers prevent many firms from growing to the size at which economies of scale become truly significant. Dicer, for example, hypothesized that there are likely multiple local minima along the full range of the industry long run cost curve.[16] If this hypothesis is true, and our research tends to support it, it is not surprising that previous econometric analyses that were based on data samples consisting almost entirely of small firms would not detect significant economies of scale.

The shape of the profit function is not the theoretically most appropriate measure of economies of scale because it includes the influence of size on both revenues and costs. More emphasis is placed on the profit model here because the econometric measurement of the industry profit function is believed to be less sensitive to the critical uncontrolled variables described earlier. The tonnage regression results obtained when operating costs are studied rather than profits are as follows:

Group	Size Range (Revenues)	Regression Coefficient	Standard Deviation	Change in Total Expense for 10% Change in Tonnage
1	1 MM - 10 MM	.982	.088	9.82%
2	10 MM - 50 MM	.986	.043	9.86%
3	Over 50 MM	.988	.038	9.88%
4	Over 50 MM (Distance 500 Miles)	1.019	.020	10.19%
5	Over 10 MM	.984	.023	9.84%

This analysis, taken at face value, suggests that there are economies of scale in all cases except for Group 4 (the large, long distance carriers). The profit model, the reader will recall, indicated that increasing returns to scale in Group 4 were more pronounced than in any group except Group 3. The explanation of this seeming inconsistency is the failure of the regression mechanism to adequately control the quality of service and related problems described earlier. To clarify, consider the relationship between output and total revenues. If the regression mechanism has adequately controlled the quality of service and related factors (i.e., if the output variable, all other factors equal, measures a homogeneous service) then the regression coefficient of the output variable in a multiple regression model to explain revenues should be 1.0. That is, if output goes up 10%, revenues should go up 10% because the same service is being sold at the same price at all levels of output. The regression results for the revenue model are reported in Exhibit 4. The comparison of the tonnage regression coefficient for output, revenues, and profits is as follows:

Group	Size Range (Revenues)	Revenues	Expenses	Profits
1	1 MM - 10 MM	.984	.982	1.075
2	10 MM - 50 MM	.991	.986	1.170
3	Over 50 MM	1.009	.988	1.525
4	Over 50 MM (Distance 500 Miles)	1.034	1.019	1.352
5	Over 10 MM	.995	.984	1.253

It is clear that among the large, long distance carriers the apparent slight diseconomies of scale are the result of some uncontrolled factor, the effects of which "load up" on the output coefficients in both the revenue and expense models. This comparison of the revenue and expense model regression coefficients for output is consistent with our thesis that carriers who have the option between maximum service and minimum cost will select maximum service because of the favorable effects of the higher service on its demand and revenue functions.

At the other end of the scale (Group 1), the regression coefficient for output in the revenue model is also significantly different from 1.0, which suggests that the regression model has not been able to control the heterogeneity of services provided by different firms in that class. This is not surprising, since the types of equipment, relative importance of intracity freight, degree of geographical concentration, labor conditions (union versus non-union, etc.) vary almost randomly between firms in that class. These observations reinforce the argument that firms in this class should not be combined with the larger classes when econometrically testing for the existence of economies of scale. Unfortunately, all of the published research that has concluded there are no economies of scale in trucking have used samples with large numbers of small carriers mixed with a handful of large carriers.

V. ON THE INTERPRETATION OF REGRESSION COEFFICIENTS

Most of the published literature has concluded there are no economies of scale in trucking, or at best, those economies of scale that do exist are not significant. Significant in this sense apparently means that large carriers are not sufficiently more efficient that small carriers cannot compete. Stanley Warner, for example, concluded that in the period 1957-1962 the "adjusted" regression coefficient for output (shipments) in the industry long run cost curve was around .98 (10% change in output causes 9.8% change in costs).[17] His interpretation of this evidence is that although these results suggest economies of scale, the economies that exist are not significant.[18]

Warner's conclusions were of particular concern, since much of the research reported here also identifies an output coefficient of .98 (using tonnage rather than shipments) in the cost model. Therefore, to determine what the output coefficient would be if economies of scale were significant, a hypothetical trucking industry in which there are pronounced economies of scale was created. The hypothesized industry has 21 carriers ranging in size from $1 MM to $201 MM all producing exactly the same service, pricing at exactly the same rate per shipment ($50) and with the same weight (1000 lbs.) per shipment. For the 21 carriers operating ratio drop in stair step fashion from 98% for the $1 MM carrier down to 87% for the $201 MM carrier.

The long run average cost curve for this hypothesized industry is shown graphically in Exhibit 2. Assuming even a constant sales/capital ratio of 4.0, before tax return on capital for the $1 MM firm is 8% and for the $201 MM firms it is 52%. More importantly the marginal cost per unit for the largest firm is roughly 15% lower than the marginal cost per unit of the smallest company. Since the industry is one in which all of the economic prerequisites for successful price discrimination clearly exists (assuming no regulation of price competition),[19] the largest carriers can afford to cut prices on specific segments of business by as much as 15% (even in a long-term perspective) in order to take business away from the smallest firms. And, of course, the smallest firm can withstand only a 2% cut in price in the long run (the operating ratio of the smallest firm is 98%).

The curve shown in Exhibit 2 is not smooth in the best theoretical sense, but

HYPOTHETICAL TRUCKING INDUSTRY DECREASING LONG TERM AVERAGE COST CURVE

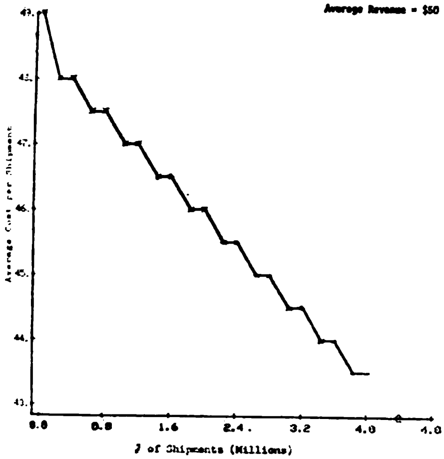

EXHIBIT 2

if it were the actual trucking industry long run average cost curve, no one could effectively argue that the industry is not subject to pronounced economies of scale. Yet the regression of the log of total expenses on the log of shipments yields a regression coefficient for output of .976.[20] **The conclusion by Warner and others that a regression coefficient of .98 does not reflect substantial economies of scale may be a misinterpretation of their own research evidence.**

VI SUMMARY AND CONCLUDING REMARKS

Large firms are more profitable than small firms, all other things equal, in the LTL general freight motor carrier industry. Contrary to the conclusions drawn by Meyer et al., and other previous researchers, this difference in profitability is not primarily explained by average length of haul. Multiple regression models explaining differences in operating ratio (which were not reported here) and models explaining differences in total profits make it abundantly clear that size of carrier is the most important explanatory statistic for profitability. Multiple regression models to explain differences in operating costs among carriers also generally indicate that expenses rise less rapidly than output, all other things equal. The research reported here generally reveals the same type of results reported by Warner and others who used similar techniques. Previous researchers, however, were apparently misled by the seemingly small differences between 1.0 (which indicates perfect output elasticity of costs) and their output regression coefficients, and erroneously concluded that the indicated economies of scale were insignificant. This paper points out that these same regression coefficients for output, if valid, generally reflect highly significant economies of scale.

However, there are reasons to be suspicious of the output of the cost models because the effects of certain factors which are critical elements in the operations-marketing infrastructure of the LTL general freight industry (most importantly quality of service) have not been adequately controlled by the quantitative models. This limitation may or may not discredit results reported here and in the previous literature for research on the shape of the industry long run cost curve. However, it is clear that substantially more definitive research in this area is required so that the multi-billion dollar national transportation policy issues currently under study can be decided based on scientific facts. Certainly the existing econometric evidence on the issue of economies of scale in trucking is inadequate.

FOOTNOTES

1 The author gratefully acknowledges the helpful comments of Jack Christy, Steve Nieman, Roger Blume, and Steve Mezger of IU International; Les Waters and Garland Chou of the University of Indiana; Bill Wagner of the University of Missouri; and Ned Moritz of the Regular Common Carrier Conference. He also gratefully acknowledges the computer analysis and programming assistance of Dave Casey and Steve Dyott of IU International.

2 C. E. Ferguson, **Microeconomic Theory** (Homewood, Illinois: Richard D. Irwin, Inc., 1966) p. 180.

3 Ibid, p. 181.

4 For these purposes a lane is defined as an origin-destination pair of terminals between which inter-city freight service is performed.

5 "Leg" refers to the inter-city movement of freight between two equipment/manpower centers regardless of whether the freight actually originates or terminates at either of the centers.

6 Much of the remainder of this section is drawn from unpublished papers written by Steven C. Nieman, Director of Transportation Development, IU International, and from conversations between the author and Mr. Nieman.

7 Alexander Morton, "Truck-Rail Competition for Traffic in Manufacturers," **Transportation Research Forum Proceedings**, 1971, p. 151.

8 R. A. Nelson, "The Economic Structure of the Highway Carrier Industry in New England," in **Motor Freight Transport for New England**, (Boston: New England Governor's Conference on Public Transportation, 1957.)

9 Merrill J. Roberts, "Some Aspects of Motor Carrier Costs: Firm Size, Efficiency, and Financial Health," **Land Economics**, August 1956, pp. 228-38.

10 Walter Adams and James Hendry, **Trucking Mergers, Concentration and Small Business: An Analysis of Interstate Commerce Commission Policy 1950-1956**. (Washington, Select Committee on Small Business of the United States Senate, 1956.)

11 J. R. Meyer et al., **The Economics of Competition in the Transportation Industries**. (Cambridge: Harvard University Press, 1959.)

12 One significant implication is that no measure of output is a true measure of scale. Two carriers with exactly the same revenues, number of shipments, and tonnage nevertheless are of two entirely different scales of operation if one is operating 30 terminals in a ten state area and the other is operating 60 terminals in a 25 state area.

13 For an excellent discussion of the Chamberlin concept of excess capacity see John M. Cassels, "Excess Capacity and Monopolistic Competition," in Readings in Microeconomics, editors William Breit and Harold M. Hochman, (New York: Holt, Rinehart, and Winston, 1967) p. 256.

14 Gary N. Dicer, "Economies of Scale and Motor Carrier Optimum Size," Quarterly Review of Economics and Business, Spring 1971, pp. 31-37.

15 Darrell Wycoff, "Factors Promoting Concentration of Motor Carriers under Regulation," Transportation Research Forum, 1973, pp. 1-6.

16 Dicer, op. cit., p. 33.

17 Stanley L. Warner, "Cost Models, Measurement Errors, and Economies of Scale in Trucking," in The Cost of Trucking: Econometric Analysis. (Dubuque: Wm. C. Brown Co., 1965), pp. 1-46.

18 The differences between 1.0 and the output regression co-efficients reported by Warner are statistically significant. Warner is referring to the economic implications of the differences in his interpretation.

19 For a discussion of the economic requirements for, and justification of, price discrimination in the transportation industry, see Charles F. Phillips, The Economics of Regulation (Homewood, Illinois: Richard D. Irwin, Inc. 1965) pp. 307-312.

20 Improved efficiencies seem to occur in stair step fashion in the industry. However, the reader can confirm that the regression coefficient does not change if the curve in Exhibit 2 is converted to a smooth curve by eliminating the odd numbered firms (data points) in Exhibit 2. (assume the smallest firm is firm #1.)