**Title**
Deregulation and Scale Economies in the U.S. Trucking Industry: An Economic Extension of the Survivor Principle



**Author**
Keeler, Theodore E.

**Publication Date**
1989-01-20

Peer reviewed

UNIVERSITY OF CALIFORNIA, BERKELEY

Department of Economics

Berkeley, California 94720

Working Paper No. 89-100

# Deregulation and Scale Economies in the U.S. Trucking Industry: An Econometric Extension of the Survivor Principle

Theodore E. Keeler

January 20, 1989

Key words: Trucking, freight, transportation, regulatory policy.

Abstract

This paper develops a new method (based on probit analysis) for the estimation of scale economies using Stigler's survivor technique. The method has the advantage that it allows several variables (such as product quality attributes and factor prices) to be incorporated into the model. This new approach is applied to the U. S. trucking industry, with data for 1975, 1980, and 1984. The results for 1980-84 (more likely to be based on the natural structure of the trucking industry because of deregulation) indicate increasing returns to scale over the entire range of outputs in the trucking industry, although the strongest and most significant evidence is for the smaller half of the sample. The results for 1975-80 are more ambiguous, most likely because regulation constrained the growth of efficient firms during that period. The more recent results contrast with those of conventional truck cost studies, which mostly show constant or decreasing returns to scale. A likely reason for this difference is that larger truck firms offer superior service to that of smaller ones, even without size-related cost advantages.

JEL Classification: 615

ACKNOWLEDGEMENT

This work was funded by the Institute of Transportation Studies at the University of California, Berkeley. I am indebted to G. Stigler, H. E. Frech III, G. Rothwell, P. Ruud, an anonymous referee, and members of the Industrial Organization Workshop at the University of Chicago for valuable comments, and to J. Ying for comments and assistance.

This paper is forthcoming in Journal of Law and Economics.

Theodore E. Keeler
Department of Economics
University of California at Berkeley

# DEREGULATION AND SCALE ECONOMIES IN THE U. S. TRUCKING INDUSTRY: AN ECONOMETRIC EXTENSION OF THE SURVIVOR PRINCIPLE

Theodore E. Keeler

University of California, Berkeley

Revised November 18, 1988

## I. INTRODUCTION

Over the past three decades, there has been much progress in the analysis of costs, production, and scale economies in U. S. industries, including transportation. And yet it can also be argued that accounting data (on which all such cost and production function estimation is based) do not give us a full story regarding scale economies in an industry. Among those to make this argument most forcefully was George Stigler, in a seminal 1958 article: to provide evidence on scale economies with less of use of accounting data, Stigler developed what he called the survivor technique, and others have used it in subsequent studies, as well.[1] The present paper extends the survivor technique so as to make it a part of an econometric (probit) model, somewhat akin to cost and production functions as they are estimated statistically, but preserving the essential features of the survivor model developed by Stigler in the 1950's. The most important advantage of this approach (compared with previous survivor studies) is that it allows for the incorporation of a number of different variables to explain survivor patterns, rather than only size, as was the case in previous studies.

The trucking industry is an appropriate one for the application of this new model of survival behavior, for several reasons. First, differences in product quality among firms are difficult to control for completely, and they are likely to be related to a firm's scale of operation. Some firms offer very rapid delivery, with higher costs, while other firms offer much slower delivery at a substantial savings in costs, both to themselves and to shippers. Although econometric cost functions estimated for the trucking industry have become increasingly sophisticated in controlling for service attributes and different output types, none (to my knowledge) have tried to control for critically important variables such as speed of delivery, schedule reliability, or overall convenience of use by shippers.[2] Yet such attributes do vary widely across firms and, a priori, may be related to a firm's scale of operation.

There most certainly are a priori reasons to believe that exclusion of these service attribute variables might result in biased estimates of economies of large-scale operation in trucking. Specifically, it is possible that a large, integrated network of truck routes could offer better service to a larger number of places than a group of smaller firms operating on relatively few routes for any one firm. Additionally, a higher density of freight traffic along a given route will allow for more frequent service (because of more frequent departures) along that route, affording faster delivery times. There are probably also advantages in convenience for a shipper in dealing with one carrier for a shipment or group of shipments than with several carriers (this last category of savings includes at least some transactions costs,[3] as well as operating expenses). All these considerations would seem to suggest that economies associated with large, integrated firms in the trucking industry may be greater than econometric studies of costs and production would imply, and that the survivor technique could provide illuminating evidence in this area. On this count, it is worth noting that the scale economies analyzed here represent a broader concept than scale economies as traditionally defined in trucking; they could better be called economies of integration, and they relate to all ways in which a large trucking firm can be more efficient than a smaller one;[4] but this broader definition is also quite consistent with Stigler's use of the term "scale economies" in his original article.

Another consideration making the trucking industry especially appropriate for survival analysis is the deregulation of firm entry and rates in trucking, brought about by the Motor Carrier Act of 1980. Deregulation has forced trucking to change from an industry whose market structure (number of firms and in some cases market share) was strongly constrained by regulatory policies to an industry whose structure has been determined by natural forces of the market place, including scale economies.

By observing changes in market share for different size classes of firms between 1980 and 1984, it is possible to get some sense of the effects of economies of integration on these changes in market share. Moreover, by extending the analysis backwards into the period of regulation, it is possible, as well, to analyze the extent to which regulation affected firms' survival patterns. This should provide useful information as to what the effects of regulation were on patterns of firm growth. For this reason, we also provide a survival analysis for the 1975-80 period (although the results must be qualified here, because the de facto process of deregulation began before the Motor Carrier Act of 1980).

There is good reason to believe, then, that the survivor technique should be a useful one for analyzing scale economies during the period just before and after deregulation of the trucking industry. Furthermore, the new technique developed here allows us to control for effects other than firm size (such as wages and route structure) which might also have affected a firm's commercial fortunes during this period. This in turn allows us to separate economies of large-scale operation from other effects in a way that previous survivor studies have not done.

Despite the insights to be gained from this new procedure, the results of this analysis are not intended to supplant results of more conventional cost studies for trucking, which are more sophisticated than those in many other industries. Rather, the results of both types of studies should be viewed together to get a clearer picture of scale economies in trucking. Specifically, if the results of a survivor analysis are viewed in conjunction with the results of previous studies of cost functions in trucking, the comparison should give some indication as to the net effect of the service quality variables on scale economies. For example, if conventional cost studies indicated decreasing returns in trucking, whereas survivor analysis indicated increasing returns, that would suggest that scale economies in service quality exist and are strong enough to offset observed scale diseconomies in costs.

The next section of this paper reviews the survivor technique as developed by Stigler, discusses its relevance to the trucking industry, and presents tabular results on market shares of different firm size groups for the trucking industry for 1975, 1980 and 1984, much as Stigler did for some other industries in his seminal 1958 article. The third part presents a new statistical model, based on probit analysis, which allows us to incorporate and control for several different variables in our analysis. The final section summarizes the results of this statistical model and discusses the implications of these results for our knowledge of the trucking industry.

## II. THE SURVIVOR PRINCIPLE AND ITS APPLICATION TO TRUCKING

The basic idea behind the survivor principle is elegantly simple: those firm size groups which are the most efficient (including all relevant dimensions of efficiency, but corresponding in essence to the minimum point(s) in the long-run average cost curve) will gain in market share, while those firm size groups which do not represent the lowest-cost scale level will lose market share. It thus follows that by analyzing the pattern of market shares for different firm size classes in an industry over time, it should be possible to get a measure of the relative efficiency of each size class, and hence measure scale economies.

It is worth noting that the scale economies revealed by this method are in no way restricted to economies of lower costs. Because the method uncovers scale economies relating to all possible types of commercial success, it also includes economies related to higher- or lower-quality goods and services produced by larger firms.

This technique has been criticized by some economists, most especially because it measures the combined effects of a number of different forces (economies of selling and advertising, for example, and government regulatory policies, as well). Furthermore, Stigler has subsequently been his own critic, noting that unless the structure of an industry shifts substantially over time, it can be difficult to use the survivor technique to identify scale economies.[5]

The method developed in the next section offers the opportunity to overcome many of these criticisms, for several reasons.

First, truck deregulation has created a better-than-normal opportunity for application of the survival principle (in the light of the problems mentioned by Stigler), because there is evidence that regulation strongly distorted the size and configuration of truck firms.[6] As a result, it appears that a very large part of the changes now observed in the trucking industry are in fact due to a shift from the structure previously imposed by regulations to a structure enforced instead by market efficiency. Such an environment should be a very good one for the application of the survivor principle, and it specifically means that the industry should not be susceptible to the problems discussed by Stigler himself regarding the difficulty of identifying scale economies using the survivor technique (that is because the shift in structure of the industry resulting from deregulation is similar to the kind of controlled experiment needed to apply the survivor principle). Also, the survivor principle can provide a worthwhile method for analyzing the effects of regulation itself, by extending the analysis back into the pre-1980 period of regulation.

Second, the present method allows for the use of however many variables are needed (as limited by degrees of freedom) to control for forces other than the scale of a firm which affect change in market share for a size class, so the factors other than scale economies affecting the results can be reduced.

Finally, despite the various problems found with the survivor technique, even its critics agree that it can be useful as a check on other methods of measuring scale economies, affording useful information which other methods fail to consider.[7] Our goal, as pointed out above, is not to use the survivor technique alone, but rather in combination with evidence from previous statistical cost studies of trucking, so it is consistent with the use which Scherer and other critics of the survivor technique would suggest. With these considerations in mind, we turn to a traditional survivor analysis of the trucking industry for 1975-80 and 1980-84,[8] using essentially the same method used by Stigler.

This conventional survival analysis is a useful exercise before showing the results of the econometric technique because it will indicate what information can be gained by using the new econometric technique discussed in the next section, compared with the more traditional survivor analysis.

For both exercises, we must consider which firms to include in our calculations, and what geographic market should be selected for those firms. As regards the firms to be included, we have included all Class I and Class II carriers of general commodities reporting at least annual data to the Interstate Commerce Commission in both years.[9] This would seem to be a reasonable delineation of the market, because it includes all hauliers of general merchandise in the United States of any consequence, while excluding such specialized applications as tank trucks, dump trucks, or household movers. The only firms exluded from the sample were United Parcel Service and its subsidiaries, mainly because, once again, package delivery service was judged to be a specialized application.

Geographically, as in most similar studies, we have treated the full United States as a market. Although some of the carriers in the sample certainly do serve local markets, nevertheless, the mobility of resources in domestic trucking and the dramatic moves of carriers into and out of vast territories since deregulation would seem to make the assumption of a national market the most reasonable one.[10]

These selection procedures resulted in a sample of 1181 firms for 1975, 882 firms for 1980 and 779 firms for 1984.[11] Table 1 presents a tabulation of market share behavior (with market shares measured in operating revenues) for each of eight firm size classes (with the size classes also based on revenues; the divisions among size classes are very similar to divisions used by Stigler for other industries) in the three years. One might argue that physical output, such as ton-miles, is a better measure of both firm size and market share than revenues, as measured in Table 1. The statistical model developed in the next section indeed uses a physical output variable, but there are two reasons for using revenue in the present table. First, revenue data are available for more firms than physical output, and (unlike the case of the statistical model in the next section) no additional data are needed for this simple tabulation. Therefore, use of revenue gives a more complete picture of scale economies using Stigler's original model. Second, the use of revenue data is consistent with

Stigler's original method for most industries, so it generates results most nearly consistent with Stigler's original method.

At the top and bottom ends of the size scale, the results appear consistent over firms and years: The smallest firm size classes lost market share and the largest ones gained it. Thus, the firms with under .25 per cent of the market went from 37.4 per cent of the market in 1975 to 34.3 per cent in 1980 to 31.8 per cent in 1984. On the other hand, firms with over 5 per cent of the market rose from none in 1975 to 11.59 per cent in 1980 to 20.8 per cent in 1984--a dramatic increase.

Between these extremes, however, the pattern was not so clear. Unlike their slightly larger peers, firms with 2.5 to 5 per cent of the market consistently fell between 1975 and 1984, whereas firms with 1 to 2.5 per cent grew or at least held their own. Firms with .75 to 1 per cent consistently declined, but those with .5 to .75 per cent declined from 1975 to 1980 and grew thereafter.

What conclusions can we draw from this mixed picture? It appears that among the largest and smallest firms, there are increasing returns to scale, and the pattern is consistent over periods of regulation and deregulation alike (this pattern is especially clear and pronounced for the smaller firms--under 1 per cent or so of the market. It must also be remembered that although deregulation officially began with the Motor Carrier Act of 1980, the Interstate Commerce Commission was loosening its controls in the late 1970's, so a consistent pattern here is not too surprising. On the other hand, for intermediate-sized firms, there is not a pattern, either among size classes or during the regulated and deregulated periods.

The results based on the conventional survivor analysis of trucking, then, do not seem to indicate a clear pattern regarding returns to scale. Rather, they would indicate a cost curve consistent with multiple local maxima and minima. There are, however, two reasons to believe that this conventional survivor analysis does not present a fully accurate picture of scale economies in trucking.

First, with the advent of deregulation in 1980, some firms started with advantages relative to others which had little to do with scale. Some firms were unionized and paid high wages. Others used much lower-paid, non-unionized drivers. Yet others were unionized, but saved money by contracting out at least some of their service to owner-operators, whose implicit wages were well below union levels. Because pre-deregulation firms were protected by entry and rate regulation, many could survive even with high wages. After deregulation, however, that changed dramatically.[12] In our survivor analysis, it is therefore necessary to control for these relative advantages enjoyed by some firms at the advent of deregulation.

Second, in order to measure scale economies in trucking, it is necessary to control for output attributes in the initial period which could affect a firm's commercial success in following periods. Some firms may be big because they haul large flows of freight on a few routes, i.e., they have high traffic densities. Other firms may haul much freight on short hauls over many routes, while others may haul the same amount of freight on longer hauls with fewer routes. Similarly, some firms haul a wide range of different commodities, while other haul just a few commodity types. So it would seem appropriate (as has already been done in more traditional forms of cost estimation) to estimate scale economies with statistical controls for product attributes, such as length of haul, which are likely to affect costs and market position. For survival analysis, though, only those attributes likely to affect commercial success over the period analyzed need be controlled for.

The following section presents an extension of Stigler's survivor technique, a statistical method designed to control for the variables mentioned above while still measuring scale economies in a manner consistent with the spirit of Stigler's original investigation.

## III. A STATISTICAL MODEL OF SURVIVING FIRM BEHAVIOR IN TRUCKING

At its simplest, Stigler's survivor technique entails classifying firms by size group and analyzing whether there is any consistent relationship
between the probability that a given size class maintains or increases its market share and the size-class's overall ranking in size.

If we have observations on size classes, Stigler's hypothesis can be stated in mathematical terms as follows:

(1) $\text{Prob}\ [MS\ (1) > MS\ (0)] = F\ [\text{Size}(0)]$

where MS(1) is the market share in a later period MS(0) is the market share of that same size class in an earlier period, and Size(0) is the average size of firms in the given size class during the first period (if the relationship between size and growth in market share is to be a deterministic one, as implied by Stigler's original hypothesis, then it is the average size in the size class during the first period which should affect the probability of growth in market share). If F were an increasing function in size, then that would be a sign of increasing returns to scale. If F were a decreasing function, that would be a sign of decreasing returns to scale. Finally, if F were a constant function, that would be a sign of constant returns to scale.

At this point, it is worth considering an alternative formulation of the survivor principle which might also seem appropriate for statistical application. That is to make the dependent variable a continuous function rather than a discrete one: the rate of growth (positive or negative) for each size class might seem appropriate. Stigler, however, presents some strong arguments against this: he states that it would be a mistake "to infer that the size class whose share is growing more rapidly is more efficient than other classes whose shares are growing more slowly; the difference can represent differences in the quantities of various qualities of resources."[13] Similarly, Stigler argues that the rate of loss of output for a given firm size class is not simply the function of efficiencies or inefficiencies from scale economies.[14] Although, in a statistical context, there could be reason to specify a model which attempts to explain all growth of market share, Stigler's arguments give good reason to place strongest credibility on the discrete model specified above in (1). Nevertheless, for purposes of comparison, and for evaluation of robustness of our hypotheses, we shall also summarize and discuss statistical results based on actual changes in market shares, rather than simply the probability of a non-negative change.

If there are observations on enough size classes, it is possible to perform discrete-choice analysis to equation (1) to test hypotheses about economies of scale: The dependent variable would be a discrete variable valued at zero if the size class lost market share, and one if it held or gained market share, and the independent variable would be a measure of size (again, however, we shall also consider a measure of change in market share as the dependent variable, for purposes of comparison).

As regards the appropriate econometric estimation procedure, it is worth noting that probit analysis was originally devised to estimate biological models of survival over members of a population.[15] Because the model under consideration here represents the random survival behavior of a large population of firms, it would appear to be most suitable for the statistical problem at hand (for the estimation of an equation with a continuous dependent variable, ordinary least squares is used).

It should be evident that with the problem set up as in (1), there is no reason to limit the number of right-hand variables to one. A size-class mean value for any other variable which is thought to affect the fortunes of firms in a given size class can be included, as well, allowing us to control for those other variables in the process of measuring scale economies.

In the present case, we have discussed several other variables which we have argued should affect the fortunes of firms in each size class. Firms which subcontract to owner operators may have lower costs than firms which hire their own drivers,[16] and hence may have a higher probability of growing during the transition to deregulation.

Similarly, firms paying higher wages may have more difficulty competing, and firms with less traffic flowing along any of their routes may have more difficulty filling up trucks and offering frequent service, so they may not fare so well, either.

To control for these differences, a probit equation was estimated to analyze change in market share for samples of size classes (described below) between 1975 and 1980 and between 1980 and 1984, using a second-degree, general polynomial expansion on four right-hand variables: output, this time defined by the physical variable of revenue ton-miles (RTM), percent of vehicle-miles performed with company-owned vehicles (PCOWN), average compensation per employee (WAGE), and average length of haul (ALH).

Revenue ton-miles have been used as a physical output measure in most previous studies of truck costs and returns to scale, because, by consensus, it best measures the overall output of a truck firm.[17]

The average length of haul variable is included to measure differences in route structure. If a firm has a higher average length of haul, holding total ton-miles constant, then it will likely have a thinner route structure, with either relatively few routes or with traffic spread out over more routes. In either case, the company may have more difficulty providing frequent service with full trucks to all the points in its system; so a negative coefficient to ALH (holding all other variables constant) would suggest that there are indeed economies of integration for larger, denser route networks (this expected result for ALH is somewhat different from what one might expect it to do in a cost equation; this point is explained further below).

One could continue adding variables to this equation, as has appropriately been done in the estimation of more conventional truck cost functions. However, many of the additional variables used in other truck cost functions (such as number of shipments or average shipment size) are not available for anywhere near the full sample of firms used in this analysis (no more than half the firms in this sample reported them). Furthermore, it is important to remember that not everything which affects a firm's costs will affect its survival. For example, a firm which specialized in high-value commodities under regulation might (if the market warranted) move to lower-value commodities without necessarily losing market share--the fact that it carried high value commodities under regulation would certainly affect its costs under regulation, but it would be less likely to affect its success under deregulation if the firm were free to shift commodities carried with some ease. On the other hand, a route structure might be more difficult to change quickly, so it could affect the firm's viability.

Given these considerations of theoretical appropriateness and data availability, the variables mentioned above would seem suitable for the present analysis.

A generalized, second degree polynomial form was selected for this analysis so as to place as little restriction as possible on the form of the estimated equation (though the implications of a simpler, linear specification will be discussed, as well). Furthermore, all variables are estimated as deviations around their mean, so that the mean of each variable is zero. This is a useful characteristic, because it means that the first order coefficients in the probit equation represent the derivatives of the estimated function with respect to each of the variables when the variables are evaluated at their means.[18]

The equation estimated, then, takes the following form:

$$(2) \quad ^{-1}(\text{Prob}) = A + B\ ALH + C\ PCOWN + D\ WAGE + E\ RTM + F\ 1/2\ ALH^2 + G\ 1/2\ PCOWN^2 + H\ 1/2\ ALH^2 + I\ 1/2\ RTM^2 + J\ ALH\ PCOWN + K\ ALH\ WAGE + L\ ALH\ RTM + M\ PCOWN\ WAGE + N\ PCOWN\ RTM + O\ WAGE\ RTM$$

where Prob is the probability that market share did not decrease for a given size class, $^{-1}$ is the inverse of a standard cumulative normal distribution function, and the other variables are as defined above. The maximum likelihood estimator used in probit analysis selects the values of the estimated parameters that maximize the likelihood of observing the true outcomes of 0's and 1's found for the dependent variable.

The firm sample consists of all Class I and Class II motor carriers reporting the needed data. This comes to 824 firms in 1975, 627 firms in 1980 and 671 firms in 1984. (It will be noted here that because of incomplete data, the number of firms used in this analysis is smaller for each year than for the analysis shown in Table 1. But the bias from this fact is minimized by calculating all market shares for size classes, discussed in the data appendix, using the full sample of firm revenues as a base in each year.)

The issue as to how to stratify the firms into size classes is an important one, and it is discussed in the data appendix to this paper. Briefly stated, the firms were stratified into 287 non-overlapping size classes for 1975-80 and 251 similar size classes for 1980-84. The data sources for the sample and some of the other issues in processing the data are discussed in the data appendix, as well.

Equations corresponding to (2) were estimated using probit analysis, and the results are shown in Table 2 for 1975-80 and Table 3 for 1980-84. In each case, the equation was estimated for the entire sample, and for subsamples representing the halves of the firms that are smallest and the halves that are the largest, as well. Furthermore, Tables 4 and 5 show the least squares results for estimating equation (2) when the dependent variable is the growth in market share of the relevant size class, rather than the discrete survivor variable.

## IV. RESULTS

The results are revealing in several ways. We discuss first the primary hypothesis of this study, that there is a relationship between firm size (as measured by revenue ton-miles during the initial period) and commercial success (as measured by the probability that the market share of a given size class grew over each of the two periods).

For the 1975-80 period, the probit equation suggests some evidence of scale economies. In the equation for the entire data sample, the RTM variable is positive and marginally significant, and the RTM squared term is positive but not significant. For the smaller half of the size classes, the RTM variable is quite significant, but the squared term is again insignificant. For the larger half of the classes, the RTM variable is positive but insignificant, and the RTM squared variable is negative and insignificant. For this period, there is very weak evidence of scale economies for the smaller firms in the sample, and no evidence at all of scale economies for the larger firms.

For the 1980-84 period, the probit equation provides stronger evidence of scale economies, although the evidence is strongest for the smaller firms in the sample. For the smaller half of the size classes, the RTM and RTM squared variables are both positive and highly significant, and for both the larger half of the firms and for the sample as a whole the RTM and RTM squared variables are both positive and at least marginally significant. This implies that, with other variables held at their means, higher output had a positive effect on market share for all size classes throughout the sample,[19] but clearly the effect is most pronounced and clearly significant for the smaller half of the size classes in the sample.

The evidence here, then, suggests that there were increasing returns to scale in the range of the smaller half of the firms in the sample during both periods, but the evidence is stronger and sharper during the deregulated period of 1980-84. For the larger firms in the sample, there is no evidence of either scale economies or diseconomies before 1980, but mild evidence of scale economies after 1980.

The results of the probit equations consistently suggest the importance of controlling for variables other than size in estimating scale economies by this method. Specifically, the wage variable is negative at the sample mean for both periods. However, it is insignificant before 1980, but significant after 1980, confirming the industry wisdom that low-wage firms have increased their advantage since deregulation (this is reasonable, since route restrictions to some degree protected high-wage firms from competition before deregulation). Other variables had less effect, at least at the sample mean. For the typical firm, renting truck services from outside the firm had little if any significant effect on its probability of success either before or after 1980. A number of the higher-order and interaction terms are, however, significant, indicating that the polynomial specification is not an unreasonable one for purposes of the present estimation.

How would our results change if we believed that the appropriate dependent variable were growth (positive or negative) in market share, rather than probability of not losing market share? The results for this supplementary exercise are shown in Tables 4 and 5.

As these tables show, the results do not change for the important years of 1980-84 (the years during which we most expect survivor analysis to measure scale economies). Specifically, the RTM and $RTM^2$ variables are both positive, and although the coefficients are at best marginally significant for the first-order term in both cases, they are quite significant for the second-order terms, especially for the sample as a whole and for the larger firms. Thus, although the results place more emphasis on scale economies for large firms rather than for small ones, the results nevertheless are consistent with the result of scale economies throughout the sample (a lesser degree of significance in the case of this second set of equations could be consistent with Stigler's earlier hypothesis that the discrete model is a better measure of survivorship).

The continuous equations tell the same story for 1980-84 as the discrete ones in other dimensions besides firm size. For example, they indicate that at sample mean of variables, size classes of firms that paid higher wages tended to lose market share compared with those with lower wages.

The continuous results are much more ambiguous for 1975-80 than for 1980-84. For example, the $RTM^2$ terms are consistently negative, rather than positive.

There is one other alternative specification for these equations which is worth exploring briefly here, and that is the possibility of using simple, linear specifications in the four independent variables, rather than polynomial expansions. This exercise yielded qualitatively the same results as those described above, in that the coefficient of the size (RTM) variable was positive for each type of dependent variable (continuous or discrete) and size group (smaller or larger) described above. The only difference was that the standard errors of the estimates were always much larger. Significance tests indicated no variables with coefficients significant at the 5 per cent level, and only for one group of firms in one time period (smaller firms 1975-80) were any of the coefficients in any of the periods significant at the 15 per cent level. This suggests that for the samples analyzed here, the polynomial specifications were not only more general than the linear ones, but they also yielded more meaningful results.

For all the equations examined so far it is worth considering the differences between the 1975-80 results and those for 1980-84. As previously described, the 1980-84 results consistently suggest scale economies (to differing degrees of significance, depending on the firm sample and the method of estimation used, however). On the other hand, the 1975-80 results tell no such consistent story. This result is consistent with our earlier argument that the survivor principle can be used to measure scale economies only when firms are free to expand and contract in response to natural market forces. Before 1980, regulation by the ICC prevented firms from so adjusting, so it is not surprising that the survivor principle applied before 1980 provided so few consistent results.

## V. IMPLICATIONS AND CONCLUSIONS

To explore the implications of these results, we address the following additional issues in this section. First, how do the results of this study, especially post-1980 ones, relate to the results of other, more conventional studies of scale economies in trucking? Second, to the extent that there is any discrepancy between the findings of this study and the findings of previous ones, what are the likely reasons? And third, what further research is suggested by these findings?

In brief summary, the results of the present paper suggest that there are scale economies in trucking after 1980, most especially (but probably not exclusively) for the smaller half of the firms in the sample.

Most available evidence from conventional studies of scale economies in trucking is based on data from the pre-1980 period. The results of Friedlaender and Chiang, Chiang and Friedlaender, and Daughety, Nelson, and Vigdor all indicate that there are decreasing returns to scale almost over the entire range of output of trucking companies, especially the larger ones.[20] On the other hand, Friedlaender and Bruce, working with a sample of the largest truck firms between 1974 and 1979, find a complicated pattern of scale economies and diseconomies, a pattern which changed over the years that they studied.[21] However, their results indicate scale economies for the largest firms in the group as of 1979, but diseconomies for smaller firms in the sample (which are still among the larger firms in the industry). Keeler finds very mild evidence of diseconomies of scale for a sample of large truck firms.[22] There are very few studies of truck costs based completely on post-deregulation data; what evidence exists will be discussed below.

The evidence from cost studies before deregulation, then, is mixed, with some indication of scale economies and some of diseconomies. Even those studies which find scale economies in trucking, however, find them for only some of the largest firms in the industry, whereas the present study finds them over the entire range of outputs, but especially among smaller firms. Overall, then, the results of earlier studies for the United States would seem to contrast with the present results, which show at least some evidence of increasing returns to scale over the entire range of outputs in the trucking industry.[23]

What explains this apparent discrepancy between the present study, based on the survivor technique, and previous studies, based on cost accounts? There would appear to be two possible explanations: first, that there are scale economies in the trucking industry which are not measurable with conventional cost analysis, but which are measurable with the survivor technique; and second, that technology in the trucking industry has changed since deregulation, and that while there were no scale economies prior to 1980, they do exist now.

We consider first the possibility of scale economies unmeasured by more conventional studies. There is a strong possibility that such economies exist, and they are most likely due to interfirm differences in service quality. There are considerable benefits to shippers to being able to call a single truck line to get goods shipped to larger service territories, and, all other things equal, larger trucking companies appear to offer these benefits, especially in the area of less-than-truckload freight. Indeed, even before deregulation, certain LTL companies, such as Consolidated Freightways, Yellow Freight, and Roadway Express pursued a policy of expansion through buying up operating rights of existing companies, developing large, integrated route networks before deregulation occurred. These firms have continued to be quite profitable since deregulation, as well.

This conclusion must be viewed as speculative until further research is done on the topic, but it is consistent with what casual evidence was available at the time of this writing. It is also analogous to results found by other studies of the airline industry, that an integrated, single- carrier route network offers significant service-related benefits to travelers.[24]

The same line of reasoning also suggests why large, unionized firms which are not the very largest have had much difficulty under deregulation. They seem to have many of the high operating costs associated with large, unionized firms, without the nationwide service network to compensate. One example of such a large regional trucking company would be McLean, which went bankrupt in 1985. Other similar companies which failed or contracted sharply since 1980 would include Gateway and TIME-DC.

On the other hand, some intermediate-sized, regional truck firms have been quite successful under deregulation, including, for example, Overnite, Carolina, and Smith's. These firms all originated in the South, and have been characterized by relatively low costs and low wages. In these cases, low factor prices would appear to have offset disadvantages in size relative to the largest firms.

There is, however, also some reason for believing the second explanation of our results and their difference from the previous literature that must be considered. That is the possibility that truck technology shifted as a result of deregulation, and that although there were not conventional scale economies before 1980, there were after that time. Indeed, there is one study, by Ying, whose results suggest that, in fact, scale economies in the trucking industry themselves shifted subsequent to deregulation.[25] Ying finds that the industry went from one of essentially constant returns to scale before deregulation to at least mild scale economies thereafter. Why might this have occurred? It is possible that the flexibility allowed by deregulation, especially to vary routes and rates to fill empty returns, for example, has enabled firms to take advantage of larger-scale operations in a way that they were unable to do before. This more conventional explanation for scale economies of trucking would seem to be especially applicable to the smaller firms in the samples, and it is indeed for them that the present study has found the strongest evidence of advantage to larger firm size.

So there is some evidence supporting both explanations for our observations of scale economies in trucking after 1980, and it is possible that both forces were at work. Further research will be needed to clarify these issues.

It is now worth considering some policy implications of this work. The results of increasing returns to scale might be taken as evidence that deregulation of trucking was a mistake, and that reregulation is needed. Such a conclusion would be seriously wrong, for several reasons. First, given that trucking companies can change operating territory so easily, the market for most services could be considered to be a national one, and there is nothing in this paper to indicate that scale economies are so great as to allow only one firm nationwide (to the contrary, several large firms are growing). Second, and closely related, the low level of sunk costs in the trucking industry indicates that potential entry plays a strong role in keeping truck rates down, making markets for trucking somewhat akin to contestable markets (markets for truckload shipping, in which many firms could easily enter during a short period of time, are more likely to be contestable that less-than-truckload markets, however, where a system of warehouses and a large route structure are both likely to impose some sunk costs).[26]

Third, the importance of both of these considerations is empirically demonstrated by the long-run experience with truck deregulation, both with fresh produce in the U. S. and with many years' experience with deregulation abroad. Especially enlightening is the experience of Australia, which deregulated trucking for its relatively thin long-haul markets for all truck transportation in 1954. In that country, all long-haul trucking has been controlled by only four large firms for many years, yet there is strong evidence that such a level of competition was more than sufficient to drive truck rates down to long-run costs, with no excess profits at all.[27] So while the evidence shown in the present paper is enough to indicate that large firms may increase their market shares in the U. S. trucking industry, that does not in any way suggest that reregulation of the industry is appropriate: experience abroad, plus experience with agricultural goods in the U. S., plus preliminary evidence from truck deregulation in the U. S.[28] all provide good reasons to believe that there will be more than ample competition remaining to assure the fruits of workably competitive markets to U. S. consumers, especially if antitrust laws now in effect are enforced.

Certainly, more research needs to be done on the relationship between firm size, service quality, and scale economies in the trucking industry. Our results cannot determine for certain that it is superior service quality which allows the largest firms to grow despite higher accounting cost than smaller firms.

Nevertheless, the present results demonstrate strongly the continued power of the survivor principle for estimating the extent of scale economies in an industry, nearly thirty years after Stigler originally did so, and for uncovering evidence not available through more conventional studies of cost and production functions.

## DATA APPENDIX

The data used for this paper are all reported to the Interstate Commerce Commission by the individual firms. They were published in Trinc's Manual of the Trucking Industry, 1976 and 1981, for data for the years 1975 and 1980, respectively. For 1984, they were published by the Motor Carrier Annual Report, 1984. For the statistical sample discussed in Section III, all firms which reported the needed data were included in the analysis.

Because of the need to work with maximum degrees of freedom to estimate the probit equation, we have solved the problem of how to stratify the sample in a way quite different from that used by previous studies. For purposes of our estimation, it is important to do as little aggregation as possible--to throw away as little information as possible. Hence, it is preferable to stratify the sample into as many size classes as possible. On the other hand, making the size classes too small makes it likely that they will be empty in one year or another for a large number of observations, and that, in turn, leads to inefficient estimates of the desired parameters, as well.

The following method generates a large number of size classes and, at the same time, allows individual size classes large enough that very few of them are "empty boxes."[29] First, we organize all observations on all firms in descending order by market share (based on revenues), combining each two-year set (since these numbers are in terms of the physical variable revenue ton-miles, they can easily be combined to create size class numbers). Combining the observations for the two years generates a single series containing 1441 observations for 1975-80 and 1298 observations for 1980-84 (as explained below, however, the right-hand variables in estimated in the equations are based on first-year values only--1975 for 1975-80 and 1980 for 1980-84; combining the observations has been done only for purposes of stratification into size classes).

We then generate size classes by stratifying the firms into groups of five,[30] allowing the market share of the firm at the bottom of each size class to determine the boundary between size classes. Although this combined sample for both years is used to generate size classes, it must be emphasized that the independent (right-hand) variables for the equations estimated are based only on the first-year observations included in that size class (i.e., 1980 values for the 1980-84 calculations). This procedure, along with the necessary combining of several size classes in each sample,[31] generates a total of 287 size classes for 1975-80 and 251 size classes for 1980-84.

Since each size class contains five firms, then, the first size class would contain the top five firms; the second size class would contain the sixth firm through the tenth firm, and so on. As an explanatory example, the lineup of firms in the first size class might then be Consolidated Freightways, 1984; Yellow Freight, 1984; Consolidated Freightways, 1980; Roadway Express, 1984; Yellow Freight, 1980. The right-hand variables would be calculated based on the mean values for the 1980 firms in the class, including, in this case, Consolidated Freightways, 1980, and Yellow Freight, 1980. Change in market share for the two years is based on comparing the sums for firms in the class for the beginning and end years. Obviously, for the estimation to work, it is important that each size class have at least one observation for the first year in the sample (if this were not so, the size class would have no values for the independent variables). In each case (both 1975-80 and 1980-84), there were several size classes of five in which this did not happen. In those cases, the classes were aggregated to classes of ten, instead.

No firms were excluded from the sample because they went out of business before the end of the period, or because they did not come into business until the end year--

excluding either type of firm would obviously bias the calculations.

The reason for using beginning-year variables on the righthand side is straightforward: if there is causality, it must be from the initial year. In other words, it is reasonable to hypothesize that it is a low wage, large size, etc., in the beginning year which gives the firms in a given size class an advantage or disadvantage (this, too, is consistent with Stigler's earlier methods).

In order to calculate both continuous and discrete dependent variables, it was necessary to calculate market share in each year for each size class. For these purposes, for the 1975-80 analysis, the market share in 1975 is the sum of revenue ton-miles for all 1975 observations in a given size class divided by total ton-miles for all carriers in 1975, and the 1980 market share is the sum of all RTM's for all 1980 observations in the size class, again divided by total RTM's for all firms in 1980.

For purposes of calculating market share, it would be desirable to get a more complete denominator than RTM's for firms reporting RTM's. It would be better to use as a denominator an estimate of all RTM's for all Class I and II carriers, increasing the accuracy of the estimated change in market share.

Total RTM's for all Class I and II carriers were calculated for each year using the following technique. For all carriers reporting RTM's, an average ratio of revenue per ton-mile was calculated. Then, for remaining firms (not reporting RTM's), RTM's were calculated assuming the same revenue per ton-mile as for the firms reporting RTM's. Estimated RTM's for non-reporting firms were then added to reported RTM's for remaining firms.

FOOTNOTES

1. See George J. Stigler, The Economies of Scale, 1 Journal of Law and Economics 54-71 (1958). It has subsequently been applied to U. S. manufacturing industries by Thomas R. Saving, Estimation of Optimum Size of Plant by the Survivor Technique, 75 Quarterly Journal of Economics 569-607 (1961); Leonard W. Weiss, The Survival Technique and the Extent of Suboptimal Capacity, 72 Journal of Political Economy 246-61 (1964); and, more recently, to the physicians' service industry by H. E. Frech and P. Ginsberg, Optimal Scale in Medical Practice: A Survivor Analysis, 47 Journal of Business 23-36 (1974).

2. See, for example, Ann F. Friedlaender and Richard C. Spady, Freight Transport Regulation (1981); Ann F. Friedlaender and S. Judy Wang Chiang, Productivity Growth in the Regulated Trucking Industry, in T. Keeler, ed., Research in Transportation Economics, Vol. I, 149-184 (1983); S. Judy Wang Chiang and Ann F. Friedlaender, Truck Technology and Efficient Market Structure, 67 Review of Economics and Statistics 250-258 (1985); Ann F. Friedlaender and Sharon S. Bruce, Augmentation Effects and Technological Change in the Regulated Trucking Industry, in A. F. Daughety, ed., Analytical Studies in Transport Economics 29-64 (1985); Andrew F. Daughety, Forrest D. Nelson, and William R. Vigdor, An Econometric Analysis of the Cost and Production Structure of the Trucking Industry, in Daugety, supra, 65-96; and T. E. Keeler, Public Policy and Productivity in the Trucking Industry, 76 American Economic Review 153-58 (1986).

3. For a survey of the literature on the relationship between transactions costs and economies of integration in firms, see Oliver E. Williamson, The Modern Corporation: Origins, Evolution, Attributes, 19 Journal of Economic Literature 1536-1568 (1981).

4. For a large trucking firm with multiple routes, economies of integration include more than scale economies in the strictest sense. Economies of large route networks can be thought of as economies of density combined with economies of vertical integration; that is, economies of density stem from combining more traffic on one route. Economies of vertical integration here stem from the fact that if traffic moves from city A to city B to city C, it may be more economical for freight to stay with the same trucking firm from A to C, rather than changing firms with trucks connecting at point B in between. These economies of route network operation can also be thought of as economies of scope (as defined by Baumol, Panzar, and Willig, Contestable Markets and the Theory of Industry Structure, 1981) because they may allow one firm serving several cities through a hub to operate more economically than firms without such hubbed networks.

5. George J. Stigler, The Organization of Industry, 89-94 (1968), especially p. 89.

6. For a survey of the literature on the effects of truck regulation, see Thomas G. Moore, Rail and Truck Deregulation, in L. Weiss and M. Klass, eds., The Revolution in Regulation: What Actually Happened, 14-39 (1985).

7. For a survey of these considerations leading to that conclusion, see F. M. Scherer, Industrial Market Structure and Economic Performance, 93 (1980).

8. One might reasonably ask whether the analysis should be extended back before 1975. While this might be a worthwhile exercise, it also has some problems. First, for comparison with the deregulated period, truck technology and especially the highway system supporting it were somewhat different before 1975 (see Keeler, supra, note 2), and comparability of the pre-deregulation period in the distant past to the post-deregulation period is questionable. Second, as will be evident from the analysis below, the data processing requirements for handling a large number of years would be considerable.

9. It would be most desirable to include the very smallest truck firms, Class III, in the analysis, as well. This is especially relevant given that many of the most recent new entrants may be quite small. Unfortunately, the data just do not exist as needed for Class III carriers, because they are not required to report it to the ICC.

10. Many trucking companies have grown rapidly into new territories since deregulation. Also, relatively low sunk costs in the trucking industry might make that industry somewhat akin to a theoretically "contestable" industry, in which a potential entrant can drive prices to competitive levels without actually entering. See E. E. Bailey and W. J. Baumol, Deregulation and the Theory of Contestable Markets, 1 Yale Journal on Regulation 111-137 (1984).

11. This pattern of a declining number of firms within the industry would seem to contradict the commonly-held view that many new firms have entered trucking since deregulation. The numbers presented here do not contradict this viewpoint: sorting the data by firm suggests that under 400 firms (under half the firms in existence in 1980) existed under the same name in 1984. This suggests that indeed there was a high level of turnover in the industry.

12. Nancy L. Rose, The Incidence of Regulatory Rents in the Motor Carrier Industry, 16 Rand Journal of Economics 299-318 (1985) presents some interesting evidence on the effects of deregulation on the profits of different truck firms. Moore, supra, note 3, provides a survey of earlier evidence on the effects of regulation.

13. Stigler, "The Economies of Scale," supra, pp. 58-59.

14. Ibid., pp. 59-60.

15. See H. Theil, Principles of Econometrics, 630 (1971).

16. See N. Rose supra, note 8.

with prosperity, or because its initial size is too small a scale, so it must grow to survive?). It is nevertheless interesting that his conclusions are in some ways similar to those in the present paper.

24. See D. Carlton, W. Landes and R. Posner, Benefits and Costs of Airline Mergers: A Case Study, 11 Bell Journal of Economics 65-83 (1980); T. Keeler and M. Abrahams, Market Structure, Pricing, and Service Quality in the Airline Industry under Deregulation, in W. Sichel and T. Gies, Application of Economic Principles in Public Utility Industries (1981); and E. E. Bailey and J. Williams, Sources of Economic Rent in the Deregulated Airline Industry, unpublished, 1986.

25. J. S. Ying, "Implications of Regulatory Reform for Productivity and Technical Change in the Trucking Industry: An Econometric Cost Analysis of the Effects of the Motor Carrier Act of 1980," Ph. D. dissertation, Department of Economics, University of California, Berkeley, 1987.

26. See footnote 5.

27. See Stewart Joy, Unregulated Road Haulage in Australia, 16 Oxford Economic Papers 274-85 (July, 1984), and T. Keeler, Regulation and Modal Market Shares in Long-Haul Freight Transport: A Statistical Comparison between Australia and the United States, in J. R. Nelson and H. O. Whitten, eds, Foreign Regulatory Experiments: Implications for the U. S., Chapter IX (1977).

28. See Ying, supra.

29. The decision as to how to stratify the sample and how large to make the size classes is nevertheless an arbitrary one. Another possible method would be to stratify the sample based on the sizes of firms in the initial-year sample only--say, the top four firms in 1980, the next four, and so on. Although this approach generated fewer degrees of freedom (and

using this procedure groups of four firms seemed the best to avoid large numbers of empty cells in both the beginning and end years), nevertheless, it generated results almost identical to those shown for the full sample in Tables 2 and 3--significant scale economies in 1980-84, but at best weak evidence of scale economies for 1975-80 (the only difference here from the results shown in Table 3 is that the T-statistic for the RTM term was less significant, although still above one).

30. As stated above, the appropriate size of a size class is arbitrary. Nevertheless, some experimentation indicated that the results were quite robust to variation between size classes smaller and larger than five firms (say, three, four, six, seven, or more firms). As previously mentioned, the number five seemed most reasonable here as a compromise between the need for many observations (which comes from having more size classes) and the inefficiency of many empty boxes (which comes from stratifying into many size classes, more of which are empty the larger the number of classes).

31. In order for a size class to be useful as an observation, however, it is necessary that it have some observations for the initial year (i.e., some observations for 1980 in the 1980-84 sample). In cases in which a set of five observations was empty of 1980 data points, the two groups of five each were combined into a single group of ten. There were very few cases (fewer than three for each of the time periods) for which this happened. Also, in both data sets, the total number of observations did not yield an integer value when divided by 5. There was a remainder of the 2 smallest firms in 1975-80, and a remainder of the 3 smallest in 1980-84. The group of 2 was combined with the preceding group for a group of 7 in the 1975-80 case, and the group of 3 was treated as a separate group in 1980-84.

Table 1. Evidence on firms and revenues by size class of firm for the years 1975, 1980, and 1984

| Firm Class-- % of Industry Revenues | 1975 No. of Firms | 1975 Revenues (% of Tl.) | 1980 No. of Firms | 1980 Revenues (% of Tl.) | 1984 No. of Firms | 1984 Revenues (% of Tl.) |
|---|---|---|---|---|---|---|
| Over 5% | 0 | 0.00 | 2 | 11.59 | 3 | 20.80 |
| 2.5 to 5% | 4 | 14.35 | 3 | 10.50 | 2 | 7.12 |
| 1 to 2.5% | 7 | 10.15 | 12 | 17.50 | 11 | 17.09 |
| .75 to 1% | 12 | 10.54 | 11 | 9.55 | 6 | 5.36 |
| .5 to .75% | 18 | 11.21 | 9 | 5.04 | 11 | 6.18 |
| .25 to .5% | 41 | 15.38 | 31 | 11.51 | 31 | 11.58 |
| .1 to .25% | 110 | 16.75 | 93 | 15.40 | 87 | 13.99 |
| Under .1% | 989 | 21.62 | 721 | 18.91 | 628 | 17.88 |
| All firms | 1181 | 100.00 | 882 | 100.00 | 779 | 100.00 |

Source: For 1975 and 1980, Trinc's Transportation Consultants, Trinc's Blue Book--Yearbook of Motor Carriers, 1981 Edition. For 1984, American Trucking Associations, Inc., 1984 Motor Carrier Annual Report. Data here are calculated from the respective listed sources.

Table 2. Probit Results, 1975-80--Dependent variable is probability that market share did not fall for each size class

| Variable | Full Sample | Smaller 1/2 | Larger 1/2 |
|---|---|---|---|
| Constant | -0.5316394 | -0.4757427 | 3.8098886 |
| | (0.120491 ) | (0.178655 ) | (87.862108 ) |
| ALH (thousands of miles) | 0.0663900 | -2.8824000 | 109.0328000 |
| | (1.004400 ) | (2.080100 ) | (129.185300 ) |
| PCOWN | 0.0052789 | 0.0159841 | -0.3763073 |
| | (0.004276 ) | (0.007255 ) | (0.323563 ) |
| RTM (millions) | 0.0016320 | 0.0028510 | -0.3045000 |
| | (0.000980 ) | (0.001290 ) | (1.625900 ) |
| WAGE | -0.0117162 | -0.0120102 | 2.6599258 |
| | (0.054272 ) | (0.080529 ) | (2.918117 ) |
| 1/2 $ALH^2$ (millions of miles) | 6.0260000 | 10.4600000 | 16.1400000 |
| | (3.640000 ) | (6.891000 ) | (59.260000 ) |
| 1/2 $PCOWN^2$ | 0.0004809 | 0.0005774 | 0.0003807 |
| | (0.000136 ) | (0.001928 ) | (0.000360 ) |
| 1/2 $RTM^2$ (billions) | 0.0007149 | 0.0009020 | -3.1820000 |
| | (0.000767 ) | (0.001332 ) | (7.567000 ) |
| 1/2 $WAGE^2$ | -0.011393 | 0.0010024 | 0.0679541 |
| | (0.005910 ) | (0.008650 ) | (0.021808 ) |
| ALH*PCOWN | 0.0512200 | -0.0430200 | 0.4691000 |
| | (0.034290 ) | (0.057650 ) | (0.208700 ) |
| ALH*RTM | -0.0073320 | -0.0097940 | 1.0740000 |
| | (0.003848 ) | (0.006584 ) | (1.227000 ) |
| ALH*WAGE | -0.0006815 | -0.0000740 | -0.0016561 |
| | (0.000417 ) | (0.000876 ) | (0.001555 ) |
| PCOWN*RTM | 0.0329200 | 0.0757000 | -3.7790000 |
| | (0.033820 ) | (0.042990 ) | (2.981000 ) |
| PCOWN*WAGE | -0.0033187 | -0.0071604 | -0.0048647 |
| | (0.001510 ) | (0.002768 ) | (0.003167 ) |
| WAGE*RTM | 0.0003147 | 0.0000566 | 0.0239100 |
| | (0.000624 ) | (0.000868 ) | (0.026590 ) |
| Log Likelihood ratio | -167.6114600 | -81.0921000 | -57.2945930 |
| Observations | 287 | 144 | 143 |

Table 3. Probit Results, 1980-84--Dependent variable is probability that market share did not fall for each size class

| Variable | Full Sample | Smaller 1/2 | Larger 1/2 |
|---|---|---|---|
| Constant | -0.5316394 | -0.4757427 | 3.8098886 |
| | (0.120491 ) | (0.178655 ) | (87.862108 ) |
| ALH (thousands of miles) | -1.0323000 | -87.7224000 | -4.4979000 |
| | (0.912300 ) | (78.896700 ) | (1.515200 ) |
| PCOWN | 0.0052789 | 0.0159841 | -0.3763073 |
| | (0.004276 ) | (0.007255 ) | (0.323563 ) |
| RTM (millions) | 0.0014930 | 3.4921000 | 0.0013910 |
| | (0.001171 ) | (1.461500 ) | (0.001325 ) |
| WAGE | -0.0117162 | -0.0120102 | 2.6599258 |
| | (0.054272 ) | (0.080529 ) | (2.918117 ) |
| 1/2 $ALH^2$ (millions of miles) | 5.2360000 | 20.9500000 | 10.5400000 |
| | (2.525000 ) | (23.380000 ) | (3.322000 ) |
| 1/2 $PCOWN^2$ | 0.0004809 | 0.0005774 | 0.0003807 |
| | (0.000136 ) | (0.001928 ) | (0.000360 ) |
| 1/2 $RTM^2$ (billions) | 0.0005707 | 12.5200000 | 0.0005642 |
| | (0.000311 ) | (5.364000 ) | (0.000324 ) |
| 1/2 $WAGE^2$ | -0.011393 | 0.0010024 | 0.0679541 |
| | (0.005910 ) | (0.008650 ) | (0.021808 ) |
| ALH*PCOWN | 0.0598400 | 0.1278000 | 0.0411600 |
| | (0.030140 ) | (0.106500 ) | (0.038470 ) |
| ALH*RTM | -0.0059160 | -0.6380000 | -0.0060220 |
| | (0.002798 ) | (0.584900 ) | (0.003015 ) |
| ALH*WAGE | -0.0006815 | -0.0000740 | -0.0016561 |
| | (0.000417 ) | (0.000876 ) | (0.001555 ) |
| PCOWN*RTM | -0.0155300 | 0.2054000 | -0.0158900 |
| | (0.030880 ) | (1.338000 ) | (0.064550 ) |
| PCOWN*WAGE | -0.0033187 | -0.0071604 | -0.0048647 |
| | (0.001510 ) | (0.002768 ) | (0.003167 ) |
| WAGE*RTM | -0.0000833 | 0.0118600 | -0.0000530 |
| | (0.000102 ) | (0.006171 ) | (0.000114 ) |
| Log Likelihood ratio | -148.0397000 | -69.6810640 | -0.6600245 |
| Observations | 251 | 126 | 125 |

Table 4. Least Squares Results, 1975-80. Dependent variable is per cent change in market share for or each size class

| Variable | Full Sample | Smaller 1/2 | Larger 1/2 |
|---|---|---|---|
| Constant | -0.5316394 | -0.4757427 | 3.8098886 |
| | (0.120491 ) | (0.178655 ) | (87.862108 ) |
| ALH (thousands of miles) | 33.7629000 | 4.5797000 | 2113.6619000 |
| | (65.715300 ) | (111.134700 ) | (2771.633400 ) |
| PCOWN | 0.0052789 | 0.0159841 | -0.3763073 |
| | (0.004276 ) | (0.007255 ) | (0.323563 ) |
| RTM (millions) | 0.1045000 | 0.1238000 | 0.3067000 |
| | (0.058460 ) | (0.062910 ) | (32.609300 ) |
| WAGE | -0.0117162 | -0.0120102 | 2.6599258 |
| | (0.054272 ) | (0.080529 ) | (2.918117 ) |
| 1/2 $ALH^2$ (millions of miles) | 168.1000000 | 67.9700000 | 3237.0000000 |
| | (147.000000 ) | (177.600000 ) | (1051.400000 ) |
| 1/2 $PCOWN^2$ | 0.0004809 | 0.0005774 | 0.0003807 |
| | (0.000136 ) | (0.001928 ) | (0.000360 ) |
| 1/2 $RTM^2$ (billions) | -0.0367600 | -0.0987100 | -61.6300000 |
| | (0.032140 ) | (0.034000 ) | (157.000000 ) |
| 1/2 $WAGE^2$ | -0.0113931 | 0.0010024 | 0.0679541 |
| | (0.005910 ) | (0.008650 ) | (0.021808 ) |
| ALH*PCOWN | 0.9259000 | -5.0801000 | 10.3732000 |
| | (1.993200 ) | (2.440600 ) | (5.596900 ) |
| ALH*RTM | -0.3527000 | -0.1951000 | 22.6300000 |
| | (0.137600 ) | (0.145000 ) | (25.660000 ) |
| ALH*WAGE | -0.0006815 | -0.0000740 | -0.0016561 |
| | (0.000417 ) | (0.000876 ) | (0.001555 ) |
| PCOWN*RTM | 3.7420000 | 6.0990000 | 75.2400000 |
| | (2.139000 ) | (2.217000 ) | (58.760000 ) |
| PCOWN*WAGE | -0.0033187 | -0.0071604 | -0.0048647 |
| | (0.001510 ) | (0.002768 ) | (0.003167 ) |
| WAGE*RTM | 0.0785300 | 0.1180000 | 0.4367000 |
| | (0.037260 ) | (0.038640 ) | (0.756500 ) |
| R Squared | 0.2866160 | 0.4391580 | 0.4710580 |
| Observations | 287 | 144 | 143 |

Table 5. Least Squares Results, 1980-84. Dependent variable is per cent change in market share for each size class.

| Variable | Full Sample | Smaller 1/2 | Larger 1/2 |
|---|---|---|---|
| Constant | 10.5188010 | 10498.5110000 | 24.0250300 |
| | (13.417457 ) | (7861.730000 ) | (18.758636 ) |
| ALH (thousands of miles) | 50.3070000 | -7929.0672000 | -98.1527000 |
| | (84.108800 ) | (5554.360100 ) | (135.392900 ) |
| PCOWN | 1.7332241 | 13.4661700 | 1.1924400 |
| | (0.429121 ) | (12.903382 ) | (0.716027 ) |
| RTM (millions) | 0.1026000 | 154.7523000 | 0.1113000 |
| | (0.104200 ) | (114.928800 ) | (0.128800 ) |
| WAGE | -1.1108580 | -131.3576100 | 0.1984952 |
| | (1.663305 ) | (58.054677 ) | (3.002320 ) |
| 1/2 $ALH^2$ (millions of miles) | 364.6000000 | 3443.4000000 | 501.7000000 |
| | (201.600000 ) | (1649.300000 ) | (271.200000 ) |
| 1/2 $PCOWN^2$ | 0.0641199 | 0.0804112 | 0.0484948 |
| | (0.010171 ) | (0.014044 ) | (0.017350 ) |
| 1/2 $RTM^2$ (billions) | 0.0000718 | 0.5692000 | 0.0000632 |
| | (0.000025 ) | (0.420200 ) | (0.000029 ) |
| 1/2 $WAGE^2$ | 0.4076899 | 0.4443702 | 0.3811026 |
| | (0.123941 ) | (0.195346 ) | (0.191751 ) |
| ALH*PCOWN | 7.8471000 | 10.7314000 | 7.1090000 |
| | (2.241100 ) | (5.816800 ) | (3.087000 ) |
| ALH*RTM | -0.6250000 | -61.6000000 | -0.5995000 |
| | (0.251400 ) | (41.160000 ) | (0.296400 ) |
| ALH*WAGE | 12.7997000 | 49.8033000 | 7.2551000 |
| | (7.645000 ) | (27.482400 ) | (10.930700 ) |
| PCOWN*RTM | -0.0026160 | 0.0743400 | -0.0019290 |
| | (0.002512 ) | (0.093130 ) | (0.003070 ) |
| PCOWN*WAGE | 0.1553047 | 0.0613236 | 0.2276440 |
| | (0.050026 ) | (0.083537 ) | (0.077370 ) |
| WAGE*RTM | -0.0066960 | -0.9597000 | -0.0043340 |
| | (0.009008 ) | (0.420800 ) | (0.011130 ) |
| R Squared | 0.2408020 | 0.3200800 | 0.2577160 |
| Observations | 251 | 126 | 125 |

Jan-89

RECENT ISSUES OF THE WORKING PAPER SERIES
OF THE DEPARTMENT OF ECONOMICS
UNIVERSITY OF CALIFORNIA, BERKELEY

Copies may be obtained from the Institute of Business and Economic Research. See the inside cover for further details.

8887 Bronwyn H. Hall
ESTIMATION OF THE PROBABILITY OF ACQUISITION IN AN EQUILIBRIUM SETTING
Aug-88.

8888 Richard J. Gilbert and David M. Newbery
Entry, Acquisition, And the Value of Shark Repellent

Aug-88.

8889 Richard J. Gilbert
THE ROLE OF POTENTIAL COMPETITION IN INDUSTRIAL ORGANIZATION

Sep-88.

8890 Joseph Farrell and Robert Gibbons
CHEAP TALK WITH TWO AUDIENCES: A TAXONOMY

Sep-88.

8891 Alessandra Casella and Jonathan Feinstein
MANAGEMENT OF A COMMON CURRENCY

Sep-88.

8892 Steven M. Goldman and Vai-Lam Mui
ECONOMIC GROWTH AND GENERALIZED DEPRECIATION

Sep-88.

8893 Roger Craine and Douglas Steigerwald
RAIDERS, JUNK BONDS, AND RISK

Oct-88.

# RECENT ISSUES OF THE WORKING PAPER SERIES
# OF THE DEPARTMENT OF ECONOMICS
# UNIVERSITY OF CALIFORNIA, BERKELEY

Copies may be obtained from the Institute of Business and Economic Research. See the inside cover for further details.

8894 Barry Eichengreen
THE RESPONSIBILITIES OF A CREDITOR NATION

Oct-88.

8895 Richard J. Gilbert
MOBILITY BARRIERS AND THE VALUE OF INCUMBENCY

Oct-88.

8896 Pranab Bardhan
SOME REFLECTIONS ON THE USE OF THE CONCEPT OF POWER IN ECONOMICS

Nov-88.

8897 Barry Eichengreen and Lawrence H. Goulder
THE U.S. BASIC INDUSTRIES IN THE 1980S: CAN FISCAL POLICIES EXPLAIN THEIR CHANGING COMPETITIVE POSITION?
Nov-88.

8898 Roger L. Ransom and Richard Sutch
THE TREND IN THE RATE OF LABOR FORCE PARTICIPATION OF OLDER MEN, 1870-1930: A REVIEW OF THE EVIDENCE
Nov-88.

8899 Paul A. Ruud
Extensions of Estimation Methods Using the EM Algorithm

Dec-88.

89100 Theodore E. Keeler
Deregulation and Scale Economies in the U.S. Trucking Industry: An Econometric Extension of the Survivor Principle
Jan-89.

89101 John S. Ying and Theodore E. Keeler
Pricing in a Deregulated Environment: The Motor Carrier Experience

Jan-89.