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An Analysis of Motor Carrier Marketing Strategies, Information Technologies, and Productivity

# An Analysis of Motor Carrier Marketing Strategies, Information Technologies, and Productivity

by

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16. ABSTRACT

A Malmquist Index will be used to measure productivity and efficiency for U.S. general freight motor carriers in the 1990's. The investigator will examine the relationship between these efficiency measures and the marketing strategies chosen by individual carriers. A newly available dara set that includes both information on marketing strategy and the information technologies that each carrier has adopted will be used. The analysis will also determine which of the newly adopted information technologies used by trucking firms have led to the largest increases in productivity.

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## DISCLAIMER

**ABSTRACT**

This study uses a unique data set collected in a study commissioned by the American Trucking Association, to examine the relationship between productivity and the adoption of various information technologies by motor carrier firms. The focus of this study is on information technologies that are used by trucking firms themselves, not necessarily technologies that provide an interface between transportation agencies and trucking firms. Thus, the focus on information technology refers to the impact on trucking firm operations, rather than the usefulness of these technologies to governmental agencies

The measure of productivity used here is the non-parametric Malmquist Index. A tobit regression model is used to determine the extent to which various information technologies have a significant impact on firm productivity. Results suggest that backroom technologies, EDI in particular, are the types of information technology that are most consistently correlated with improvements in firm productivity.

## I. Introduction

It is generally acknowledged that in a competitive industry inefficient firms will not survive in the long run. Thus, it becomes important for firms both to use existing resources efficiently and also adopt new technologies which will increase efficiency and firm productivity. Indeed, one of the industry goals named by the American Trucking Association (ATA) in 1999 was to increase trucking productivity.

The U.S. trucking industry has been facing competitive market conditions since the Motor Carrier Act of 1980 (MCA) eliminated most economic regulations and left the industry to the vagaries of the marketplace. McMullen and Okuyama (2000) find that immediately following deregulation, economic efficiency of trucking firms improved as firms were able to rationalize their network structures without the restrictions placed by regulators. McMullen and Lee (1999), using a stochastic cost frontier, found that long run industry survivors in the deregulated marketplace were the ones which were the most efficient.

Given the importance of efficiency and productivity gains in assuring long run survival, trucking firms should be anxious to adopt new technologies which are productivity enhancing

This study uses a unique data set collected in a survey commissioned by the American Trucking Association to collect data on the adoption of various information technologies by motor carrier firms. The survey collected information on both on-board and backroom technologies. On board technologies include on-board computers (OBC), satellite communications systems (SATCOM)), and Automatic Vehicle Locations systems (AVL). Backroom technologies include electronic data exchange (EDI), computer aided routing (CAR), and computer aided dispatching (CAD). The purpose of this study is to determine whether adoption of these various technologies by trucking firms increase productivity.

In addition to information technologies, McMullen and Okuyama (2000) and others have suggested that measured productivity may be influenced with the quality or type of service a carrier offers. For instance, if a firm strives to provide high quality, frequent service, it may have to run trucks partially full and this would result in lower measures of efficiency defined as output (tonmiles) per unit of input. Thus, this study will include a marketing strategy measure which was also collected in the ATA survey. In particular, we will look at whether there is an impact on productivity depending on whether a firm adopts a low freight rate (LFR) marketing strategy or prefers to concentrate on some aspect of service quality. The measure of productivity used here is the non-parametric Malmquist Index as explained by Grosskopf (1993) and used in many studies of productivity and efficiency. The Malmquist Index can be decomposed into two components: economic efficiency change (the part of productivity gain which results from a firm using it's given inputs to get more output) and technical efficiency change (increases in productivity due to technological change.)

Once the Malmquist Productivity Index and its component indices of economic efficiency and technological efficiency are calculated, a tobit regression model is then run to determine the extent to which the various information technologies enumerated above affect productivity gains. Results suggest that backroom technologies, EDI in particular, are associated with economic efficiency gains. While the other on board technologies do not seem to affect productivity measures, it is possible that they may influence the way in which firms organize their production.

The following section provides a brief introduction to the information technologies considered in this study.

## II. Information Technologies

Information technologies are expected to impact motor carrier operations through a number of channels**.** First, they can help carriers increase vehicle and utilization through increased monitoring and reducing unnecessary out-of route miles by drivers. Second, fuel costs may be reduced as technologies are used to improve routing. Finally, administrative costs are expected to fall as new technologies are adopted which involve paperless transactions.

The advanced information technologies considered here fall into two groups: on-board technologies and backroom technologies. The on-board technologies included in this study are on-board computers, satellite communications systems, and automatic vehicle locations systems.

On-board computers (OBC) basically process data that they receive from sensors and other devices used on trucks**.** They keep records of readings and provide the fleet operator with performance information necessary to monitor drivers. Hubbard (2001) argues that on-board computers give fleet managers a way to measure driver performance**,** thus reducing the cost of monitoring drivers. Trucking firms usually have a choice between hiring drivers to drive their trucks or hiring owner-operators. Since owner-operators own and operate their own trucks and usually pay for fuel, they have a vested interest in maintaining their truck and providing good fuel mileage. Without an effective monitoring system for company drivers who do not have a vested interest in their trucks, many firms choose to use owner-operators because of the lower monitoring costs. Hubbard (2001) finds that over time as firms adopt on-board computers, they use more company drivers relative to owner-operators. If this is how on-board computers are used, then one would not necessarily expect a change in overall productivity, but a change in the way firms choose to organize production.

The other two onboard technologies considered, SATCOM and AVL, make it possible for firms to pinpoint the location of a truck at any point in time. In addition to vehicle tracking, SATCOM technologies also provide communication between the vehicle and the dispatcher which allows for real time coordination of fleet routing and dispatching activities. Thus, SATCOM can be thought of as an "active" technology where there is immediate feedback between the truck, dispatchers, and shippers whereas AVL is a "passive" technology which does not allow for ease of communication between the firm and the drivers. AVL systems can be integrated with other systems such as CAD and CAR to provide customers with information on current shipment status. AVL is a system often used to help recover stolen vehicles and may be a requirement for hauling specialized commodities. These systems should help in routing trucks and providing shippers real time information as to the location of their shipments. If this information is used along with backroom routing technologies, there could be productivity gains through better utilization of trucks.

Electronic Data Interchange (EDI) is a backroom strategy which makes information available to both the shipper and the carrier in a more accurate and timely manner. The adoption of EDI is strongly driven by consumer (shipper) demand for conducting business electronically. This technology allows for company to company computer communications which enable transmission of information more easily between companies. For instance, EDI allows information on the status of shipments to be transmitted between shipper and carrier quickly. EDI is also used to conduct billing, invoicing and other financials transactions between firms to take place electronically. EDI use increased in the 1990s as documented by Crum, Johnson, and Allen (1998) who find that the greatest perceived benefit of EDI use is in providing better consumer service. However, their 1996 survey results show that the carriers did perceive increase office/clerical efficiency as being a benefit of EDI use. Thus, there is reason to believe that the adoption of EDI may contribute to overall motor carrier productivity.

The other backroom technologies considered here are computer aided dispatching (CAD) ad computer aided routing(CAR), both of which are expect to be positively related to productivity improvements in trucking. The use of these technologies may be integrated with the onboard computer technologies, especially the SATCOM and AVL systems which pinpoint locations for dispatchers.

**III. Marketing Strategies**

Following the MCA of 1980, firms in the increasingly competitive industry began to adopt different sorts of marketing strategies. Corsi et al (1991) find that the firms pursued marketing strategies that fell into either providing service at the lowest freight rate (LFR), or trying to provide h high service quality, usually distinguished by reliable and on-time performance (OTP).

That shipper of high value commodities might be willing to pay more for on-time service than shippers of lower value commodities who were more interested in the transportation rates. Although both price and quality are important to shippers, some give more weight to one or the other and, accordingly, some motor carrier firms concentrate more on service quality such as OTP while other focus on providing service at the least possible rates ( LFR) .

The reason to be concerned about marketing strategy is that usually costs more to provide output if an OTP strategy is pursued than if an LFR strategy is followed. Since the productivity measures use only physical units of input and output, firms that pursue OTP strategies may appear to be less efficient than firms which are concentrating on providing LFR service. Thus, it is optimal to consider the marketing strategy pursued by firms when trying to compare productivity across firms.

Fortunately, in addition to the Motor Carrier Technology (MCT) survey collecting data on carrier technologies, it also asked that firms rank five different marketing strategies:

Lowest freight rates (LFR)

On-time performance (OTP)

Short turn around on customer requests (STACR)

Safety performance (SPERF)

Specialized/dedicated equipment (SPEC)

Respondents rated each strategy on a scale of one to five, one being the most important.

The following section introduces the Malmquist methodology used to measure productivity in this study. The data and the empirical Malmquist productivity results are then presented along with a tobit regression which is used to identify significant factors influencing productivity. These factors include the technological variables discussed above in addition to marketing strategies and a couple of other variables expected to influence motor carrier productivity.

## IV. Malmquist Productivity Index

The original derivation of the Malmquist Index can be found in Caves, Christensen, and Diewert (1982). This definition makes use of the Shephard (1953) concept of distance functions. The discussion here closely follows the presentation found in Fare, Grosskopf, and Lee (1995). Application of these techniques include Forsund (1993); Fare, Grosskopf, Lindgren, and Roos (1992); and Fare, Grosskopf, Norris, and Zhang (1994).

The basic intuition is to define an efficient production frontier, constructed using observed data points. This frontier then represents efficient production given the existing technology. Efficiency in any year is measured as each firm's distance from the production frontier.

The actual calculation of the frontier is achieved using linear programming, usually data envelope analysis (DEA) techniques introduced by Charnes, Cooper, and Rhodes (1978). For a theoretical discussion of DEA, see Lovell (1993) and Grosskopf (1993). DEA techniques produce Farrell (1957) efficiency measures which are identical to the distance functions required for the Malmquist Index (Forsund, 1993).

To derive the Malmquist Index, it is assumed that there is a production technology, $S^t = \{(x^t, y^t): x^t \text{ can produce } y^t\}$, which describes all possible sets of input-output vectors for each time period, t= 1,...T,. The model used here assumes constant returns to scale; an assumption is consistent with the results of Bruning and Olson (1982) who used efficiency indexes to test for economies of scale in U.S. trucking. Many other researchers have found evidence of constant returns, both before and after the MCA (McMullen and Stanley, 1987; Grimm, Corsi, and Jarrell, 1989; McMullen and Tanaka, 1995; Adrangi, Chow and Raffiee, 1995).

The output based distance function at time t is defined as:

(1) $$D_o^t\left(x^t, y^t\right) = \inf\left[\theta : \left(x^t, y^t/\theta\right) \in S^t\right].$$

This function is homogeneous of degree one in outputs and completely describes the technology in that $(x^t, y^t)$ belongs to $S^t$ only if $D^t_0(x^t, y^t)$ is less than or equal to one.

Caves, Christensen, and Diewert (1982) introduced the Malmquist Productivity Index which involves the use of mixed time distance functions using information from both periods t and t+1:

(2) $$D_o^{t+1}\left(x^t, y^t\right) = \inf\left[\theta : \left(x^t, y^t/\theta\right) \in S^{t+1}\right]$$

and

(3) $$D_o^t\left(x^{t+1}, y^{t+1}\right) = \inf\left[\theta : \left(x^{t+1}, y^{t+1}/\theta\right) \in S^t\right].$$

The Malmquist Productivity Index can be written as the geometric mean of two mixed period distance functions (Fare, Grosskopf, and Lee, 1995):

(4) $$M_o\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)} \frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^t, y^t\right)}\right]^{1/2}$$

Following Fare, Grosskopf, Lindgren, and Roos (1989), equation (4) can be rewritten as:

(5) $$M_o\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)} \left[\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_o^t\left(x^t, y^t\right)}{D_o^{t+1}\left(x^t, y^t\right)}\right]^{1/2}$$

Where the first term measures the change in efficiency and the square root of the second (bracketed) term represents the change in technology between the two periods.

Since output based distance functions are the reciprocal of Farrell's measure of technical efficiency, they can be calculated using the linear programming methodology shown in Fried, Lovell, and Schmidt (1993). The reciprocal of the distance function for firm k in a single period is:

(6) $$\left[D_o^t\left(x^{k',t}, y^{k',t}\right)\right]^{-1} = \max \theta$$

subject to

$$\theta y_m^{k',t} \leq \sum_{K=1}^{k} z^{k,t} y_m^{k,t} \qquad m = 1,\ldots,M,$$

$$\sum_{K=1}^{k} z^{k,t} x_n^{k,t} \leq x_n^{k',t} \qquad n = 1,\ldots N,$$

$$z^{k,t} \geq 0, \qquad k =,\ldots,K \cdot$$

Yearly distance functions are calculated for each firm. The mixed period distance functions required for calculation of the Malmquist Index are derived from the following linear programming formulation:

(7) $$\left[D^{o^t}\left(x^{k',t+1}, y^{k',t+1}\right)\right]^{-1} = \max\theta$$

subject to

$$\theta y_m^{k',t+1} \leq \sum_{k=1}^{K} z^{k,t} y_m^{k,t}, \qquad m = 1,\ldots M,$$

$$\sum_{k=1}^{K} z^{k,t} x_n^{k,t} \leq x_n^{k',t+1} \qquad n = 1,\ldots, N,$$

$$z^{k,t} \geq 0, \qquad k = 1,\ldots K.$$

Equations (6) and (7) are then repeated for all firms and time periods to calculate Malmquist Productivity Indices.

One advantage of the Malmquist methodology is that it does not require information on input prices, only quantities. This eliminates possible bias associated with imprecise measurement of factor prices, especially the price of capital. Another benefit is the ease with which multiple outputs can be considered. Given the known heterogeneity of trucking output, tonmiles alone are not an adequate measure of output. This methodology allows multiple outputs. Finally, this non-parametric technique does not impose any behavioral assumptions nor does it specify any particular functional form.

## V. Data

The data used in this study comes from two sources. The first is the Motor Carrier Safety, Operations, and Technology (MCSOT) survey of 1800 for-hire motor carrier firms conducted for the American Trucking Association. The second source is the financial and operating statistics for Class I and II motor carriers as reported to the U.S. Department of Transportation and summarized in the 1995 and 1997 publications *Motor Carrier Annual Report* (published by the ATA) and the Technical Transportation Services (TTS) publication *Blue Book of the Trucking Industry*.

In total there were 760 firms which responded to the MCSOT survey. Of those firms, there were 347 general freight firms of which full data sets were available for only the 124 firms included in this study.

The MCSOT survey, conducted in 1998, asked firms to identify which information technologies they had adopted in 1996 and which they were using in 1998. The survey also asked carriers to rank their marketing strategies on a scale of 1 to 5 with the strategies listed being lowest freight rate, on-time performance, short turn around on customer orders, safety, and specialized equipment. All of the technology and marketing strategy data were obtained from this survey.

The MCSOT survey had information on whether the firm used on board computers (OBC), Satellite Communications (SATCOM) and Automatic Vehicle Locations systems (AVL). These three technologies were grouped together in a dummy named HIGHTECH which was set equal to one if the firm had any one of the three technologies, equal to zero otherwise. Similarly, there was a backroom dummy, BKRM created to indicate if the firm had adopted any one of the three backroom technologies: electronic data interchange (EDI), computer aided routing (CAR) or computer aided dispatching (CAD).

It is clear from the U. S. DOT MCSOT report (1999), that the investigators expected that adoption of the various technologies considered would enable carriers to lower costs and increase efficient utilization of both vehicles and drivers by reducing empty miles or out of route miles. It was also expected that increased vehicle/driver monitoring and improved routing would reduce fuel costs. Finally savings were expected through ... "increased desk-side productivity and reduced administrative costs through migration to a "paperless" organization and use of decision support systems," U.S. DOT MCSOT, p. 25)

The MCSOT survey was sent to 1800 for-hire motor carriers and there were 760 respondents. Of those firms, there 347 general freight carriers which identified themselves as 69 less-than-truckload (LTL) and 278 truckload (TL) firms. Of the 347 general freight carriers, the number using different technologies in 1996 and adopting either an LFR or OTP freight strategy and the various information technologies, are shown in Table 1.

In 1996, backroom technologies (BKRM) were clearly more widely used by general freight carriers than the on-board (HITECH) technologies: 52 percent of the carriers used at least one backroom technology whereas only 26 percent of firms used a HIGHTECH (on-board technology). By 1998 70 percent of carriers used a backroom technology whereas 39 percent were using an on-board technology. Of the backroom technologies, EDI was the most frequently used with 35 percent of general freight carriers in the sample using EDI in 1996 over half using EDI in 1998. In general, LTL carriers were the heaviest users of EDI with 68 percent of LTL carriers using EDI in 1998 as compared to only 46 percent of TL carriers. The prevalence of EDI and the growth in EDI use observed in our sample of general freight carriers is notable.

Of the on-board technologies, SATCOM experienced an increase in usage between 1996 and 1998 with the share of all carriers using this technology increasing from 21 to 34 percent. AVL usage, which serves a similar function to SATCOM in locating vehicles, increased from 14 to 24 percent. The use of OBC only increased from 6 to 8 percent of all general freight firms between 1996 and 1998.

Information on the marketing strategy was only collected once. Carriers were asked to rank the following on a scale of 1 to 6 with 1 being the most important and 6 being the least important to marketing their company to customers:

Lowest freight rate (LFR)

On-time performance (OTP)

Short turn-around on customer requests (STACR)

Safety Performance (SPERF)

Specialized equipment/dedicated equipment (SPEC)

Other (specify)

For the entire MCSOT sample of 760 firms, the number ranking each of the first five specific strategies is reported in Table 2. The total reporting a ranking for each strategy may be less than 760 since some firms did not rank a particular strategy. Only about 9 percent of the firms ranked LFR as their number one marketing strategy, however over 70 percent of the carriers ranked OTP as their number one marketing strategy.

The bottom two sections of Table 2 show the breakdown of market strategy rankings for general freight firms in the entire sample and then the marketing strategy rankings for the 124 general freight firms which constituted the sub-sample for this study. This study was limited to those 124 general freight firms because they were the only ones for which complete data sets were available. These 124 firms seem to follow the same general pattern regarding marketing strategy ranking as the entire general freight sector (347 firms) from the MCSOT survey.

Note that the general freight sector tends to rank specialized/dedicated equipment low than the entire sample. That is because the full sample of 760 firms includes those in specialized commodity parts of the industry which often require special equipment to carry the commodity in question. General freight commodity carriers usually use more generic equipment and leave special commodities which require special equipment, to specialized carriers.

For all general freight carriers, about 77 percent said that on-time performance (OTP) was their number one marketing strategy whereas only 9 percent said that lowest freight rate (LFR) was their highest ranked strategy. However, 29 percent of firms indicated that LFR was either their first or second highest ranked marketing strategy.

One problem with the marketing strategy data collected is that it is not clear what it means for firms to have "safety performance" or "short turn around time" as marketing strategies. It is not clear whether, or how, firms distinguish between "short turn around time" and "on-time performance" as marketing strategies—as short turn around time appears to be a dimension of on-time performance. Similarly, what does a firm mean when it says that "safety performance" is it's primary marketing strategy? Does the firm run ads boasting about low accident rates? Once again, having a low accident rate could be interpreted as a dimension of service quality which could be related to "on-time performance" or "short turn around time" as lots of accidents surely slow down the total transport time for shipments.

Finally, it should be noted that OTP and LFR were the two most frequently cited marketing strategies and were often ranked as number 1 or 2. Since theory tells us that firms which focus exclusively on LFR may have longer and more variable transport times than OTP performers as they wait for loads to fill to capacity to reduce per unit costs, it is hard to see how a firm could successfully pursue both strategies at once (as #1 and #2) strategies. Perhaps firms focus on OTP or LFR exclusively in certain markets of with certain commodities.

The second data source used here was the financial and operating statistics of the motor carrier firms. To calculate a Malmquist Index requires two year's worth of data, in this case 1995 and 1997. The financial and operating statistics provided data on the following variables which were used as inputs in the calculation of the Malmquist Productivity Index: number of employees, number of power units, and gallons of fuel (calculated by taking vehicle miles and dividing by 5). On the output side, we used tonmiles and average length of haul and average load as attributes of the output.

In addition to the factors discussed above, there is reason to believe that there may be a relationship between union membership and firm productivity. On one hand, unions claim that their workers are more productive (justifying higher wages and salaries). On the other, many have claimed that imposition of various work rules and practices constrain workers and reduce firm productivity. Kerkvliet and McMullen (1997) find that unionized firms have a higher cost structure than non-unionized firms, largely due to higher wages for unionized workers. However, their results do not directly address the productivity of unionized workers.

We include a union variable based on data from the financial and operating statistics. After consultation with industry representative, it was decided to use the percent of benefits which a carrier derives from health and welfare expenditures as the measure of firm unionization (UNION). Since expenditures in this category denote union activity, they are used as a proxy for the degree of unionization. Firms with a very small percentage may have a few unionized employees and the rest may be non-union. Heavily unionized firms may have all unionized drivers and handlers and only a few non-unionized management.

Means for the financial and operating statistics used for these analyses are shown in Tables 3 and 4.

**VI. Results**

The results of the Malmquist estimation are presented in Table 5 for the 124 firms for which we had all the data required for both the Malmquist Index and the technology data. The first column lists the overall Malmquist Index, the second column is the economics efficiency gain and the third column is the technological efficiency gain.

The results for the Malmquist and the component Indices were then put into a tobit regression model and regressed on variables that were expected to affect productivity. These variables include the technology dummies discussed above. First we used both the HIGHTECH and BKRM dummies and then used dummies for each individual technology (EDI, SATCOM, etc.) In addition, a marketing strategy dummy for LRF was set equal to one if LFR was ranked number one as a marketing strategy by the firm. It was expected that firms which pursued an LFR strategy would have higher productivity than those that did not.

Other than the technological and marketing strategy dummies, we include a measure of firm size, gross revenues (GROSSREV) to see whether productivity is related to firm size. We also include a union variable which indicated the percent of unionized workers in the firms (defined as health and welfare contributions divided by all pension contributions). If union workers are more productive, then we would expect this variable to be positively related to the Malmquist.

Finally, we include a variable which shows the percent of miles operated by owner-operators (OOP) rather than company drivers. Hubbard's work suggests that owner operators may be more productive than company operators, especially for firms which do not have monitoring technologies. On the other hand, anecdotal evidence suggests that owner-operators are less reliable and have equipment that is more likely to break down --- thus suggesting that OOP would be negatively related to productivity.

Results from the tobit regressions are presented in Tables 6 and 7.

Table 6 shows the results for the tobit of the Malmquist, the Economic Efficiency, and the Technology change on firm size (measured by Gross revenue (GRREV)), BKRM, HIGHTECH, and a marketing strategy variable, LFR. Results show that, as expected BKRM had a positive and significant impact on the Malmquist Index of productivity. None of the other variables are statistically significant for the overall Malmquist.

When the Malmquist is decomposed into the economic (EC) and technological efficiency (TC) components, the marketing strategy, lowest freight rate (LFR) has a positive and significant, impact on TC.

In an effort to gain more insight into which technologies are responsible for the impact on productivity, the BKRM dummy was split into the component technologies: EDI, CAD, and CAR. For consistency, we did the same with the HIGHTECH onboard technologies: SATCOM, OBC, and AVL. We ran tobit regressions for various combinations of these variables on the Malmquist and the EC and TC indexes. In addition, we added the percent of owner operators (OOP) and whether a firm was union or non-union to the set of regressors as these are variables hypothesized to have a potential impact on productivity.

Results presented in Table 7 show that none of these variables have a significant impact on the overall Malmquist, but they do affect its EC and TC components. Included in the regressions shown are the variables which showed significance in any of the regressions. SATCOM is retained as the HIGHTECH variable with the highest levels of significance.

Also interesting is the positive and significant impact on productivity from unionization. This supports the long held union stance that unionized workers are more productive.

In the TC regression, the LFR imparts a positive and significant impact on technical efficient --- confirming the hypothesis that marketing strategy does have an impact on the technical efficiency component of productivity. This finding that marketing strategy affects the TC measure, helps explain McMullen and Okuyama's (2000) finding that during the transition to deregulation in the 1980's, motor carrier firms, on average, experienced declines in the TC component of the Malmquist. This was observed at the same time that the firms had consistently positive efficiency (EC) gains. The positive EC gains were expected and could be attributed to firms operating more efficiently without regulations that had restricted them from operating at the lowest possible cost. McMullen and Okuyama speculated that apparent regression in technology could be explained by firms increasingly adopting higher cost marketing strategies such as on-time performance (OTP). The results here show a clear technical efficiency advantage to firms which adopt LFR marketing strategies --- which provides some collaboration for their explanation of previous results.

These overall results suggest that adoption of various information technologies may not directly increase productivity as much as previously thought. Indeed, Brynjolfson and Hitt (2000) argue that information technologies have broad powers to reduce the costs of coordination and information, but may also enable firms to increase service quality and other intangible aspects of products. This is in line with Hubbard's arguments regarding how information technologies may be adopted to allow firms to organize their production in a different manner. His example being the use of monitoring afforded by on-board computers may make firms more willing to rely on company drivers rather than owner operators.

The large productivity gains due to adoption of information technologies which were expected by the MCSOT researchers were not found. However, despite the lack of large productivity gains adoption of these information technologies may have enabled firms to operate better in a market where owner operators may becoming harder to find (especially during the 1990s when many owner operators left the industry and got jobs elsewhere.) Thus, the technology gave the firms the ability to adapt to a changing labor market rather than imparting any large increase in efficiency. It is possible that without the technologies, efficiency would have decreased due to tightening labor markets.

Of particular importance in these results is the positive and significant impact on economic efficiency (EC) deriving from a firm's use of EDI. This suggests that the large increases in EDI use in the 1990's may not only be to provide consumer satisfaction, but also to achieve cost saving through efficiency/productivity gains.

## VII. An Extension: The Impact of Information Technologies and Marketing Strategies on Motor Carrier Costs

The results presented above suggest that neither the adoption of various information technologies nor the pursuit of the listed marketing strategies, have a large impact on motor carrier productivity. Of course, the reason firms are interested in increasing productivity is to lower unit costs. Thus, we would expect that marketing strategies and information technologies do not have a significant impact on motor carrier costs.

Accordingly, we estimate a standard translog cost function for our sample of general freight commodity carriers using the above explained dummies for marketing strategy (OTP and LFR) as well as the backroom technology dummy (BKRM) and the on-board technology dummy (HITECH).

In general, the cost function is written in terms as:

(8) $C = C(p, y, a)$

where C represents long run costs, y measures output, p is a vector of input prices and a is a vector of firm attributes.

The translog cost function provides a second order approximation to (8) and is written as:

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

where $\epsilon$ is a normally distributed disturbance term and each variable represents the deviation from its sample mean. Symmetry and homogeneity of degree one are imposed on the parameters and, to increase efficiency, we estimate factor share equations simultaneously with the cost function. Because cost shares sum to one, one of the share equations is dropped and Barten (1969) has shown that the results are invariant to the equation dropped. Additive disturbances are appended to the cost equation and the remaining factor share equations.

The vector of firm outputs includes TONMILES, average length of haul (ALH), average load (ALOAD), and LTL dummy (=1 if a firm is an LTL carrier, =0 if it is a truckload, TL, carrier), and HITECH and BKRM dummies as defined above. Factor prices are the price of labor (PL), price of capital (PK), price of rented capital (PR), and price of fuel (PF).

Results from the translog estimation are shown in Table 8 and show no significant impact of marketing strategies, OTP or LRF, or information technology on motor carrier cost. As explained above, this is consistent with the finding that these variables did not have a significant impact on motor carrier productivity.

The only interesting result is that the SPERF marketing strategy, defined as equal to 1 if the firm ranked a safety marketing strategy as its number one marketing strategy, had a positive impact on carrier cost. This coefficient was only significant at the 10% level, but it suggests that firms which actively pursue a marketing strategy of safety performance, have higher costs. It should be noted that the SPERF marketing strategy was not found to have a significant impact on the Malmquist productivity measure or its component parts.

Of course, safety can be an important service quality attribute for a shipper of fragile and high value commodities. While firm, which focus on safety may have higher costs; shippers may be willing to pay for this higher service quality. This remains a topic for further research.

**VIII. Conclusions and Suggestions for Future Research**

The results of this research do not find a significant relationship between on-board information technologies and motor carrier productivity, measured using a Malmquist Index of productivity. In particular, on-board computers, satellite communications systems, and automatic vehicle location systems were not found to contribute as expected to productivity growth between 1996 and 1998.

As noted above, there are reasons to believe that the adoption of such technologies be more motivated by other factors such as being able to change the way the firm is organized, rather than for intrinsic productivity gains. In particular, if firms are better able to monitor drivers and trucks through use of on-board computers systems, then they may decide to use more company trucks and drivers rather than relying on hiring owner operators.

Similarly, if these technologies are adopted with the motivation of increasing motor carrier safety by allowing firms to more closely monitor truck speeds, maintenance scheduling, and other safety related behaviors, there may be an increase in truck safety performance which is not being captured in the Malmquist productivity index used in this study. In this case, significant increases in safety performance may be achieved although the Malmquist index shows no productivity gain.

A problem inherent in the survey data collected in the MCSOT study is that firms all responded as to whether they used the various kinds of technology. This is reported as a binary dummy variable which does not reflect the extent to which each firm uses a technology. It is possible that there is great variability in the number of trucks in individual firms which have the information technology installed and which use the on-board technology. For instance, a firm which has one truck out of 500 which has an on-board computer installed would show up in this data set as a having a “1" for on-board computer use although it would probably not influence the overall firm productivity as much as it would if all 500 trucks had employed the technology.

Finally, much of the technology literature indicates that it takes a while for the impacts of technology to be felt. In particular, there is a process of technological diffusion which takes place over time. Given the fact that the data used in this study came from a survey of adopted technologies in 1996 and 1998, it is possible that the productivity impact of these adoptions were not felt immediately. If there were a longer time series of data regarding the adoption of various technologies by motor carrier firms, we might find that the cumulative impact on productivity might be greater than that found in this study.

A possible reason that electronic data interchange (EDI) systems were found to be positively related to productivity may be because by 1996 these systems had been in place for several years and the adoption rate had exceeded 70 of the firms on our sample. This may lend support to the hypothesis that the other information technologies may end up having significant impacts on productivity over time.

As far as marketing strategies are concerned, the lowest freight rate marketing strategy was found to be positively related to the technology component of productivity gain. This is a result that was expected.

As a final recommendation, this study points out the need for additional data to be collected from motor carriers regarding their use of technology over time if the cumulative impact of technology on productivity is to be measured. There is also a need to collect more detailed information on the use of technology — for instance how many trucks in a carrier's fleet use the technology, etc. Future research might focus more on the relationship between technology and the firm's safety record since the purpose of the technology adoption appears to be for reasons other than cost-reducing productivity gains.

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***Table 1: Technologies Adopted by MCSOT General Freight firms in 1996 and 1998***

| | TRUCKLOAD | LTL | TOTAL |
|---|---|---|---|
| **SATCOM** | | | |
| 1996 | 59 (21%) | 15 (22%) | 74 (21%) |
| 1998 | 98 (35%) | 19 (28%) | 117 (34%) |
| **OBC** | | | |
| 1996 | 12 (4%) | 8(12%) | 20 (6%) |
| 1998 | 17 (6%) | 11 (16%) | 28 (8%) |
| **AVL** | | | |
| 1996 | 38 (14%) | 11 (16%) | 49 (14%) |
| 1998 | 70 (25% | 15 (22%) | 85 (24%) |
| **HIGHTECH** | | | |
| 1996 | 68 (24%) | 21 (30%) | 89 (26%) |
| 1998 | 110 (40%) | 25 (36%) | 135 (39%) |
| **EDI** | | | |
| 1996 | 86 (31%) | 36 (52%) | 122 (35%) |
| 1998 | 129 (46%) | 47 (68%) | 176 (51%) |
| **CAR** | | | |
| 1996 | 58 (21%) | 19 (28%) | 77 (22%) |
| 1998 | 91 (33%) | 26 (38%) | 117 (34%) |
| **CAD** | | | |
| 1996 | 91 (33%) | 23 (33%) | 114 (33%) |
| 1998 | 124 (45%) | 34 (49%) | 158 (46%) |
| **BKRM** | | | |
| 1996 | 139 (50%) | 41 (59%) | 180 (52%) |
| 1998 | 191 (75%) | 52 (75%) | 243 (70%) |

***Table 2: Ranking of Marketing Strategies***

**Entire MCSOT Sample (n=761)**

| Rank | LFR | OTP | STACR | SPEC | SPERF |
|---|---|---|---|---|---|
| 1 | 71 | 533 | 41 | 112 | 58 |
| 2 | 132 | 148 | 166 | 145 | 130 |
| 3 | 131 | 37 | 207 | 178 | 144 |
| 4 | 130 | 16 | 146 | 189 | 173 |
| 5 | 195 | 14 | 130 | 102 | 184 |
| 6 | 89 | 5 | 48 | 19 | 46 |

**General Freight Sample (n= 347)**

| Rank | LFR | OTP | STACR | SPEC | SPERF |
|---|---|---|---|---|---|
| 1 | 30 | 266 | 16 | 33 | 17 |
| 2 | 70 | 54 | 87 | 61 | 53 |
| 3 | 57 | 11 | 111 | 84 | 54 |
| 4 | 67 | 4 | 59 | 89 | 84 |
| 5 | 77 | 8 | 43 | 64 | 99 |
| 6 | 43 | 3 | 21 | 12 | 30 |

**General Freight Sub-sample used in the Malmquist (n=124)**

| Rank | LFR | OTP | STACR | SPEC | SPERF |
|---|---|---|---|---|---|
| 1 | 11 | 89 | 6 | 11 | 9 |
| 2 | 27 | 19 | 30 | 22 | 18 |
| 3 | 15 | 7 | 44 | 33 | 14 |
| 4 | 30 | 1 | 21 | 27 | 26 |
| 5 | 27 | 6 | 12 | 24 | 40 |
| 6 | 13 | 2 | 8 | 6 | 15 |

***Table 3: Summary Statistics for Data Used in the Estimation of the Malmquist Index (Means and Standard Deviations) n=124***

| | *1995* | | *1997* | |
|---|---|---|---|---|
| | **Mean** | **Std Deviation** | **Mean** | **Std Deviation** |
| **INPUTS** | | | | |
| ***Number of Employees*** | 1235 | 3938 | 1330 | 4019 |
| ***Number of Power Units*** | 548 | 1540 | 564 | 1454 |
| ***Gallons of Fuel*** | 7371 | 19655 | 8235 | 20116 |
| **OUTPUTS** | | | | |
| ***Tonmiles (TONMI)*** | 501177 | 1468224 | 650760 | 2092355 |
| ***Average Length of Haul (ALH) (000 Miles)*** | 564 | 488 | 575 | 480 |
| ***Average Load (ALOAD) (Tons)*** | 13 | 6 | 13 | 6 |

***Table 4: Means and Standard Deviation for Tobit Regression Variables (n=124)***

| | **Mean** | **Standard Deviation** |
|---|---|---|
| ***GROSSREV ($1000)*** | $105,794.8 | $332185.52 |
| ***UNION (%)*** | 14 | 26 |
| ***THRWYMILES (000)*** | 38735.69 | 98523.98 |
| ***OOP (%)*** | 22 | 30 |

***Table 5: Malmquist Index and Component Technical Efficiency (EC) and Technological Change (TC) Indices for 124 General Freight Commodity Carriers***

| ***TRUCKING COMPANY*** | ***CITY LOCATION*** | ***STATE*** | ***Output-Oriented Malmquist Index*** | ***Efficiency Change (EC)*** | ***Technical Change (TC)*** |
|---|---|---|---|---|---|
| Wilhelm Trucking Co. | Portland | OR | 1.47 | 1.49 | 0.98 |
| Alvan Motor Freight, Inc. | Kalamazoo | MI | 0.84 | 0.67 | 1.25 |
| Midwest Motor Express, Inc. | Bismarck | ND | 0.98 | 0.88 | 1.11 |
| Roadway Express, Inc. | Akron | OH | 1.12 | 1 | 1.12 |
| National Freight, Inc. | Vineland | NJ | 0.96 | 0.94 | 1.03 |
| Hatcher Trucking Co., Inc. | Roanoke | VA | 1.06 | 0.7 | 1.51 |
| Blue & Gray Transportation | Richmond | VA | 0.88 | 0.84 | 1.04 |
| Los Angeles-Yuma Freight Lines | Yuma | AZ | 1.05 | 0.95 | 1.11 |
| MCO Transport, Inc. | Wilmington | NC | 0.96 | 0.95 | 1 |
| Volpe Express, Inc. | Norristown | PA | 0.97 | 0.85 | 1.14 |
| Devine Intermodal | West Sacramento | CA | 1.01 | 0.95 | 1.06 |
| ABF Freight System, Inc. | Fort Smith | AR | 1.09 | 1.01 | 1.09 |
| T. P. Freight Lines, Inc. | Tillamook | OR | 0.84 | 1 | 0.84 |
| Youngblood Truck Lines | Fletcher | NC | 1 | 1 | 1.01 |
| Consolidated Freightways | Portland | OR | 1.11 | 1 | 1.11 |
| Buske Lines, Inc. | Litchfield | IL | 0.67 | 0.66 | 1.02 |
| Dick Harris & Son Trucking | Lynchburg | VA | 0.99 | 0.95 | 1.04 |
| Graham Ship By Truck Co. | Kansas City | KS | 1.22 | 1.23 | 0.99 |
| A.A.A. Cooper Transportation | Dothan | AL | 1.01 | 0.89 | 1.13 |

| | | | | | |
|---|---|---|---|---|---|
| Waller Truck Co., Inc. | Richmond | MO | 0.55 | 0.55 | 0.98 |
| Bryan Truck Line, Inc. | Montpelier | OH | 0.45 | 0.43 | 1.04 |
| Wilson Trucking Corp. | Fishersville | VA | 1.06 | 0.75 | 1.41 |
| Houff Transfer, Inc. | Weyers Cave | VA | 1.06 | 1.03 | 1.02 |
| New Penn Motor Express, Inc. | Lebanon | PA | 1.03 | 0.86 | 1.21 |
| Brown Line, Inc. | Mount Vernon | WA | 0.85 | 0.81 | 1.05 |
| Hunt Transportation, Inc. | Omaha | NE | 0.9 | 0.89 | 1.02 |
| Paul Musslewhite Trucking | Levelland | TX | 0.99 | 0.66 | 1.49 |
| Seward Motor Freight, Inc. | Seward | NE | 1.12 | 1.12 | 1.01 |
| Watkins Motor Lines, Inc. | Lakeland | FL | 1.02 | 1 | 1.01 |
| Estes Express Lines | Richmond | VA | 1.23 | 1.01 | 1.21 |
| Severance Trucking Co., Inc. | Woburn | MA | 0.95 | 0.63 | 1.51 |
| Brown Transfer Co. | Kearney | NE | 0.58 | 0.49 | 1.2 |
| B & D Transfer, Inc. | Liberty | PA | 1 | 0.88 | 1.13 |
| Old Dominion Freight Line | High Point | NC | 1.11 | 1.01 | 1.1 |
| A. J. Metler Hauling & Rigging | Knoxville | TN | 1.37 | 1.4 | 0.98 |
| Baylor Trucking, Inc. | Milan | IN | 1 | 0.99 | 1.01 |
| Overnite Transportation Co. | Richmond | VA | 1.01 | 0.91 | 1.11 |
| Southeastern Freight Lines | Lexington | SC | 0.77 | 0.69 | 1.12 |
| W. C. McQuaide, Inc. | Johnstown | PA | 2.81 | 2.56 | 1.1 |
| Eck Miller Transportation | Rockport | IN | 1.33 | 1.33 | 1 |
| James H. Clark & Son | Salt Lake City | UT | 1 | 1 | 1 |
| John Cheeseman Trkg | Fort Recovery | OH | 0.19 | 0.19 | 1.01 |
| Craig Transportation Co. | Perrysburg | OH | 0.88 | 0.89 | 0.99 |
| A & B Freight Line, Inc. | Rockford | IL | 0.96 | 0.89 | 1.08 |
| Cape Cod Express, Inc. | Wareham | MA | 0.86 | 0.63 | 1.36 |
| Averitt Express, Inc. | Cookeville | TN | 0.96 | 0.93 | 1.04 |

| | | | | | |
|---|---|---|---|---|---|
| Milan Express Co., Inc. | Milan | TN | 0.93 | 0.9 | 1.02 |
| American Freightways, Inc. | Harrison | AR | 0.94 | 0.82 | 1.15 |
| Southwest Truck Service | Watsonville | CA | 1.23 | 1 | 1.23 |
| Cresco Lines, Inc. | Crestwood | IL | 1.06 | 0.99 | 1.07 |
| Professional Trptn Svces. | Boise | ID | 0.85 | 0.49 | 1.72 |
| B-D-R Transport, Inc. | Westminster | VT | 1.11 | 1.12 | 0.99 |
| East Penn Trucking , Inc. | Lehighton | PA | 0.99 | 0.94 | 1.05 |
| J. B. Hunt Transport, Inc. | Lowell | AR | 2.06 | 2.04 | 1.01 |
| Wallace Transport, Inc. | Planada | CA | 1.36 | 1.32 | 1.03 |
| Lisa Motor Lines, Inc. | Dallas | TX | 0.87 | 0.93 | 0.93 |
| Eidson & Ussery, Inc. | Marshall | MO | 0.97 | 0.88 | 1.1 |
| Art Pape Transfer, Inc. | Dubuque | IA | 1 | 1.02 | 0.98 |
| Adams Transit, Inc. | Friesland | WI | 1.02 | 0.95 | 1.07 |
| Tennessee Express, Inc. | Nashville | TN | 1.03 | 1 | 1.03 |
| Cannon Express Corp. | Springdale | AR | 1.47 | 1.48 | 0.99 |
| Danny Herman Trucking | Mountain City | TN | 0.81 | 1 | 0.81 |
| H & W Trucking Co., Inc. | Mount Airy | NC | 0.99 | 0.72 | 1.39 |
| Central Virginia Trucking | Lynchburg | VA | 1.05 | 1.04 | 1.01 |
| American Pacific Forwarders | Chino | CA | 1.1 | 1 | 1.1 |
| Perfetti Trucking, Inc. | Blairsville | PA | 1.25 | 1.26 | 0.99 |
| Penske Logistics, Inc. | Beachwood | OH | 0.97 | 0.95 | 1.03 |
| East-West Motor Freight, Inc. | Selmer | TN | 1 | 0.98 | 1.02 |
| Scalea's Airport Service | Folcroft | PA | 0.69 | 0.45 | 1.53 |
| Black Hills Trucking, Inc. | Casper | WY | 1.01 | 0.83 | 1.21 |
| Ronwal Transportation, Inc. | Hammond | IN | 0.77 | 0.76 | 1.02 |
| Truck Service, Inc. | Forest City | NC | 0.99 | 1.01 | 0.98 |
| Atlantic Carriers, Inc. | Atlantic | IA | 1.01 | 1.01 | 1 |

| | | | | | |
|---|---|---|---|---|---|
| Adrian Carriers, Inc. | Milan | IL | 0.99 | 0.97 | 1.02 |
| A. N. Webber, Inc. | Kankakee | IL | 1.17 | 1.17 | 1 |
| Nationwide Magazine & Book Dist'b. | Irving | TX | 0.98 | 0.94 | 1.04 |
| M. C. Van Kampen Trucking | Wyoming | MI | 0.97 | 0.7 | 1.39 |
| Teresi Trucking, Inc. | Lodi | CA | 1.1 | 1.08 | 1.02 |
| Cowen Truck Line, Inc. | Perrysville | OH | 0.93 | 0.93 | 0.99 |
| T. B. & P. Express, Inc. | Daleville | IN | 0.96 | 0.95 | 1.01 |
| Shane Transport | Fresno | CA | 0.96 | 0.89 | 1.08 |
| Tony's Express, Inc. | Pico Rivera | CA | 2.29 | 2.19 | 1.05 |
| Maverick Transportation | Little Rock | AR | 1 | 0.99 | 1.01 |
| Nationwide Express, Inc. | Shelbyville | TN | 0.99 | 0.64 | 1.54 |
| Customized Trptn | Jacksonville | FL | 1.01 | 1.02 | 0.99 |
| GTL Transport Co., Inc. | Suffolk | VA | 0.94 | 0.91 | 1.03 |
| SC Transport | Gaston | SC | 1.02 | 1.01 | 1.01 |
| The Great American Trucking Co., Inc. | Peachtree City | GA | 3.82 | 1 | 3.82 |
| B.I. Transportation, Inc. | Burlington | NC | 1.04 | 1.02 | 1.01 |
| Comtrak, Inc. | Memphis | TN | 1.01 | 0.98 | 1.03 |
| Penn's Best, Inc. | Meshoppen | PA | 1.18 | 1.16 | 1.02 |
| Benny Whitehead, Inc. | Eufaula | AL | 0.95 | 0.67 | 1.42 |
| Jevic Transportation, Inc. | Delanco | NJ | 1.94 | 1.87 | 1.04 |
| T & T Trucking, Inc. | Lodi | CA | 0.91 | 1 | 0.91 |
| Tripp Brothers Trucking | Missoula | MT | 1.02 | 1 | 1.02 |
| USA Truck, Inc. | Van Buren | AR | 0.99 | 0.99 | 1 |
| Smith Bros. Trucking, Inc. | Bardstown | KY | 0.94 | 0.9 | 1.05 |
| Dick Lavy Trucking, Inc. | Bradford | OH | 0.99 | 1.03 | 0.97 |
| Jolliff Transportation | East Peoria | IL | 1.16 | 1.13 | 1.03 |
| Hansen Trucking | Jerseyville | IL | 1.15 | 1.1 | 1.04 |

| | | | | | |
|---|---|---|---|---|---|
| Wausau Carriers, Inc. | Wausau | WI | 0.95 | 0.95 | 0.99 |
| Emerson Trptn Division | Saint Louis | MO | 1.05 | 1.05 | 1 |
| S & S Truck Line, Inc. | Kansas City | KS | 1.01 | 1.01 | 1 |
| Dirksen Transportation, Inc. | Ripon | CA | 1.53 | 1.5 | 1.02 |
| Bradford Trucking, Inc. | Cactus | TX | 0.95 | 1 | 0.95 |
| Dist-Trans Co. | Columbus | OH | 0.7 | 0.8 | 0.88 |
| Celebrity Freight Systems | Paducah | KY | 1 | 1.02 | 0.98 |
| Barr-Nunn Transportation | Granger | IA | 0.92 | 0.91 | 1 |
| T.T.I., Inc. | Eden | WI | 1.05 | 1 | 1.05 |
| Transport Distribution Co. | Joplin | MO | 0.99 | 0.97 | 1.02 |
| Hot Shot Express, Inc. | Spring City | PA | 0.96 | 0.77 | 1.25 |
| Pope Transport Co. | Mount Olive | NC | 0.99 | 0.97 | 1.02 |
| Best Way Express, Inc. | Saint Pauls | NC | 1.22 | 0.93 | 1.32 |
| Quick Delivery Service, Inc. | Mobile | AL | 1.39 | 1.19 | 1.16 |
| S & S Transportation, Inc. | Rantoul | IL | 1.01 | 0.97 | 1.04 |
| Stever Trucking, Inc. | Springfield | MO | 0.87 | 0.86 | 1.02 |
| Pilot Transport, Inc. | Brighton | MI | 0.84 | 0.54 | 1.54 |
| Atkinson Freight Lines of PA | Bensalem | PA | 1.01 | 1 | 1.01 |
| Jack Jones Trucking, Inc. | Chino | CA | 0.87 | 0.68 | 1.28 |
| Adams Motor Express, Inc. | Carnesville | GA | 0.99 | 0.97 | 1.01 |
| Inter-Cal Contract Carriers | Sacramento | CA | 1.15 | 0.81 | 1.42 |
| Americana, Inc. | Wolcott | IN | 0.97 | 0.93 | 1.04 |

*Table 6*

***Tobit Regression of MALM, EC, and TC on HITECH, BKRM, LFR, and GRREV***

| | **MALM** | **EC** | **TC** |
|---|---|---|---|
| **C** | **.97** | **.92** | **1.08** |
| | **(17.48)** | **(21.05)** | **(25.82)** |
| **HITECH** | **-.10** | **-.0003** | **-.11** |
| | **(-1.13)** | **(-.0049)** | **(-1.63)** |
| **BKRM** | **.17** | **.09** | **.06** |
| | **(2.14)** | **(1.54)** | **(1.08)** |
| **LFR** | **.08** | **- .02** | **.12** |
| | **(1.05)** | **(-.39)** | **(2.15)** |
| **GRREV** | **.81 E-07** | **.89 E-07** | **-.21 E-07** |
| | **(.75)** | **(1.04)** | **(.27)** |

***T-statistics in parentheses***

***Table 7***

***Tobit Regression of MALM, TC, EC on EDI, SATCOM, LFR, UNION, OOP and GRREV***

| | **MALM** | **EC** | **TC** |
|---|---|---|---|
| **C** | **.977** | **.90** | **1.10** |
| | **(16.46)** | **(20.26)** | **(25.15)** |
| **EDI** | **.09** | **.15** | **-.08** |
| | **(1.25)** | **(2.71)** | **(-1.43)** |
| **SATCOM** | **-.11** | **-.06** | **-.05** |
| | **(-1.29)** | **(-.94)** | **(-.78)** |
| **LFR** | **.08** | **-.04** | **.14** |
| | **(1.06)** | **(-.71)** | **(2.52)** |
| **UNION** | **.20** | **.24** | **-.09** |
| | **(1.46)** | **(2.29)** | **(-.82)** |
| **OOP** | **.12** | **-.02** | **.12** |
| | **(1.04)** | **(-.19)** | **(1.34)** |
| **GRREV** | **.55 E-07** | **.19 E-07** | **.31 E-07** |
| | **(.49)** | **(.29)** | **(.37)** |

***t-statistics in parentheses***

**Table 8: Translog Cost functions results**
**Dependent Variable: Total Cost**

| **Estimated Coefficients for Translog Cost Function Dependent Variable LN(Total Cost)** | | | | |
|---|---|---|---|---|
| | | | | |
| | | | | |
| **Variable** | **Estimate** | **Std Error** | **T Value** | **P > \|t\|** |
| | | | | |
| Intercept | 10.487 | 0.093 | 113.24 | <.0001 |
| PF | 0.127 | 0.005 | 23.48 | <.0001 |
| PL | 0.445 | 0.017 | 25.96 | <.0001 |
| PK | 0.239 | 0.019 | 12.82 | <.0001 |
| PR | 0.190 | 0.018 | 10.36 | <.0001 |
| ALOAD | -0.975 | 0.159 | -6.12 | <.0001 |
| ALH | -0.184 | 0.136 | -1.36 | 0.1768 |
| TONMI | 0.965 | 0.043 | 22.57 | <.0001 |
| LTL | 0.176 | 0.102 | 1.72 | 0.0863 |
| SAFETY | 0.136 | 0.082 | 1.66 | 0.0987 |
| PF sq. | 0.062 | 0.007 | 8.49 | <.0001 |
| PL sq. | 0.079 | 0.026 | 3.01 | 0.003 |
| PK square | 0.095 | 0.017 | 5.71 | <.0001 |
| PR square | -0.042 | 0.016 | -2.63 | 0.0092 |
| ALOAD sq. | 0.403 | 0.195 | 2.07 | 0.0403 |
| ALH sq. | 0.017 | 0.119 | 0.15 | 0.8836 |
| TONMI sq. | 0.070 | 0.033 | 2.13 | 0.0346 |
| PF*PL | -0.038 | 0.010 | -3.98 | <.0001 |
| PF*PK | 0.005 | 0.006 | 0.87 | 0.387 |
| PF*PR | 0.002 | 0.009 | 0.24 | 0.8097 |
| PF*ALOAD | 0.005 | 0.006 | 0.79 | 0.4292 |
| PF*ALH | 0.021 | 0.005 | 4.05 | <.0001 |
| PF*TONMI | 0.004 | 0.003 | 1.33 | 0.1837 |
| PL*PK | -0.037 | 0.009 | -3.92 | 0.0001 |
| PL*PR | 0.035 | 0.010 | 3.53 | 0.0005 |
| PL*ALOAD | -0.117 | 0.024 | -4.91 | <.0001 |
| PL*ALH | -0.041 | 0.021 | -1.96 | 0.0516 |
| PL*TONMI | 0.030 | 0.009 | 3.15 | 0.0019 |
| PK*PR | -0.016 | 0.009 | -1.78 | 0.0764 |

| | | | | |
|---|---|---|---|---|
| PK*ALOAD | 0.051 | 0.018 | 2.79 | 0.0059 |
| PK*ALH | 0.021 | 0.014 | 1.51 | 0.1333 |
| PK*TONMI | -0.034 | 0.009 | -3.65 | 0.0004 |
| PR*ALOAD | 0.061 | 0.024 | 2.49 | 0.0137 |
| PR*ALH | 0.000 | 0.021 | -0.01 | 0.9954 |
| PR*TONMI | 0.000 | 0.000 | -0.68 | 0.4948 |
| ALH*ALOAD | 0.292 | 0.210 | 1.39 | 0.1652 |
| ALOAD*TONMI | -0.146 | 0.064 | -2.29 | 0.0231 |
| ALH*TONMI | -0.043 | 0.078 | -0.54 | 0.5865 |
| HITECH | -0.033 | 0.108 | -0.31 | 0.7585 |
| BKRM TECH | 0.111 | 0.074 | 1.5 | 0.1347 |