PROCEEDINGS —
Seventeenth Annual Meeting

Theme:
"Beyond The Bicentennial:
The Transportation Challenge"

October 28-29-30, 1976
Sheraton-Boston Hotel
Boston, Massachusetts

Volume XVII • Number 1 1976

T
R
F

TRANSPORTATION RESEARCH FORUM

ECONOMISTS have long argued that regulation has perpetuated a rail rate structure based upon value of service rather than cost of service, resulting in an allocation of traffic between modes which does not reflect their relative social costs.[1] This paper examines the methodology of a number of studies which have quantified the extent and costs of misallocation and found that they are substantial. Serious biases in the methodology are shown to exist.

Meyer et al estimated, based upon 1950 data, that 575 billion revenue ton miles of traffic could be carried by the railroads at the cost required to move 416 billion revenue ton miles by truck.[2] The study concluded that "a substantial share of the intercity truck traffic apparently represents a higher cost of transportation to society than would rail transportation . . ."[3]. Domencich and Woods, applying the cost estimates produced by Meyer et al to the traffic data contained in the 1963 Census of Transportation, concluded that 24.2 percent of the truck share consists of misallocated traffic at a social cost of 8 billion dollars.[4] Harbeson estimated misallocation costs to be between 1.129 and 2.291 billion dollars per year.[5] A recent study by Sparling employed Harbeson's methodology with 1970 cost data and estimated the loss to be between $689 million and $4.213 billion.[6]

The sizeable differences in the results of these studies reflect differences in the cost and traffic data used and the specific methodologies employed, but they all conclude that the extent and costs of misallocation are substantial.

The basic methodology of the studies (hereafter, the "least cost studies") are also similar. They all utilize comparisons of aggregate traffic data and the average operating costs and shipper-borne costs associated with each mode for shipments of various distances to identify the amount of traffic carried by the mode which (on average) has the highest costs. The studies (except Meyer et al) then utilize this information to estimate the social costs of misallocation. The methodology will be referred to as the "least cost" approach.

This paper evaluates the properties of the "least cost" studies as estimators of the extent and costs of misallocaion. Section I reviews the factors which determine the optimum allocation of individual shipments. A probabilistic model of traffic allocation is developed to reflect evidence that the full costs of rail and truck transport vary considerably across individual shipments of a given distance. In Section 2, the "least cost" method is described and its assumptions delineated. In Section 3, the probabilistic market share model is used to demonstrate that the "least cost" methodology is positively biased as an estimator of traffic misallocation and social losses. Evidence that the cost estimates used in the "least cost" studies overestimate the average rail cost advantage is also presented.

The final section develops a new approach to the problem based on the probabilistic market share model and reports some preliminary results.

SECTION 1: FACTORS DETERMINING OPTIMUM MODE CHOICE: A MICRO VIEW

The review of studies of traffic allocation which employ aggregate data must be based upon a firm understanding of the factors influencing the cost minimizing choice of mode at the micro level, the level of individual shipments. The section briefly considers the operating costs of the modes and then turns to service quality. Based upon the discussion, a probabilistic market share model is developed.

Operating Costs, Service Quality, and Mode Choice

The production of rail and truck transport service is a complex process, and the operating costs of the modes reflect costs of performing the functions required to complete a shipment. The main functions include loading and unloading, pick-up and delivery operations, consolidation, switching (rail only) line haul movement, and interlining. The cost components vary with the size, density and length of haul, car and trailer type required, accessibility of the shipper or consignee to the rail network and main roads, density of rail traffic over route of shipment, handling characteristics of the commodity, terrain, climate, and other factors. Costs also vary with the firms performing the shipment. The operating costs of making a shipment by rail relative to the costs of truck transport vary for individual shipments. They depend upon the values of the various factors cited above.

The "least cost studies" contain service quality adjustments to rail and truck costs in recognition that the products offered by rail and truck firms differ in quality as well as in tariff costs.[7] The unavailability of rate data limits the possibility of studying the relative value of the two products over the population of shipments through direct estimation of demand curves for rail and truck transport. However, this problem may be in part circumvented by considering the underlying determinants of the demand curve.

Transportation is only one aspect of an industrial operation. The "systems approach" to management has empha-

Estimating Misallocation of Traffic Between Rail and Truck Transport

*by Joseph G. Altonji**†

sized the tradeoffs and interrelationships between quality of transportation and inventory, production, and marketing practices. The cost minimizing mode choice for a particular shipment is determined by (1) the freight rate and service quality (performance) vectors of each mode, (2) a vector of the firm's logistical characteristics and (3) commodity characteristics.

Service quality has a number of dimensions. Average transit time is important because of the capital costs of goods in transit. These costs may be very high for high value commodities and/or those which deteriorate physically, suffer from demand or supply related changes in market value, or from obsolescence. The size of the safety stock required to protect against stockout due to variability of use rates is also time related. Finally, for shipments which represent a response to an unanticipated need, average (and minimum) transit time may be crucial.

Time reliability is important because of the significance of planning for both the shipper and consignee. First, it affects inventory costs because time reliability influences the size of the safety stock needed to prevent stockouts as well as the probability that a stockout will occur. Secondly, late (and early) shipments disrupt warehouse operations.

The minimum shipment sizes at which carload and truckload rates may be attained also affect inventory costs, since the larger the minimum economical shipment size, the larger the storage capacity and average inventory size which must be maintained. For low volume goods, large shipment sizes may be impractical.[8] Other service characteristics include the probability of loss and damage, quality of loading and unloading services, and the packaging requirements associated with rail and truck transport.

It should be noted that the importance of the different service factors varies with commodity characteristics, such as value per ton, seasonality of demand, fragility, perishability, and storage costs. They also vary with characteristics of the shipper's operation, such as storage capacity and location of the sending and receiving plants relative to transportation facilities. In addition, the performance of the modes in the various service dimensions varies with the commodity type and origin and destination of the shipment.

Surveys of shippers support the above discussion. They indicate that service factors such as time reliability and average transit time are often as important in the modal choice decision as rate differences between modes. They also suggest that the importance of the different dimensions of the transportation product, as well as the performance of the modes in the dimensions, is variable over the shipper population.[9]

A Probabilistic Market Share Model

The above discussion suggests that the total cost of rail and truck transport consists of a number of cost components, each of which is functionally related to shipper, commodity, and geographic variables which describe the shipment and the transport products from which a choice must be made. Values of these variables differ across shipments, as does the total cost differential between the modes. The implication is that the total cost differential between rail and truck for particular shipments of a given distance block (i) may be regarded as a random variable described by some probability density function (pdf).

More formally, let $Cdif_i$ be a random vector of the modal cost differences (truck-rail) in each service cost or operating cost dimension for a particular shipment in distance block i. Let $TCdif_i$ equal the total cost differential between modes (truck-rail). $TCdif_i$ is equal to the sum of the cost components (the components of $Cdif_i$). The probability distribution of $TCdif_i$ is jointly determined through the functional relationships which determine $Cdif_i$ by the distributions of relevant shipper, commodity and geographic variables. There is reason to believe that the distribution is approximately normal.[10]

$TCdif_i$ is a composite function of a number of random variables. Its distribution would be approximately normal if it is a sum of one or more normal random variables and/or the sum of

*Charles River Associates.

†The author would like to thank Professors Richard C. Levin, Merton J. Peck and Jon K. Peck for their suggestions and encouragement. Computer support provided by Charles River Associates, Inc. is also gratefully acknowledged.

several random variables which are not greatly skewed and have some independence.[11] The basic contention, then, is that many factors affect transport costs and the effects of individual factors vary over shipments. This view is supported by consideration of the kinds of factors which determine the various cost components.[12] Evidence from surveys of shippers and a British survey of shipments also support this view. (See footnote 9 above.) A more thorough understanding of the determinants of transport costs is needed, but the author's assessment is that the assumption that $TCdif_i$ is normal is a reasonable one.

The discussion of $TCdif_i$ is now complete. From the conception of $TCdif_i$ as a random variable for individual shipments, the jump to a probabilistic market share model is straightforward. For any particular shipment, the efficient mode is described as follows:

Efficient Mode—Value of $TCdif_i$ for a Particular Shipment in Distance Block i

Rail—$TCdif_i > 0$ (i.e. truck costs above rail costs)

Truck—$TCdif_i \leqslant 0$ (i.e., truck costs below rail costs) (1)

Since $TCdif_i$ is normally distributed, the truck share may be represented as follows:

$$Tshr_i^* = F_{TCdif_i}(0) = \int_{-\infty}^{0} \frac{1}{\sqrt{2\pi\alpha_i^2}} \exp \frac{(TCdif_i - \overline{TCdif_i})^2}{2\alpha_i^2} \, dTCdif_i \qquad (2)$$

where:

$TShr_i^*$ = the optimum truck share in distance block i

F_{TCdif_i} = the cumulative distribution function of $TCdif_i$

α_i^2 = the variance of $TCdif_i$

$\overline{TCdif_i}$ = the average value of $TCdif_i$.

It may easily be shown that the larger the average rail cost advantage (the larger the value of $TCdif_i$) the smaller the optimum truck share.

The market share model is now complete. Below it is used in evaluating the "least cost" studies and as the basis of an approach to estimation of misallocation which is better suited to the aggregate cost and traffic data used in them.

SECTION 2: THE "LEAST COST" APPROACH

This section describes the methods and assumptions of the "least cost" studies. Specific reference is to Harbeson[13] and Sparling.[14] As stated earlier, the "least cost" procedure is based upon the determination of the total cost of rail and truck transportation, including operating and service quality-related costs for shipments of various distances and sizes. Sparling uses the cost comparison in conjunction with the amount of traffic in the various distance classes to determine a cost-based allocation of traffic.[15] The result is then compared to the existing allocation to determine the amount of traffic carried by the high cost mode in each group. Sparling and Domencich and Woods[16] interpret this traffic to be misallocated. Harbeson interprets the traffic share of the high cost mode to include misallocated traffic. He interprets the cost gap to be the social losses net of the benefits of using the high cost mode.[17] All the studies estimate the social costs of misallocation by multiplying the amount of traffic carried by high cost mode by the difference between the costs of the modes.

With the procedure outlined, attention may be turned to the calculation of the cost differences. Harbeson and Sparling make use of ICC data to determine the terminal and line haul variable costs of rail and truck transport.[18] The rail estimates are average figures for shipments with average values for load factor, line haul speed, switching time, train size, and many other parameters affecting the costs of particular rail shipments.[19] In addition, the relationship between operating costs and distance is an average for all the railroads in a region and for all origin-destination pairs a given distance apart. Finally, Sparling's estimates are for shipments in general service boxcars (unequipped) and Harbeson's are for a weighted average of the costs of the different equipment types.[20] Rail costs vary significantly with the type of equipment.

The estimates of truck operating costs are similar in nature. It was noted earlier that the ICC formulae, which provide information on the relationship between the components of operating costs of the modes and the weight and distance of the shipments, are in most cases literally the average value of the components for a sample of shipments of the given distance and weight. Harbeson and Sparling are both mindful that the formulae are not "readily applicable, without substantial changes to specific movements."[21] The "least cost" studies then, use the results for average shipments from average formulae.

The studies are forced to make an assumption about the shipment size which constitutes the relevant comparison between rail and truck. The assumption is necessary because the relationship between operating costs and shipment size and, consequently, between rates and shipment size, is different for boxcar and truck shipments. Minimum shipment size for which economical rates may be attained is generally higher for rail than truck. Harbeson, following Meyer, compared the costs of average size truck load shipments with those of average size carload shipments. He then attempted to adjust for the inventory, ordering, and storage costs associated with the size differential. The shipment size assumption has a strong effect on the estimate of the operating cost differential between rail and truck — the rail advantage when calculated for shipments of the same size is lower for many shipment sizes.[22]

The least cost studies have attempted to adjust for service quality differences between the two modes in the dimensions of average shipping time, minimum shipping size, and pick up and delivery service. Meyer et al attempted to characterize the costs of differences in average shipping time and minimum shipment size with equations involving what were believed to be representative values of a number of parameters.[23] As estimators of average service differential, the equations and the parameter values used suffer from a number of shortcomings, but it will simply be noted that neither the form of the equations nor the parameters used in them, such as interest rate, travel speed, and commodity value are in any way variable with the commodity type, shipment size, size of the shipper, and other characteristics of the shipment. Thus, the figures used in the quality of service adjustments are at best averages, although the importance of each element of quality of service is in fact dependent upon a number of factors specific to each shipment.

Estimation of Misallocation and Social Costs

The components of rail and truck costs are combined to yield $\overline{TCdif_i^*}$, an estimate of the average difference between truck and rail costs for each distance block. The optimum allocation of traffic in each distance block i is determined according to the following rule:

Efficient Mode, Distance Block i	Value of $\overline{VTCdif_i^*}$
Rail	$0 < \overline{TCdif_i^*}$
Truck	$0 \geqslant \overline{TCdif_i^*}$

Sparling (and Domencich and Woods) estimate the amount of misallocated traffic by summing the traffic carried by the inefficient mode in each mileage block. Harbeson, Sparling and Domencich and Woods calculate the social costs of misallocation by multiplying the absolute value of $\overline{TCdif_i^*}$ by the amount of traffic carried by the high cost mode and summing over all mileage blocks. The assumption, then, is that the value of $TCdif_i$ for the shipments carried by the high cost mode is on the average equal to $\overline{TCdif_i^*}$, which in turn is assumed to equal the true average differential for the shipments in distance block i, $\overline{TCdif_i}$.

The assumptions of the least cost procedure may be summarized as follows:

1) The procedure used to attain $\overline{TCdif_i^*}$ yields a reasonable estimate of $\overline{TCdif_i}$. (Errors in $\overline{TCdif_i^*}$ will result in errors in the determination of the efficient mode and/or errors in the estimates of the social losses of a given misallocation of traffic.)

2) The use of estimates of $\overline{TCdif_i}$ at the highly aggregate level of the distance block to determine optimum allocation of all the shipments within the distance block results in an unbiased, reasonably accurate estimate of the amount of traffic misallocated in each mileage block. The use of $\overline{TCdif_i^*}$, the estimate of $\overline{TCdif_i}$, in calculating the social costs of shipments carried by the mode with higher average costs results in an unbiased and reasonably accurate estimate of the social costs of a given misallocation of traffic.

The next section argues that assumptions 1 and 2 are violated. The results of the studies are then reconsidered in light of the violated assumptions.

BIASES IN THE "LEAST COST" APPROACH

Biases in the Estimates of $\overline{TCdif_i}$

The authors of the "least cost" studies carefully note the shortcomings of the estimates of the average operating and service related costs of rail and truck transport.[24] These must be kept in mind in interpreting the studies' results. A detailed critique of those estimates will not be offered given the caveats in the "least cost" studies. The emphasis here is on fundamental problems with the methodology rather than the data used in them. However, a few reasons why the estimates may be biased in favor of rail will be noted.

First, Harbeson and Sparling's estimates of the advantage of the smaller minimum shipment size of truck relative to rail appear to seriously understate the truck advantage. Sparling's estimate, based upon an inventory formula developed by Meyer et al. and also used by Harbeson, amounts to less than 1 percent of the rail costs calculated by Sparling for all shipment distances.[25]

Second, the studies do not reflect time reliability and probability of loss and damage. In these dimensions truck has an advantage. It is also worth noting that the I.C.C. estimates of truck costs used in the study are for Class I and II carriers of general commodities. However, recent research has indicated that the railroads' principle competition is from owner operators working in the exempt market or on leasing arrangements with regulated special commodity carriers. The costs of these firms appear to be competitive with the railroads for a wide range of commodities.[26]

Finally, it has not been recognized that there is a fundamental bias in the manner in which $\overline{TCdif_i}$ is estimated which tends to favor rail over trucks. $\overline{TCdif_i}^*$, which the studies interpret as the average difference in the costs of serving shipments by truck rather than rail, is in fact an estimate of the costs of serving existing truck traffic by truck minus the average costs of serving existing rail traffic by rail. However, the rail traffic share is biased toward commodities which are dense, easily handled and/or are not highly susceptible to loss and damage. Truck costs as well as rail costs are lower for the shipments carried by rail than for the shipments carried by truck. Consequently, $\overline{TCdif_i}^*$ is biased in favor of rail due to differences in the composition of rail and truck traffic on which the cost estimates are based.

In summary, the estimates of $\overline{TCdif_i}$ are based on less than ideal data and appear to be biased in favor of rail.

Biases of Aggregation Given That $TCdif_i$ is Variable

Little attention has been given to the properties of highly aggregated comparisons of the average costs of the modes used in the studies given that the truck-rail cost differential is variable within the unit of analysis — the distance block. It will be shown that the method used by Harbeson and Sparling is positively biased as an estimator of traffic misallocation and as a predictor of traffic shifts following rate deregulation. The method is also positively biased as an estimator of the social costs of a given misallocation of traffic. These criticisms are valid even if the operating cost and service equations of the "least cost" studies are correct in the sense that they yield true estimates of the average difference in the costs of the modes for shipments in each of the mileage blocks (i.e., $\overline{TCdif_i}^* = \overline{TCdif_i}$ for all i).

The "Least Cost" Method as an Estimator of Traffic Misallocation

First, it will be argued that the "least cost" method is positively biased as an estimator of traffic misallocation and as a predictor of modal shifts. In fairness it should be noted that Harbeson does not interpret all traffic carried by the high cost mode (truck) to be misallocated traffic. However, Sparling appears to[27] and Domencich and Woods use the calculation of traffic misallocation as the basis for predicting modal shifts following rate deregulation.[28]

The fact that on average the total costs of one mode (e.g., truck) are higher than the competing mode at a given distance does not imply that those costs are higher for all of the shipments carried by the high cost mode given that the total costs of the modes vary. This is shown by describing the impact of rate regulation on the total cost to the shipper of rail and truck in terms of the impact of rate distortions on the distribution of $TCdif_i$. It is then possible mathematically to represent the amount of traffic misallocated and compare the amount to the estimate of traffic misallocation from the "least cost" method.

Shipper decisions are based upon the difference in the total costs of rail and truck shipments faced by them, including the effects of rate distortions.

The components of the difference in the costs of truck and rail to the shipper are represented in (3)

$$STCdif_i = RTgap_i + OCdif_i + Sdif_i \quad (3)$$

where

$STCdif_i$ = the difference (truck-rail) faced by a shipper for a particular shipment

$OCdif_i$ = the operating cost differential

$Sdif_i$ = the service quality differential (in dollars), and

$RTgap_i$ = the gap between the difference in the rates of the modes and the $OCdif_i$.

Since $TCdif_i$ equals the sum of $OCdif_i$ and $Sdif_i$,

$$STCdif_i = RTgap_i + TCdif_i. \quad (4)$$

If rates were cost based, their difference would equal $OCdif_i$ and $RTgap_i$ would equal 0 for all shipments. $STCdif_i$ would equal $TCdif_i$ and be distributed as $N(\overline{TCdif_i}, \alpha_i^2)$. There would be no misallocation of traffic. The effect of value of service pricing and other forms of rate distortion resulting from regulation is to introduce a gap between $STCdif_i$ and $TCdif_i$. Shipments are misallocated if the rate distortion is large enough to make the sign of $STCdif_i$ opposite from that of $TCdif_i$. $STCdif_i$ has the joint distribution of $RTgap_i$ and $TCdif_i$ where the distribution of $RTgap_i$ is determined by I.C.C. policies.

Let $STCdif_i$ have the pdf, f_{STCdif_i}, so that the existing truck share may be represented as follows:

$$Tshr_i = \int_{-\infty}^{0} f_{STCdif_i} \, STCdif_i$$

It will be assumed that in a given distance block, traffic is misallocated from the low cost mode (rail) to the high cost mode (truck) only.[29] For a shipper to choose truck, $STCdif_i$ must be less than zero. A shipment for which $STCdif_i$ is less than 0 is misallocated only if $TCdif_i$ is simultaneously greater than 0. These shipments may be represented by evaluating the pdf of $STCdif_i$ conditional upon $TCdif_i$ for all values of $STCdif_i$ less than zero and $TCdif_i$ greater than zero.

$$\text{Misallocated traffic} = \int_{-\infty}^{0} f_{STCdif_i} \Big|_{TCdif_i} STCdif_i \int_{0}^{\infty} \frac{1}{\sqrt{2\pi\alpha_i^2}} \exp - \frac{(TCdif_i - \overline{TCdif_i^2})}{2\alpha_i^2} \, TCdif_i \tag{5}$$

Correctly allocated traffic may be expressed in a similar way. For these shipments the range of $TCdif_i$ is all values less than zero.

$$\text{Correctly Allocated Traffic} = \int_{-\infty}^{0} f_{STCdif_i} \Big|_{TCdif_i} STCdif_i \int_{-\infty}^{0} \frac{1}{\sqrt{2\pi\alpha_i^2}} \exp - \frac{(TCdif_i - \overline{TCdif_i^2}}{2\alpha_i^2} \, TCdif_i \tag{6}$$

Since it is assumed that traffic is misallocated in one direction only, $STCdif_i$ must be less than zero if $TCdif_i$ is less than 0 and so (6) is equal to $Tshr_i^*$, the optimum truck share represented in (2) above. Since $Tshr_i$, the fraction of traffic actually carried by truck, is equal to the sum of (5) and (6), it is clear that interpreting the entire traffic share of the high cost mode for a given distance block to be misallocated substantially overstates the true amount of misallocation. Furthermore, use of his interpretation in predicting modal shifts following deregulation (assuming cost based rates would be adopted by the industry) will overstate the shifts by the amount represented in (6). The error is an increasing function of the variance of the components of $TCdif_i$ which are independent of the rate distortion ($RTgap_i$). In other words, the greater the importance (relative to the effects of I.C.C. policies) of the various cost and service quality components in determining the difference in the total costs of the modes to the shipper ($STCdif_i$), the more often $STCdif_i$ and $TCdif_i$ are of the same sign and the less often that traffic would shift if the rate distortions were eliminated.

The important point is that the algebraic sign and size of the average difference between rail and truck costs cannot be used to determine misallocation without information on the distribution (e.g., the variance) of total costs over shipments in the distance block. Only if there is little variance can average costs be legitimately applied to determine the allocation of all the shipments.

This result may be understood within the framework of conventional economic analysis by considering that the overall importance and variance in service quality related factors across shipments determines the rate levels at which shippers are indifferent between modes. The distribution of the critical rate levels underlies the relationship between the demand curves of the modes. The larger the variance, the smaller the cross elasticity of demand for the modes and the fewer shipments would be affected by a given rate distortion. The least cost studies treat the demand curves for rail and truck as infinitely elastic at the rate level at which $\overline{STCdif_i} = 0$. Survey evidence suggests that mode choice is not extremely price sensitive, and there is sketchy econometric evidence that cross elasticity of demand between the modes is fairly low.[30] Furthermore, the operating costs of the modes, like shipper preferences, also vary across shipments, and rate levels reflect variations in these costs as well as factors associated with value of service pricing. The amount of traffic misallocation resulting from the I.C.C.'s rate making policies is probably a small fraction of the truck share in distance blocks where it is the high cost mode.

The results of this section may be dramatized by considering the estimates of traffic misallocation which would be produced by the least cost methodology if rail and truck rates are in fact cost-based. As mentioned earlier, in such a world the distribution of $STCdif_i$ is identical to $TCdif_i$, and consequently, there is no misallocation of traffic. However, as shown below, the "least cost" method would find the entire market share of the high cost mode to be misallocated.

High Cost Mode	Value of $\overline{TCdif}_i$	Least Cost Estimate of Traffic Misallocation	Actual Misallocation	Error of Least Cost Estimate
Truck	+	$Tshr_i$	0	$Tshr_i$
Rail	–	$Rshr_i$	0	$Rshr_i$

One must conclude that the method is not reliable as an indicator of misallocation or as a predictor of traffic shifts following deregulation.

Biases in the Estimate of Social Costs

The "least cost" studies overestimate the social cost of misallocation per unit of traffic carried by the mode with higher average costs. The studies (including Harbeson) assume this cost to be equal to the estimate of the average cost differential, $\overline{TCdif}_i^*$. However, the differential in the costs of the modes for shipments carried by truck will be smaller than the average differential. An informal proof of this proposition follows. It will be assumed that truck is the high cost mode. The basic argument is that the shipments for which the rate distortion is sufficient to cause a shift in modes are those for which the rail advantage is smallest.

Shipments go by truck only if $STCdif_i \leqslant 0$. Substituting from (4), this condition is equivalent to

$$STCdif_i = RTgap_i + TCdif_i \leqslant 0. \quad (7)$$

Given the distribution of $RTgap_i$, the larger the value of $TCdif_i$, the less likely that $STCdif_i$ is less than 0 and that the shipment has gone by truck. This implies that the average of $TCdif_i$ for shipments which have gone by truck (shipments which satisfy (1)) is smaller than the average for all shipments. This is the case as long the I.C.C. is not successfully following the perverse policy of completely offsetting variations in $TCdif_i$ by increasing $RTgap_i$.

SECTION 4: A TEST OF THE HYPOTHESIS OF MISALLOCATION USING PROBIT ANALYSIS

Fundamentally, the "least cost" approach is not suited to the study of freight traffic allocation at the levels of aggregation for which cost and traffic data are available. The approach applies to aggregate data a microeconomic decision rule appropriate to individual shipments. It has been shown the approach is invalid when the transport cost characteristics of shipments within the unit of analysis (the distance block) are variable, as is the case in the rail-truck market.

The probabilistic market share model developed in Section 2 is a "macro" model based upon explicit consideration of the conditions surrounding individual shipments. It provides a link from the aggregate data to individual shipments in a market through which the aggregate data may be interpreted. In this section it is extended into a formal empirical model to test the hypothesis of misallocation through the technique of probit analysis. Due to space limitations, the focus is on model development, but some preliminary empirical results are briefly reported.

Assumptions

The assumptions of the present section follow from Section 2.

1) $TCdif_i$ = is a random variable distributed as $N(O,\alpha_i^2)$.

2) $\overline{TCdif}_i^* = \overline{TCdif}_i + E_i$ where E_i is the error in the estimate of $\overline{TCdif}$ attained in the least cost study.

3) $RTgap_i$ = the impact of I.C.C. policies on the rail-truck rate differential. Its distribution depends upon I.C.C. rate making policies.

4) $STCdif_i = TCdif_i + RTgap_i$. Its distribution is a function of I.C.C. policies and the distribution of $TCdif_i$.

An additional assumption about the relationship among the α_i in different distance blocks is necessary if the parameters of the market share model are to be estimated over the data from different distance blocks. There is good reason to believe that α_i is an increasing function of the average values of rail costs and truck costs.

$TCdif_i$ is equal to truck costs minus rail costs, each of which are assumed to be normally distributed for the shipments in a given distance block. With increasing distance, the average value of rail and truck costs rise. They rise because each of the components of line haul related operating and service costs increase for both modes. Consequently, the effect of differences in characteristics of shipments on the costs of rail and truck transport are amplified, and α_i rises somewhat as a result of the increase in the cost level as the shipment distance rises. Variance per unit of fixed costs (including service related costs) is probably much larger than variance per unit of distance related costs. Thus, it will be assumed that α_i equals the square root of the sum of the variance of fixed costs and a component that is proportional to the level of line haul costs at distance i. This assumption follows from a property of normal random variables.[31]

Under the above assumptions,

$$\alpha_i = \sqrt{\alpha_k^2 + \alpha_v^2 \cdot LHavg_i^2} \text{ for all i.} \quad (8)$$

where

α_k = The square root of the variance of rail and truck costs which are constant with distance;

α_v = The square root of the variance of rail and truck costs which are variable with distance;

$LHavg_i$ = The average of the means of rail and truck distance related costs.

The Model to Be Estimated

The empirical model will be described. It is based upon the model presented earlier. From Equation (4), if there is no rate distortion, $STdif_i = TCdif_i$ and

$$Tshr_i = \int_{-\infty}^{0} \frac{1}{\sqrt{2\pi\alpha_i^2}} \exp - \frac{(STCdif_i - \overline{STCdif_i})^2}{2\alpha_i^2} \quad (9)$$
$STCdif_i$

$STCdif_i$ may be transformed into a standard normal variable [N(0,1)] by subtracting its mean and dividing by α_i yielding (10):

$$\int_{-\infty}^{-\overline{STCdif}_{i/\alpha_i}} \frac{1}{\sqrt{2\pi}} \exp - \frac{([STCdif_i - \overline{STCdif_i}]/\alpha_i)^2}{2} \quad (10)$$
$[STCdif_i - STCdif_i]/\alpha_i$

where $[STCdif_i - \overline{STCdif_i}]/\alpha_i$ is N(0,1). By definition, $-\overline{STCdif_i}/\alpha_i$ is the probit of $Tshr_i$ and will be called $Ztshr_i$. Thus,

$$Ztshr_i = -\frac{1}{\alpha_i} \cdot \overline{STCdif_i} \quad (10a)$$

Substituting for α_i from (8) yields

$$Ztshr = -\frac{1}{\sqrt{\alpha_k^2 + \alpha_v^2 \cdot LHavg_i^2}} \cdot \overline{STCdif_i} \quad (11)$$

From assumption 1, $\overline{TCdif_i^*} + E_i$ may be substituted for $STCdif_i$, under the null hypothesis of no rate distortion. For the moment, it will be assumed that the "least cost" estimates of $\overline{TCdif_i}$ are accurate, and $E_i = 0$.

To be useful in testing for the effect of regulation the model must allow for the different ways that I.C.C. policies could introduce a gap between $STCdif_i$ and $TCdif_i$. The different ways are accounted for in (12) below, which is a more general expression of (4).

$$STCdif_i = A + (c)\,[\overline{TCdif_i^*}] + U_i + TCdif_i \quad (12)$$

$$\overline{STCdif_i} = A + (1 + c)\,[\overline{TCdif_i^*}] + U_i \quad (13)$$

where A and C are constant for all distance blocks and U_i is independent of $TCdif_i$, has an expected value of 0 for any given distance block, and is specific to each distance block. If A or C are different from 0, or the variance U_i is large, then rate distortions are present.

The relationship between the A, C and U_i and I.C.C. policies is straight forward. The variable A equals the constant impact of I.C.C. policies on $STCdif_i$. To test whether the I.C.C. lowers truck rates or raises rail rates in this way, it is necessary to test whether $A \neq 0$. The variable C equals the proportion by which I.C.C. policies reduce (or increase) the rail cost advantage. If C is found to be less than (greater than) 0, then the I.C.C. engages in such a policy. Finally, the variable U_i represents the impact of I.C.C. policies which are non-uniform across distance and which are independent of $\overline{TCdif_i^*}$. It is assumed, however, that the standard deviation of U_i increases with $\sqrt{\alpha_k^2 + \alpha_v^2 LHavg_i^2}$. More specifically it is assumed that $\frac{U_i}{\sqrt{\alpha_k^2 + \alpha_v^2 LHavg_i^2}}$ is distributed as $N(0,v^2)$. The expected value for U in any one distance block is 0, and its variance, relative to the variance of $TCdif_i$, is constant across i.

Substituting from (13) for $\overline{STCdif_i}$ in (11) yields:

$$\mathrm{Ztshr}_i = - \frac{A}{\sqrt{\alpha_k^2 + \alpha_v^2 \cdot \mathrm{LHavg}_i^2}} + \frac{(1 + C)}{\sqrt{\alpha_k^2 + \alpha_v^2 \cdot \mathrm{LHavg}_i^2}} \cdot \overline{\mathrm{TCdif}}_i^* + \frac{U_i}{\sqrt{\alpha_k^2 + \alpha_v^2 \cdot \mathrm{LHavg}_i^2}} \qquad (14)$$

LHavg_i, TCdif_i, and Tshr_i may easily be obtained from the data in the least cost studies. The values of Ztshr_i corresponding to Tshr_i may be derived from a statistical hand book. The data may be used to estimate (14), using non-linear least squares. Unfortunately, only 3 of the 4 parameters are identified. However, the estimates of α_k, α_v and C imply a specific estimate of the sensitivity of market shares to the total costs of the two modes. Consequently, existing qualitative and quantitative evidence on the sensitivity of demand to price changes may be used in bounding the estimates.

Since the estimates of α_k and α_v indicate the sentitivity of market shares to rate distortions, they may be used in conjunction with (14) to determine the extent of misallocation in each distance block. The social costs of misallocation may be calculated by using the formula for the mean of a truncated normal distribution to estimate the mean of TCdif_i for the misallocated shipments.[32]

The author has estimated the model with cost and traffic data similar to that in Sparling and Harbeson. Its explanatory power is high (corrected $R^2 = .975$), indicating that shifts in the relative costs of the modes explain the shifts in traffic shares very well. The estimated coefficients were several times the size of their standard errors. The preliminary results are consistent with the hypothesis that $C = 0$, but suggest that rates may be distorted by a constant amount. However, the author believes the cost data to be biased in favor of rail transportation (i.e., $E_i > 0$ for most i) and conclusions must await further research. Effort should be directed toward improving the cost estimates, the utilization of data for different years, and disaggregation by commodity type.[33]

CONCLUSIONS

It has been shown that comparison of average costs of rail and truck with aggregate traffic data is not a valid test or measure of traffic misallocation and/or the social cost of rate regulation. It is invalid because the relative costs of the modes vary for shipments of a given distance. Consequently, the general conclusion of the studies reviewed here — that large traffic shifts would occur and that substantial savings would be realized if cost based rates were adopted following deregulation — must be reconsidered. The paper has developed a model of traffic shares that is suitable for aggregate data of the type used in the studies under review, and which may be used to test for traffic misallocation. The results of a preliminary application of the model are encouraging, but much remains to be done.

FOOTNOTES

1 See, for example, J. R. Meyer, M. J. Peck, J. Stenason and C. Zwick, **The Economics of Competition in the Transportation Industries**, (Cambridge, MA: Harvard University Press, 1960); Merrill J. Roberts, "Transportation Costs Pricing, and Regulation" in **Transportation Economics** (New York: National Bureau of Economic Research, 1965); Ann F. Friedlaender, **The Dilemma of Freight Transportation Regulation** (The Brookings Institution, 1969); Robert W. Harbeson, "Toward Better Resource Allocation in Transportation," **The Journal of Law and Economics**, October 1969, pp. 321-338; and Thomas G. Moore, "The Feasibility of Deregulating Surface Freight Transportation," in **Competition and Regulation**, ed. by A. Phillips, (Washington, D.C.: The Brookings Institution, 1975), pp. 55-98.

2 Meyer et al, op. cit., p. 165. This study included a thorough analysis of the cost of rail and truck transport for shipments of different distances. It should be noted that the study never uses the cost comparisons to actually estimate the extent or social costs of traffic misallocation.

3 Ibid., p. 194.

4 Thomas A. Domencich and Douglas W. Woods, "Competition in Intercity Freight Transportation," **Transportation Research Forum**, 1971, pp. 258, 274.

5 Harbeson, op. cit., p. 332.

6 Lee I. Sparling, "Rate Regulation and Freight Traffic Allocation—A Review and Revision," **Social Science Working Paper Number 68**, California Institute of Technology, 1974, pp. 19-24.

7 This section reflects a number of writings on service quality and the nature of the transport product, including Walter Oi and Arthur Hurter, **Economics of Private Truck Transportation**, (William C. Brown Company for the Transportation Center, Northwestern University, 1965); Paul Roberts and Donald Dewees, **Economic Analysis for Transport Choice**, (D. C. Heath, 1971), pp. 61-73; and Brian Kullman, "A Model of Rail/Truck Competition in the Intercity Freight Market," unpublished Ph.D. dissertation, Department of Civil Engineering, M.I.T., 1973, Chapter 3. See also his discussion of the work of Alexander Morton in Chapter 4.

8 For particular shippers, a good may be shipped in small volumes because the role of the good in the production process of the consignee and/or the operation of the consignee are small. Buhl has presented evidence from the 1963 Census of Transportation that the truck share varies inversely with plant size. See Walter F. Buhl, "Intercity Highway Transport Share Tends to Vary Inversely with Size of Plant," **Highway Research Record**, No. 175, pp. 9-14.

9 For example, see the 1962 shipper survey performed by the American Association of Railroads and the 1966 National Transportation Project Survey, cited in Kullman, op. cit., Chapter 3. A recent British study of the determinants of modal choice based upon a sample of shipments, found the freight rate per se to be unimportant in the choice of mode, with indirect service related cost dominating the shipper's decision. The study found that 60 percent of consignments had one or more "special feature of the consignment" which influenced the choice of mode. These included the need for specialized equipment, perishability, urgency, and the provision of special services in conjunction with delivery. All of these factors were found to favor truck over rail. See B. T.

Bayliss, Transport for Industry Study, Ministry of Transport, 1968, p. 40.

10 The form of the distribution is important to section 4 below, but not to the critique of the "least cost" method in section 3.

11 The latter condition is based upon the central limit theorem.

12 The numerous factors affecting operating costs have already been discussed. The process of transportation may be divided into several components, including pickup and delivery, terminal operations, and line haul expenses. The costs of each have some independence. For example, the location of a plant on a siding influences pickup and delivery costs, but would not affect line haul costs. Shipments between origin and destination pairs of high traffic density might involve lower than average line haul costs because of longer trains. The I.C.C. cost formulas make provision for adjusting the cost estimates of a given shipment to account for greater than average train length. (See Interstate Commerce Commission, Bureau of Accounts, Rail Carload Cost Scales by Territories for the Year 1970, Washington, D.C., 1973.) The estimates of the percentage of total costs that are variable and of most of the components of operating costs prepared by the I.C.C. are statistically derived or are averages over individual shipments. The cost formulas contain provisions for adjustment to reflect special circumstances.

Probability of loss and damage is related to physical characteristics of a good, which should be to a large degree independent of the time performance of the modes between particular points. The availability of special rail and/or truck equipment to reduce perishability is another variable which would affect the risk of loss and damage and would be expected to have some independence from time performance.

The average transit time for the modes is not a simple function of distance. Rail performance is affected by the location of the shipper and consignee relative to switching yards (i.e., the number of switchings required to move a car from point A to B), the quality of the yards, the railroad involved, the density of traffic between the points and other factors. (See Carl D. Martland, "Origin to Destination Unreliability in Rail Freight Transportation," unpublished Masters Thesis, M.I.T. Department of Civil Engineering, May 1972.) Truck performance between two points also reflects a variety of factors. Similar arguments could be made with respect to unreliability, availability of equipment and other factors.

13 Harbeson, op. cit.

14 Sparling, op. cit.

15 Ibid., pp. 6, 17.

16 Domencich and Woods, op. cit., pp. 273-274.

17 Harbeson, op. cit., p. 334.

18 Ibid., and Sparling, op. cit., pp. 17-18.

19 See the description of the cost estimates in I.C.C., Bureau of Accounts, op. cit.

20 See Harbeson, op. cit., pp. 326-327, and Sparling, op. cit., pp. 17-18.

21 Harbeson, op. cit., p. 324, and Sparling, op. cit., p. 8.

22 Sparling utilized Harbeson's approach for one set of calculations. (Sparling, op. cit.) He found the service adjustment to be small and excluded it from his cost estimates. However, following Friedlaender (op. cit.) he also compared the costs of rail and truck shipments of the same size, commenting that "AT this state in the analysis of rate deregulation, it seems more appropriate to shift traffic to the low-cost mode without altering other shipper decisions, especially since the inventory effects of differences in service are not well formulated." (Ibid., p. 14). The assumption of such an analysis is that the shipment size is determined by logistic considerations which dominate modal choice (i.e., shipment size is independent of modal choice). That assumption, and the assumption in Sparling's other calculation are both extreme. In any event, since Sparling does not compare rail and truck costs and estimate traffic misallocation on a weight and distance block basis, further consideration is limited to his calculations for distance blocks only, which are based upon the assumption of average rail and truck shipment sizes. However, the critique in Section 3 applies to both sets of calculations.

23 See Meyer, et al., op. cit., Chapter 7 and Appendix D.

24 For example, see Sparling, op. cit., pp. 8-10.

25 Morton compared revenue per ton mile paid for truck and rail shipments of each of seven different commodities for a variety of distances and weights. Averaging across commodities he found that shippers pay a premium of about 20 percent to send a shipment of a given size by truck rather than by rail. He also found that shippers pay an additional premium of 30 to 40 percent per ton to send a shipment one half the size of a rail shipment. For a number of reasons, these figures substantially overestimate the importance of minimum shipment size for the average shipment. Never the less, the 1 percent increase used by Harbeson is too small. See Alexander L. Morton, Competition in the Intercity Freight Market, DOT, NTIS, PB 198 578, 1971, p. 138.

26 See D. D. Wyckoff and D. H. Maister, The Owner-Operator Independent Trucker, D. C. Heath and Company, 1975, Chapters 1 and 3.

27 Domencich and Woods, op. cit., pp. 273, 277 and Sparling, op. cit. pp. 6, 19.

28 Domencich and Woods, op. cit., p. 274.

29 Neither the "least cost" method nor the probabilistic market share utilized below could detect misallocation of traffic in both directions with aggregate market share and cost data. The probabilistic market share model would determine the net impact upon the market shares of the modes in each distance block.

30 See the surveys referenced in footnote 9. Evidence on the own price and cross elasticity of demand for the modes has recently been reviewed in Charles River Associates, Price Elasticities of Demand for Transportation Fuels. Prepared for the Federal Energy Administration, Office of Transportation Research, Washington, D.C. pp. 184-196.

30 For a more detailed discussion of the model developed in this section, its applications, preliminary results, and research possibilities, see Joseph G. Altonji, "An Application of Probit Analysis to the Study of Traffic Misallocation between Rail and Truck," discussion paper, June, 1976.

31 The text erroneously assumes if $K = N(u_k, \alpha_k^2)$, $X = N(u_x, \alpha_x^2)$, $LH = b \cdot X$ where b is a scalar and $W = K + LH$, then $W = N[(u_k + b \cdot u_x), (\alpha_k + b \cdot \alpha_x)^2]$. In fact, W would be $N[(u_k + b \cdot u_x), (\alpha_k^2 + b^2 \cdot \alpha_x^2)]$. In the text, $\sqrt{\alpha_k^2 + \alpha_v^2 \cdot LHavg_i^2}$ should be substituted for $\alpha_k + \alpha_c \cdot LHavg_i$.

32 For a full explanation, see Ibid.

33 See Ibid. As part of a larger study of piggyback transportation, a group in the Yale University Department of Economics is presently conducting research along these lines.