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Econometric Alternative To Rail Output Measure and Analysis

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INTRODUCTION

THE currently accepted unit of transportation output, the ton-mile, has been widely criticized for its poor performance in a variety of applications in the transportation industry. Inappropriate applications of the unit with regard to productivity analysis, fuel usage, and transportation industry output have been pointed out in several publications.[1]

Much of the shortcomings of the ton-mile unit follows from the lack of homogeniety in the unit between modes, but especially between commodity markets being served. As a result, the use of the ton-mile to compare output over time, or between carriers even within the same transportation mode is inappropriate, as long as the commodity mix, service characteristics, and other factors are not held constant. Other output related characteristics of a carrier can bias the ton-mile in its ability to measure output.

An example of one such bias is presented by Ralph Nelson in which ton-miles and freight revenues are compared between two truck carriers for the same year.[2] If we assume that freight revenue measures the value of services being offered by a carrier, (i.e., the place utility "produced" by the carrier) then one would expect a valid unit of output measure to follow the dollar value put on it. In Nelson's example, however, Carrier A generated more ton-miles than Carrier B (1.271 billion vs. 1.185 billion) but collected 20% less revenue than Carrier B. The obvious conclusion here is that the ton-miles Carrier A produced were of less value on average than those produced by Carrier B.

While Nelson points out examples of the ton-mile's improbable accuracy as an output measure by comparing it to revenues, Quast has presented a strong argument showing the ton-mile to create "untenable conclusion(s) concerning the (transportation) industry's production function."[3] Comparing the ton-mile output of two transportation modes (i.e., air and motor carriers) with varying weight and distance capacities per unit of time, he shows that the lower-weight/more-distance technology could produce less ton-miles per unit of time, with a higher level of factor use than the higher-weight/less-distance technology. The conclusion flows from the erroneous assumption that at all levels of ton-mile output, the "value" of weight to distance is constant. It is clear that at some level of distance or weight, the ratio of the value of tons to miles is changed. If this were not the case, various modes of transportation service would not be economically feasible.

The purpose of this paper is to present a measure of output for the rail industry which overcomes some of the more obvious problems with the ton-mile measure of output. The desire is to have an output measuring system which is more applicable to traditional economic analysis.

THE ECONOMETRIC ALTERNATIVE

One approach to overcoming the problem of the lack of homogeneity in the ton-mile unit of output has been the econometric technique of output measure. A relationship which had good results in a study using trucking data involves the rate of change in revenue between a group of transportation firms, with changes in shipments, average weights and average haul.[4] This model of output encompasses a wider range of the characteristics of a given transportation firm. In the rail industry specifically, the number of carloadings indicates gross volume; the amount of all product types moved. The average weight, or tons per carload can indicate differences in the product mix a given firm transports, to the degree that different products have different density and shape. With varying densities and shapes come varying possibilities to increase the value of a commodity by a given carrier moving it from one place to another. For example, the value of coal can be increased at faster rate per ton due to place utility provided by the railroad than, say, consumer goods and other merchandise. More generally, however, we assume that the higher the level of average tons per car or utilization, the greater the output at constant volume and haul. Average haul, the mean

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distance of all shipments made, also has a positive relationship with output. It is clear that if two cars of the same weight and product are moved different distances, the "output" represented by each move would be different based on the distance. The difference would be reflected by both cost and revenue differentials resulting from the moves.

Data used in this analysis involved ten Class I rail carriers in the Western District. Total revenue, total carloadings, total tonnage and average haul data was collected from 1970 through 1979.[5] The purpose of this paper is to develop an index of output for the service provided by these ten firms over the period studied, and to test the impact on aggregate output (all ten railroads combined) of various simulation scenarios.

The estimation of the model was accomplished using a natural log transformation of the data so that the model would take the following form:

$$Q = A_0 \times (C^{\alpha_1}) \times (U^{\alpha_2}) \times (H^{\alpha_3})$$

Where: Q = Rail Output

C = Cars

U = Tons per Car (annual average)

H = Miles per Car (annual average)

This form is particularly useful as it estimates elasticities directly, or the rates of change in output associated with rates of change in the three independent variables. The "proxy" for output in estimating the equation parameters is revenue.

Revenue vs. costs has been discussed by others with regard to this method of output level determination. The choice of revenue over costs as the dependent variable, can be justified due to the assumption that revenues measure the market value of the service being offered by the rail carriers. In addition, two separate studies, one using costs and another revenues, have shown that the relative impacts of the three independent variables were similar.[7] The question begs answers beyond the scope of this work, however, and we will assume, for the present, that revenue is the "correct" aggregate as a proxy for output.

ESTIMATION OF THE OUTPUT EQUATION

A pooled cross-sectional approach was used to estimate the parameters of the model equation. Since the data crosses over time (1970 through 1973) as well as over different rail carriers a set of boolean vectors were included in the regression analysis to account for changes in revenue "over time" assuming cars (C), tons per car (U) and average haul (H) constant. The nine "dummy" variables measure exogenous changes in revenue (i.e., inflation) from 1970 to each of the years preceding in the data. These variables can be defined as:

D_i = A vector with zeroes in every year except in the i^{th} year. In the i^{th} year the vector holds the value of 1,

where i goes from 1971 through 1979. In its linear form, the coefficient for D_i becomes the price index for the i^{th} year, where 1970 is the implicit base year (i.e., 1970 price index = 1.0). As Figure I indicates, the model can be thought of in terms of the "real" portion (change revenue related to C, U, and H) and the "price" portion (the change in revenue due to price level). As can be seen, the model appears to have a considerable degree of reliability with t-scores well within the range of statistical significance for each variable's coefficient. When total revenue was estimated over the cross-sectional pool, the mean squared error was \$60 ±10% of the mean of all annual revenues. The model was more accurate estimating aggregate revenue for all ten railroads, as the mean square error was ±1.3% of the mean revenue of the ten carriers for all years from 1970 through 1979. Figure II gives a graphical representation of the close fit of the model's estimate of aggregate revenue.

THE OUTPUT INDEX

If the "price" portion of the equation in Figure I is removed, an estimate of "real" output can be made with values for C, U, and H. From Figure I then we get:

$$\text{(Eq. 1)} \quad Q_{ij} = .2576 \times C_{ij}^{.998} \times U_{ij}^{.249} \times H_{ij}^{.994}$$

where, Q = Real Output

C = Cars

U = Tons/Car

H = Average Haul

i = Subscript for values from year "i"

j = Subscript for values from carrier "j"

RAIL OUTPUT MODEL SPECIFICATIONS

NOMINAL OUTPUT (REVENUE) = REAL OUTPUT x RELATIVE PRICE

$$R = 0.2756 \times C^{.998} \times U^{.249} \times H^{.994} \times (1.091D_{71} + 1.148D_{72} + 1.151D_{73} + 1.37D_{74} + 1.542D_{75} + 1.64D_{76} + 1.728D_{77} + 1.833D_{78} + 1.961D_{79})$$

T-Ratios = (—3.55 (101.63) (3.18) (34.73) (2.87) (4.55) (4.57) (10.03) (13.31) (15.08) (16.59) (17.99) (19.69)

$\bar{R}^2 = .999$ Standard Error as % of Mean % R = 0.526

F-Ratio = 41780 Standard Error as % of Mean of R = 9.728

FIGURE I

By summing estimated real output from each carrier, total or aggregate output can be defined.

$$\text{(Eq. 2)} \quad TQ_i = \sum_{i=1}^{10} Q_{ij}$$

Table I presents actual revenue, estimated revenue (or nominal output) and estimated real output (TQ), and an index of TQ with base 1970 = 1.00. As can be seen, total estimated real output has increased by 30% over the ten-year period representing a compound annual growth rate of 2.62%.

EFFICIENCIES OF VARYING SCALES ON AGGREGATE

As mentioned above, the model was estimated from data for ten Class I carriers in the Western District. The carriers represent a range of various volume handling, trackage length, and average haul levels. As a result, a variety of single carrier outputs were arrived at before a summation to an aggregate total was made.

To compare the effects of various scales on output, the sample of 10 carriers were ranked in order of highest to lowest total output from 1970 through 1979. Volumes were adjusted upward by 100,000 cars per year for the two highest output carriers. Then real output was re-estimated. The results of this are shown in Simulation I of Table II. The same algorithm was done substituting the two middle and the two lowest output carriers. Results for these simulations are represented in Simulation II and III, respectively.

As can be seen, in all years the greatest increase in aggregate output (due to the additional 100,000 carloads) came when carloads were added to the largest carriers. The effects on output by increasing middle and low carriers' carloadings were more mixed. While the 1970-1979 percent change indicates the middle size (i.e., sized = level of output as estimated) carriers contributed to aggregate output at a higher rate, a year-to-year comparison indicates both groups impacted output higher than one another in four years, and in one year (1972), the index was equal.

While this sample certainly is not large enough to draw airtight conclusions about efficiencies of scale, it appears as though the two largest railroads have average hauls and tons per car characteristics which result in greater output given increased carloadings.

The purpose here, however, is to point out the kind of economic analysis which can be applied to this technique of transportation output measurement.

Table III presents a more continuous simulation exercise. In this case the model is re-simulated ten different times, instead of the three in the preceding example. In this instance 200,000 carloads per year are added to one carrier and then the model is simulated. A ten-year summation of total output is then arrived at for each re-simulation, and com-

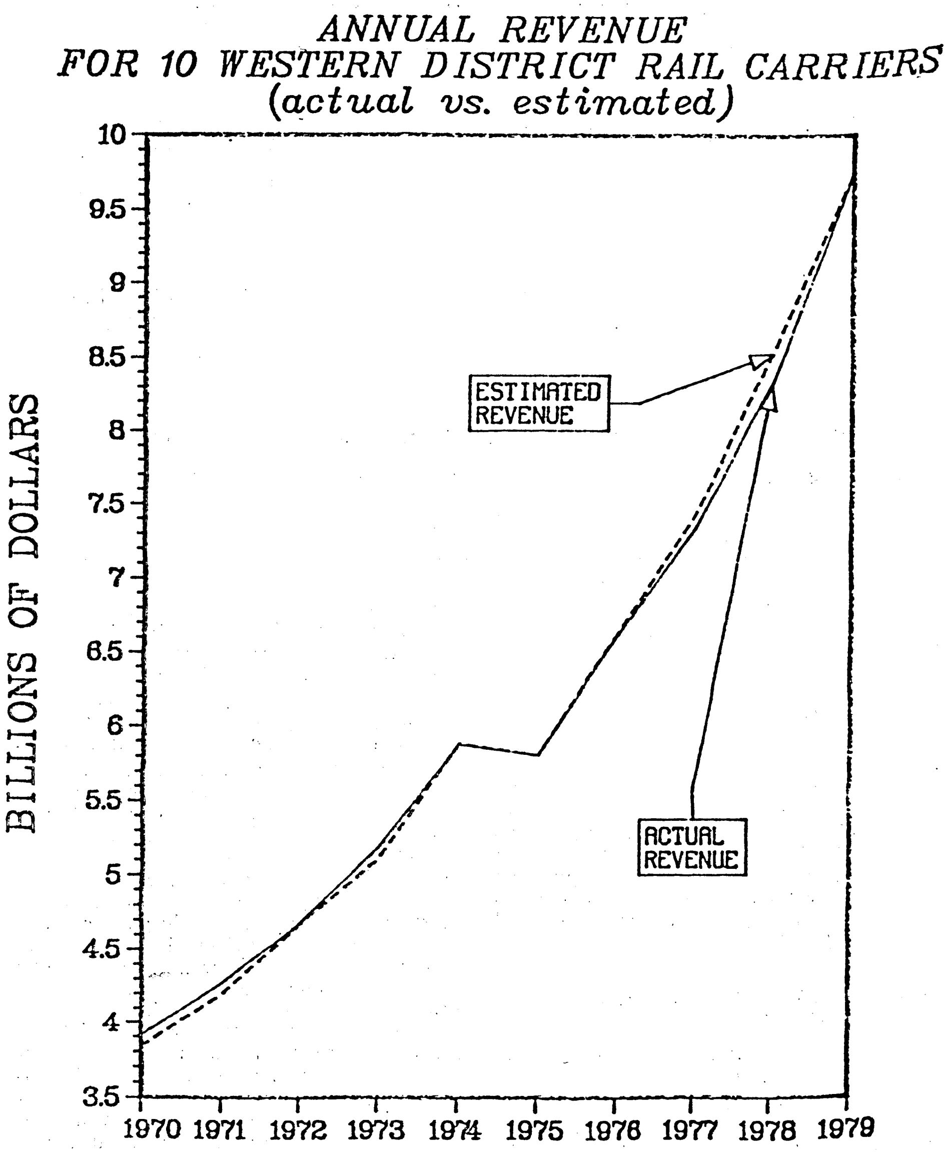

FIGURE II

pared to the actual ten-year summation of output. The percent "impact" of the addition of 200,000 cars is presented for each carrier in the far right column in Table III. The "Impact" is compared with the scale index (SI) of each carrier which is defined as each carrier's total output divided by the output for all carriers in the sample.

Figure III presents a scatter diagram of the data in Table III. The data maps out two distinct clusters. The four largest railroads in the sample cluster around line B, while the smallest six accumulate around line A. The similar slopes of line A and B indicate that within each cluster, increasing scale appears to have a negative relationship with the simulation impact. Specifically, this means that within each cluster the

TABLE I

ACTUAL OUTPUT COMPARED WITH THREE SIMULATIONS

YEAR	ACTUAL REVENUE	ESTIMATED* REVENUE	ESTIMATED OUTPUT	ESTIMATED OUTPUT INDEX
1970	3909352	3837405	3837405	1.0000
1971	4271316	4196959	3847435	1.0026
1972	4662013	4658875	4056994	1.0572
1973	5174165	5101197	4431685	1.1549
1974	5868412	5876861	4289398	1.1178
1975	5803221	5803355	3763039	.9806
1976	6616071	6626741	4039905	1.0528
1977	7330924	7421267	4295735	1.1194
1978	8321642	8522041	4650261	1.2118
1979	9740382	9747020	4970037	1.2952

*Mean square error, ((Act.—Est.)^2) = 1.8% of actual mean.

TABLE II

Year	Output* Index	Simulations I	II	III
1970	1.0000	1.0000	1.0000	1.0000
1971	1.0026	1.0043	1.0028	1.0030
1972	1.0572	1.0583	1.0570	1.0570
1973	1.1549	1.1548	1.1544	1.1543
1974	1.1178	1.1186	1.1177	1.1178
1975	.9806	.9842	.9818	.9817
1976	1.0528	1.0559	1.0530	1.0541
1977	1.1194	1.1223	1.1192	1.1195
1978	1.2118	1.2136	1.2109	1.2108
1979	1.2952	1.2966	1.2937	1.2928

*Output $\text{Index}_i = \dfrac{TQ_i}{TQ_{1970}}$, where i = 1970 through 1979.

TABLE III

IMPACT ON OUTPUT OF INCREASING VOLUME AT EACH SCALE

RANK OF CARRIER	SCALE INDEX[1]	IMPACT[2]
(1)	232.501	101.830
(2)	211.888	101.848
(3)	177.918	102.188
(4)	170.183	102.099
(5)	71.041	100.973
(6)	48.970	101.222
(7)	29.452	101.326
(8)	24.442	101.119
(9)	17.223	101.568
(10)	16.382	101.124

$$1\ \text{Scale Index} = \frac{\text{Total Estimated Output for Carrier}_i\ \text{(1970 through 1979)}}{\text{Average Output For All Carriers (1970 through 1979)}}$$

$$2\ \text{Impact} = \frac{\text{Estimated Total Output Simulated with 200 Additional Cars for Carrier}_i}{\text{Actual Estimated Total Output}}$$

AGGREGATE IMPACT OF INCREASING VOLUME AT VARIOUS SCALES

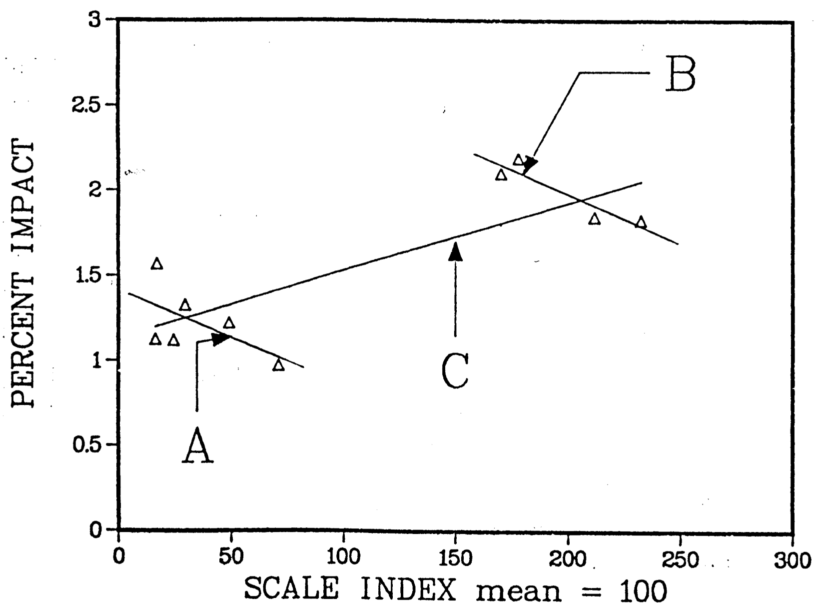

FIGURE III

smaller the carrier, the greater the impact on aggregate output of additional carloads to that carrier.

If we compare the two clusters, however, we find a perpendicular relationship to that indicated by lines A and B. If we assume the high and low clusters group around line C we find that between clusters, or a certain range of scales the efficiency of scale appears to have a positive trend. More specifically, the carriers along line A which are smaller, have a less efficient impact on aggregate output than the larger carriers along line B given equal additional carloads for individual carriers within each group. Whether this relationship is true for all scales could only be answered with a larger and more continuous sample of rail carriers.

CONCLUSIONS

It seems fairly clear that the ton-mile as a unit measure of rail (or transportation) output causes difficulties in economic theory due to its untenuous assumption of constant value ratio of tons to miles, as well as its lack of homogeniety between commodity mixes and modes.

The econometric approach presented here offers some solutions to the difficulties of the ton-mile. In addition, it is more conducive to economic analysis. In the application presented here, the economic analysis concerns efficiencies of various scales on output. Limited by the size of the sample, a fair conclusion is that within groups of like carriers, the rule of decreasing returns to scale appears to have supporting evidence. This is apparent from the indirect relationship of points within the two clusters of points in Figure III. What is most interesting is the perpendicular relationship of the cluster-to-cluster trend represented in line C of Figure III, and the point-to-point trend within each cluster (i.e., lines A and B).

As mentioned before, analysis such as this could have more meaning as the sample grows. It is clear that this approach to output measure and analysis lends itself to more applications of the analysis of traditional economic literature.

FOOTNOTES

1 Allen C. Flott et al., "The Ton-Mile: Does It Properly Measure Transportation Output?," **Transportation Research Record** 577 (1976): 19-26.

2 Ralph L. Nelson, "Measuring Motor Carrier Productivity," **Transportation Research Forum Proceedings** 17 (1976):469-477.

3 Theodore Quast, "The Output Unit in Transportation," **Transportation Journal** 10, (Winter, 1970) 5-7.

4 Ralph L. Nelson, op. cit.

5 **Moody's Transportation Manual,** 1980.

6 Ralph L. Nelson, op. city. :471.