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Estimating the Demand for Truck and Rail Transportation: A Case Study of California Lettuce

By Walter Miklius

IN THE PAST, research in transportation economics mainly focused on supply. Despite the almost universal adoption of demand-oriented pricing by transportation industries and regulatory bodies, demand received relatively little attention.

However, the apparent neglect of demand is being remedied. This is evidenced by two recent studies on demand for transportation services, one by Perle and one by Benishay and Whitaker.¹ Interest in demand is timely because of expanding transport opportunities provided by intermodal competition as well as increasing use of private carriers. As a result, the traditional use of the value of the commodity (alone or in conjunction with transport cost as a percentage of the price of the commodity at destination) as an indicator of the elasticity of demand for transport is increasingly less reliable.

The main differences between the studies cited above and the one reported in this paper are in the level of aggregation and the nature of the data. Both of the above studies dealt with the demand for transport services at national or regional levels and utilized time series data. For many purposes, however, knowledge of demand at a much less aggregated level is necessary.

This study follows an earlier one by Limmer.² It examines further the possibility of estimating demand for truck and rail trans-

port services at the commodity level by using data from a cross-sectional sample of destinations for shipments from one origin. Unlike prices of other commodities, freight rates exhibit enough cross-sectional variation at a given point in time to permit the use of cross-sectional analysis in measuring the response to differences in them. Furthermore, the ability to use cross-sectional data is important since such data can be collected through sampling if time series data are not available.

Sources and Nature of Data

The U.S. Department of Agriculture collects data on rail and truck unloads of fresh fruits and vegetables at the major U.S. cities. These data were utilized in this study. The output measures for transport services are number of cars for rail and number of carlot equivalents for trucks. The commodity being transported is lettuce, originating in California and unloaded at selected out-of-State destinations during 1964. The truck unload data were adjusted for incomplete coverage of unload reports.

Actual freight rates were used as a price measure. Several rail freight rates were in effect in 1964, depending on the minimum weight of the shipment. The freight rate applicable to the weighted average weight of shipments was used.³

Truck freight rates were obtained from shippers, truck brokers, and truckers located in California. Since interstate truck transportation

¹ E. D. Perle, "The Demand for Transportation: Regional and Commodity Studies in the United States," Univ. Chicago, 1964, and H. Benishay and G. R. Whitaker, Jr., "Demand and Supply in Freight Transportation," Jour. Indus. Econ. Vol. 14, July 1966, pp. 243-260.

² E. Limmer, "The Elasticity of Demand for Railroad Transportation of Florida Produce," Jour. Farm Econ. Vol. 37, Aug. 1955, pp. 452-460.

³ The estimated weighted average weight of rail carloads of lettuce shipped from California was 37,812 pounds. The rate applicable to the minimum weight of 36,000 pounds was used. Weighted average weight computed from data supplied by the Southern Pacific Company.

of lettuce is exempt from economic regulation by the Interstate Commerce Commission, truck freight rates fluctuate in response to changes in supply and demand in the transport markets.⁴ Therefore, instead of a single rate to each destination, a number of quoted rates were obtained. In order to minimize the effect of variation in quotations, modal instead of average rates were used.

All freight rates were converted from per standard container or per 100 pounds to per ton-mile, and they included the refrigeration charge. The choice and number of out-of-State destinations were limited by the availability of truck freight rates. The sample included 30 major U.S. population centers, most of which are east of the Mississippi River.

The Model

It was assumed that California lettuce shippers have an effective choice between truck and rail transport services to all destinations considered. Therefore, it could be expected that shippers' decisions to utilize one mode rather than another would be based on truck and rail rates. Factors other than rates, however, may affect the quantities shipped by each mode. First, the size of the market for California lettuce may have an independent effect on shipments by either mode. Other things being equal, the larger the market, the more shipments one can expect by each mode. Second, a preliminary analysis indicated possible regional differences. The destinations, therefore, were divided into two groups, those in the North Central and Northeast regions, and those in the Southern region, and a dummy variable was added to stand for the possible effect of the destination region.

Single-equation regressions were applied since both price variables are assumed to be predetermined. The rail rate is regulated and independent of the quantity of lettuce moving to any single market. Truck rates, although

established in a competitive market, can be assumed to be predetermined because they depend on the movement of all agricultural commodities from all origins to all destinations.

The size of market variable is also assumed to be predetermined. This is equivalent to an assumption that the demand for spatial movement of lettuce is infinitely inelastic with respect to transport charges. This assumption in turn does not appear to be unreasonable considering that the demand for lettuce is inelastic (available estimates at wholesale range from -0.34 to -0.50) and the transport charges account for a small percentage of the price at destination.

Initial investigation did not provide any strong indications of an appropriate mathematical form for the estimating equation. The demand relationship, therefore, was assumed to be linear in the logarithms for all variables, that is, the estimated elasticity coefficients were assumed to be constant. The following two estimating equations, for rail and truck services respectively, were used:

$$\begin{aligned} \text{Log } Q_r = & a + b_1 \log P_r + b_2 \log P_m \\ & + b_3 \log Q_t + b_4 D \end{aligned}$$

$$\begin{aligned} \text{Log } Q_m = & a + b_5 \log P_r + b_6 \log P_m \\ & + b_7 \log Q_t + b_8 D \end{aligned}$$

where:

Q_r = shipments by rail in cars

Q_m = shipments by truck in carlot equivalents

Q_t = size of the market (i.e., total shipments, $Q_r + Q_m$)

P_r = rail freight rate in cents per ton-mile

P_m = truck freight rate in cents per ton-mile

D = dummy variable for possible effect of destination region; values assigned where 1 for destinations in the North Central and Northeast regions and zero for destinations in the Southern region.

⁴ Some of the variation can be attributed to the manner of quoting rates. Shipping charges are frequently negotiated on a per load rather than a per container basis. Sometimes the refrigeration charge is included in the quoted rate; at other times it is an extra.

The expected values of coefficients, other than constant terms and dummy variable, are as follows:

<i>Rail</i>	<i>Truck</i>
$b_1 < 0$	$b_5 > 0$
$b_2 > 0$	$b_6 < 0$
$b_3 > 0$	$b_7 > 0$

The level for allowing variables to enter the regression equation was specified at $F = 1.00$.

Empirical Estimates

The statistical results for rail transport services were:

$$(1) \quad \begin{aligned} \text{Log } Q_r = & 2.98 - 8.70 \log P_r + 0.73 \log Q_t + 0.27 D \\ & (0.99) \qquad (0.20) \qquad (0.12) \end{aligned}$$

$$R^2 = 0.86$$

Results for truck transport services were:

$$(2) \quad \begin{aligned} \text{Log } Q_m = & 0.49 - 8.51 \log P_m + 6.54 \log P_r + 1.10 \log Q_t - 0.59 D \\ & (2.08) \qquad (0.98) \qquad (0.20) \qquad (0.11) \end{aligned}$$

$$R^2 = 0.83$$

The variables included in the model explained most of the variance in the rail and truck shipments, and all of the regression coefficients of entering variables were significantly different from zero in the expected direction. The demand for services of both modes appeared to be relatively elastic with respect to freight rates.

The size of market coefficient was about the same for both modes, indicating that both were affected proportionally. The coefficient of the dummy variable, on the other hand, indicated

fewer truck shipments, *ceteris paribus*, to the North Central and Northeastern destinations than to the Southern destinations, and vice versa for rails. The most plausible explanation for the regional differences refers to the type of facilities utilized. In the North Central and Northeastern destinations, older facilities are more adapted to handling rail traffic.

Two problems, however, should be noted. First, it may be argued that the relatively high R^2 is due to expected high correlation between Q_r or Q_m and Q_t . Since $Q_t = Q_r + Q_m$, the correlation is between "a part" and "a whole." To check this effect, total lettuce shipments from California (Q_t) were replaced with total lettuce shipments to a given market from all origins, Q_u .

The statistical results were as follows:

$$(3) \quad \begin{aligned} \text{Log } Q_r = & 3.14 - 8.51 \log P_r + 0.69 \log Q_u + 0.25 D \\ & (0.99) \qquad (0.19) \qquad (0.12) \end{aligned}$$

$$R^2 = 0.86$$

and

$$(4) \quad \begin{aligned} \text{Log } Q_m = & 0.27 - 9.39 \log P_m + 6.83 \log P_r + 0.97 \log Q_u - 0.61 D \\ & (2.28) \qquad (1.06) \qquad (0.20) \qquad (0.13) \end{aligned}$$

$$R^2 = 0.80$$

These results, however, could have been expected if California supplied some constant percentage of the total. Although the percentage of the total lettuce supplied by California in various markets varied between 40 and 80 percent, it was desirable to replace Q_u with a variable independent of lettuce shipments. Thus, 1964 population estimates (P_0) were used.⁵

⁵ U.S. Bureau of the Census, Population Estimates, Series P-25, No. 330, March 21, 1966, pp. 10-17. Population of cities not included in the above publication estimated from the 1960-64 percentage change in the nearest included city. 1960 population estimates from U.S. Bureau of the Census, United States Census of Population 1960, Final Report, PC(1)-1A, 1961, pp. 1-105.

The statistical results were:

$$\begin{aligned} \text{Log } Q_r &= 2.80 - 7.71 \log P_r + 0.65 \log P_o \\ &\quad (1.04) \quad (0.18) \\ (5) \quad &\quad \quad \quad + 0.22 D \\ &\quad \quad \quad (0.12) \end{aligned}$$

$$R^2 = 0.85$$

and

$$\begin{aligned} \text{Log } Q_m &= 0.31 - 9.97 \log P_m + 7.97 \log P_r \\ &\quad (2.36) \quad (1.13) \\ (6) \quad &\quad \quad + 0.91 \log P_o - 0.65 D \\ &\quad \quad \quad (0.20) \quad (0.13) \end{aligned}$$

$$R^2 = 0.79$$

Changes in results were negligible. The P_r and P_m coefficients remained relatively stable.

The second problem was the failure of truck freight rates to enter regression equations (1), (3), and (5). This could not have been a result of high collinearity because the simple correlation coefficient between P_m and P_r was only 0.10. Examination of unexplained residuals, however, suggested that the log-linear form may not have been most appropriate for rail shipments. Regression equations (1), (3), and (5) were repeated using natural numbers rather than logs. The statistical results were:

$$\begin{aligned} Q_r &= 247.89 - 1079.55 P_r + 733.76 P_m \\ &\quad (123.91) \quad (248.86) \\ (1a) \quad &\quad \quad + 0.87 Q_t + 146.91 D \\ &\quad \quad \quad (0.04) \quad (70.07) \end{aligned}$$

$$R^2 = 0.98$$

$$\begin{aligned} Q_r &= 1775.00 - 941.35 P_r + 0.42 Q_u \\ &\quad (143.49) \quad (0.02) \\ (3a) \quad &\quad \quad + 136.72 D \\ &\quad \quad \quad (80.53) \end{aligned}$$

$$R^2 = 0.97$$

$$\begin{aligned} Q_r &= 201.69 - 581.57 P_r + 342.49 P_m \\ &\quad (266.04) \quad (136.83) \\ (5a) \quad &\quad \quad + 0.38 P_o + 142.87 D \\ &\quad \quad \quad (0.02) \quad (86.98) \end{aligned}$$

$$R^2 = 0.96$$

Truck freight rate coefficients are now statistically significant in equations (1a) and (5a). Furthermore, the substantial increases in R^2 indicate that the linear equations using natural numbers give better fit for rail shipments. There was, however, very little change when regression equations (2), (4), and (6) were changed to natural numbers:

$$\begin{aligned} Q_m &= -247.82 - 733.79 P_m + 1079.54 P_r \\ &\quad (248.86) \quad (123.91) \\ (2a) \quad &\quad \quad + 0.13 Q_t - 146.91 D \\ &\quad \quad \quad (0.04) \quad (70.07) \end{aligned}$$

$$R^2 = 0.80$$

$$\begin{aligned} Q_m &= -117.28 - 797.17 P_m + 1096.01 P_r \\ &\quad (256.54) \quad (126.63) \\ (4a) \quad &\quad \quad + 0.06 Q_u - 145.23 D \\ &\quad \quad \quad (0.02) \quad (71.10) \end{aligned}$$

$$R^2 = 0.80$$

$$\begin{aligned} Q_m &= -254.05 - 722.26 P_m + 1141.51 P_r \\ &\quad (266.04) \quad (136.08) \\ (6a) \quad &\quad \quad + 0.05 P_o - 139.91 D \\ &\quad \quad \quad (0.02) \quad (73.97) \end{aligned}$$

$$R = 0.78$$

The following elasticity of demand coefficients at the centroid were obtained by means of the equations specified:

For rail services		For truck services	
Equation	Coefficient	Equation	Coefficient
(1a)	-3.19	(2a)	-4.74
(3a)	-2.98	(4a)	-5.08
(5a)	-1.97	(6a)	-3.36

The cross-elasticity of demand at the centroid for each mode was +1.00, implying relative ease in substituting the services.

The estimated elasticity of demand coefficients are larger than those obtained in the two recent studies mentioned above (see footnote 1). This could be attributed to differences in the level of aggregation and the nature of the data. The elasticity coefficients calculated from cross-sectional data are likely to pertain to the long run and those from time series data

to the short run.⁶ The estimates, however, are comparable to the following elasticity of demand coefficients for rail services estimated by Limmer for Florida produce:⁷

Oranges	-1.9	Celery	-3.6
Grapefruit	-2.2	Corn, green	-2.5
Snap beans	-2.8	Potatoes	-2.8
Cabbage	-3.3	Tomatoes	-2.7

⁶ E. Kuh and J. R. Meyer, "How Extraneous are Extraneous Estimates?" *Rev. Econ. and Statis.*, Vol. 39, Nov. 1957, pp. 380-393.

⁷ E. Limmer, *op. cit.*, p. 454.

Conclusions

The demand for transportation services of each mode, rail and truck, for California lettuce seems to be relatively elastic with respect to its own freight rates, and of unit elasticity with respect to the rates of the competing mode. The demand for truck services is relatively more elastic than that for rail services. Further work would be needed to test whether these results can be generalized to other commodities. They do indicate, however, that the estimation of demand for transport services from cross-sectional data may be feasible.