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The Domestic Demand for Airmail Service by the U.S. Postal Service

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ABSTRACT

The domestic demand for air freight service (i.e., the domestic air transportation of U.S. mail by the U.S. Postal Service) is investigated. Two types of air freight service are considered--loose sack and containerized. Input share equations derived from minimizing the translog cost function for the U.S. Postal Service are estimated. It is concluded that the own-price elasticity of demand for airmail service by the U.S. Postal Service is responsive and that the elasticity for containerized service is generally more responsive than that for loose-sack service. Consequently, air freight carriers can increase airmail revenue by decreasing rates for containerized service relative to those for loose-sack service.

Given the availability of data from the U.S. Postal Service (USPS), the purpose of this paper is to investigate the domestic demand for air freight service by USPS (i.e., in the air transportation of U.S. mail). Even if data were available for other types of air freight service, it would still be desirable to investigate separately the air freight demand for U.S. mail. Because freight transportation is an input into the firm's production process, an explicit freight demand equation can be derived from the cost function of the firm (or shipper). A similar approach was adopted by Friedlaender and Spady (1) for rail and truck freight transportation. Alternatively, studies that do not consider an explicit freight demand equation but rather simply regress transportation volume against rates, shipment characteristics, and other variables that are intuitively appealing make evaluation of the results difficult because of the uncertainty of the biases introduced by the specification error.

AIR FREIGHT DEMAND FUNCTION

In providing mail service, USPS hires designated air carriers to transport mail to destination cities or distribution centers. Air carriers, in turn, provide two general types of air service: loose sack and containerized. Containerized service involves the transportation of mail in containers supplied by the designated carriers; loose-sack (noncontainerized) service involves the transit of mail by means of the conventional canvas bags. For a sufficiently large volume of mail destined for a given location, air carriers are in a position to charge a lower rate for containerized service, because it reduces the handling costs of large mail shipments at air terminals. Therefore, the advantage of containerized versus loose-sack service to USPS is that the container rate per pound mile for a sufficiently large volume of mail (to a given destination) is lower than the corresponding loose-sack rate. Alternatively, if the mail poundage to be shipped is less than the minimum necessary quantity for containerized shipment, the loose-sack rate per pound mile will be lower. Hence there is a breakeven point in terms of mail poundage at which the two rates are identical.

Because decisions related to USPS's demand for air freight service are made at its airmail facilities, a cost function for these facilities will be specified in the following discussion. This function, in turn, will be used in the derivation of input share equations that indirectly consider the demand for loose-sack and containerized air service by USPS.

An airmail facility (AMF) is a regional collection and distribution center, that is, a central post office where outgoing mail from local post offices is consolidated for air freight movement to destination AMFs. In addition, it is a facility where incoming mail is received and distributed to local post offices. Therefore, for analytical purposes, an AMF may be treated as a firm that produces output (volume of mail moved) by combining optimal levels of productive inputs on the basis of cost minimization. Thus, in addition to the primary inputs discussed previously (i.e., the two air transit modes), labor and capital will be utilized. AMFs will employ various types of labor (e.g., office worker, dock driver, and managerial labor). Likewise, the capital input for AMFs will be heterogeneous in nature, consisting of floor space, vehicles, and various types of mechanized sorting equipment.

For smaller regional AMFs it is likely that for-hire truck transportation is an economically feasible alternative to air freight transit of mail. In fact, a 1982 report by the U.S. General Accounting Office (2) recommended that short-haul high-cost mail be diverted to for-hire truck carriers. Such an option, however, is not workable for long-haul routes of the larger AMFs considered in this study. Therefore, for-hire truck carriers are not included in the AMF variable-cost function. For the AMFs treated here, mail is moved either by USPS trucks (included in the capital variable) or by the two air transit modes.

Let us assume that the general form of the USPS short-run variable-cost function for a given AMF (where capital is the fixed input) may be expressed as

$$VC = VC\,(W_{Ai},\, W_{Lk},\, Q;\bar{K}_m) \qquad (1)$$

where

- VC = short-run variable cost incurred by a given USPS AMF,
- W_{Ai} = air freight rate per pound mile incurred by a given USPS AMF for the ith type of air freight service,
- W_{Lk} = wage rate per hour incurred by a given USPS AMF for the kth type of labor,
- Q = pounds of airmail transported from a given USPS AMF, and
- $\bar{K}_m$ = fixed amount of capital of the mth type at a given USPS AMF.

Friedlaender and Spady (1), in utilizing this methodology, have included inventory cost variables in the short-run cost function. For the USPS case, however, such variables are clearly unnecessary because inventory costs are zero by definition. Such costs are a factor only when output is owned by the firm. Note that the output variable specified in Equation 1 is outgoing mail only. A better output variable would be total mail volume (i.e., incoming and outgoing) handled at a given AMF. Data limitations, however, precluded this approach. Therefore outgoing volume was used as a proxy on the assumption that the ratio of outgoing to total mail volume is reasonably stable. Because the AMFs in this sample are relatively homogeneous in terms of size, this assumption would appear to be reasonable.

In order to derive a specific functional form for the USPS air freight demand function (i.e., an input share or direct demand function), it is assumed that Equation 1 can be expressed as a translog approximation. This function can be viewed as a second-order Taylor's series expansion in the logarithms of the variables of Equation 1.

Specifically, the translog approximation of the foregoing short-run cost function given in Equation 1 can be written as follows:

$$\begin{aligned}
\ln VC = {} & \alpha_o + \sum_i \alpha_i \ln W_{Ai} + \sum_k B_k \ln W_{Lk} \\
& + \gamma \ln Q + \sum_m \theta_m \ln \bar{K}_m \\
& + \sum_{ik}\sum A_{ik} \ln W_{Ai} \ln W_{Lk} + \sum_i B_i \ln W_{Ai} \ln Q \\
& + \sum_k D_k \ln W_{Lk} \ln Q + \sum_{im}\sum E_{im} \ln W_{Ai} \ln \bar{K}_m \\
& + \sum_{km}\sum F_{km} \ln W_{Lk} \ln \bar{K}_m + \sum_m G_m \ln \bar{K}_m \ln Q \\
& + \sum_{ij}\sum H_{ij} \ln W_{Ai} \ln W_{Aj} + \sum_{ks}\sum I_{ks} \ln W_{Lk} \ln W_{Ls} \\
& + \sum_{mr}\sum N_{mr} \ln \bar{K}_m \ln \bar{K}_r + (1/2) J (\ln Q)^2 \\
& + (1/2)\sum_i M_{ii} (\ln W_{Ai})^2 + (1/2)\sum_k O_{kk} (\ln W_{Lk})^2 \\
& + (1/2)\sum_m P_{mm} (\ln \bar{K}_m)^2 \quad i \neq j,\ k \neq s,\ m \neq r
\end{aligned} \qquad (2)$$

Differentiation of this equation with respect to the input price ($\ln W_{Ai}$) of air freight service yields the following input share equation for this service:

$$\begin{aligned}
E_{Ai}/VC = \partial \ln VC/\partial \ln W_{Ai} = {} & \alpha_i + \sum_k A_{ik} \ln W_{Lk} + B_i \ln Q \\
& + \sum_m E_{im} \ln \bar{K}_m + \sum_j H_{ij} \ln W_{Aj} + M_{ii} \ln W_{Ai}
\end{aligned} \qquad (3)$$

where E_{Ai} is the expenditure on air freight service of the ith type by a given USPS AMF.

From Shephard's lemma (3) the input share Equation 3 may be interpreted as a derived demand equation for a given AMF for freight service of the ith type. This interpretation follows, because E_{Ai} may be alternatively expressed as $W_{Ai}X_i^*$ where X_i^* is the cost minimizing input service level of the ith type of air freight service.

EMPIRICAL RESULTS

Data for estimation of input share Equation 3 for the ith type of air freight service were obtained from USPS. Two types of air freight service are considered--loose sack and containerized. However, the incorporation of containerized service in this study greatly reduced the size of the sample, because relatively few AMFs utilize containerized service. This follows because only relatively large AMFs can take advantage of the lower containerized rates. A city of the size of Norfolk, Virginia, for example, does not have sufficiently large amounts of airmail (for given destinations) for the containerized rate to be less than the loose-sack rate. Consequently, the Norfolk USPS airmail facility receives only loose-sack air freight service. Although the incorporation of containerized service in this data set greatly reduced the sample size, it is believed that the likely future importance and growth of containerized air service warrants its inclusion in the study.

Given the incorporation of containerized service, the data set is therefore restricted to 17 USPS AMFs for the 1981 USPS fiscal year. Data on capital costs were not available; thus it is assumed that the rental price of capital (W_{cm}) is constant across sample AMFs. Hence W_{cm} will not appear in the equation to be estimated. Because the AMFs in this sample are homogeneous in terms of relative size, it is probable that the variance in W_{cm} is small. Therefore, this assumption may be less restrictive than it initially appears. With respect to labor, available data were in terms of average wage rates (i.e., direct labor compensation per employee). It is therefore not possible to distinguish between different types of labor at each AMF. Consequently, in the equation to be estimated, a single labor input is included. Finally, because two types of air freight service are being analyzed, only one cross-price coefficient will appear in each equation. Thus the input share equation for the ith type of air freight service is of the following form:

$$S_{Ai} = \alpha_i + A_i \ln W_L + B_i \ln Q + H_{ij} \ln W_{Aj} + M_{ii} \ln W_{Ai} \qquad (4)$$

where W_L is the average wage rate per hour incurred by a given USPS AMF and $S_{Ai} = E_{Ai}/VC$. (Note that if i refers to loose-sack air service, then j will refer to containerized air service and conversely.)

A requirement for the cost function (from which Equation 4 would be derived) to be well behaved is that it be homogenous of degree 1 in input prices. This requirement implies the following restrictions on the parameters in Equation 4:

$$\alpha_{LS} + \alpha_C + \beta = 1 \qquad (5)$$

$$B_{LS} + B_C + B_L = 0 \qquad (6)$$

$$A_i + H_{ij} + M_{ii} = 0 \qquad i = LS, C, L; \quad j = LS, C \qquad (7)$$

where β is the intercept parameter in the labor input share equation. (Note that LS refers to loose-sack service, C refers to containerized service, and L refers to labor.)

Because there are only three variable inputs (labor, loose-sack air service, and containerized air service), it is unnecessary to estimate an input share equation for labor. However, because the input share equations are jointly determined, it is necessary to impose symmetry restrictions on M_{ij}. Specifically:

$$M_{ij} = M_{ji} \qquad i \neq j, \; i; \; j = LS, C, L \qquad (8)$$

Because the input share Equation 4 is not a direct demand equation, estimates cannot be obtained of the own-price elasticity of demand for loose-sack and containerized air freight service directly from these equations. However, Berndt and Wood (4) have shown that the own-price elasticities for loose-sack (ε_{LS}) and containerized (ε_C) air service can be derived for a given USPS AMF by using the following relationships:

$$\varepsilon_{LS} = (M_{LS,LS}/S_{A,LS}) + S_{A,LS} - 1 \qquad (9)$$

$$\varepsilon_C = (M_{C,C}/S_{A,C}) + S_{A,C} - 1 \qquad (10)$$

where M_{ii} is the same as defined previously, $S_{A,LS}$ is the estimated input cost share for loose-sack air service for a given AMF, and $S_{A,C}$ is the estimated input cost share for containerized air service for a given AMF.

The estimated input share equations for USPS air freight service by using a cross section of 17 USPS airmail facilities in fiscal year 1981 are as follows:

$$\begin{aligned} S_{A,LS} = {} & \underset{(-0.02308)}{-0.4428} + \underset{(2.3462)}{0.0786} \ln W_L \\ & + \underset{(0.2990)}{0.0027} \ln Q + \underset{(1.3614)}{0.0185} \ln W_{A,C} \\ & - \underset{(-3.1884)}{0.0971} \ln W_{A,LS} \qquad \bar{R}^2 = 0.2488 \end{aligned} \qquad (11)$$

$$\begin{aligned} S_{A,C} = {} & - \underset{(-0.02906)}{0.4260} + \underset{(2.1307)}{0.0458} \ln W_L \\ & + \underset{(1.1719)}{0.0070} \ln Q + \underset{(1.3614)}{0.0185} \ln W_{A,LS} \\ & - \underset{(-3.2744)}{0.0644} \ln W_{A,C} \qquad \bar{R}^2 = 0.1458 \end{aligned} \qquad (12)$$

(t-Statistics are given in parentheses.)

The signs of the coefficients in Equations 11 and 12 agree with a priori expectations with the possible exception of the wage variable ($\ln W_L$). The positive sign for the wage coefficient in both equations indicates that as the average wage rate for labor increases, the proportion of variable cost allocated to air freight service for a given AMF is expected to increase. Initially the result appears to be counterintuitive. However, as previously noted, only relatively large AMFs are considered in this study. If larger AMFs incur higher wage costs per unit of labor and spend more on air freight service (as a percentage of total variable cost) than relatively smaller facilities, it therefore follows that the sign of the wage coefficient would be positive. In Equation 11, the own input price and wage variables are significant at the 0.01 and 0.05 levels, respectively; in Equation 12, these variables are significant at the 0.01 and 0.10 levels, respectively. Note that the sign of $\ln W_{A,C}$ in the loose-sack input share and the sign of $\ln W_{A,LS}$ for the containerized input share equations are positive but insignificant. This result is expected, because loose-sack and containerized transit modes are not substitutes. For containerized transit to be feasible on a cost-minimization basis, it is necessary that $Q \geq Q_{min}$ (where Q_{min} is the minimum required volume for containerized shipment); otherwise loose-sack service is less expensive. Therefore, rational behavior precludes substitutability between the two modes.

TABLE 1 Own-Price Elasticity of Demand for Loose-Sack and Containerized Air Mail Service

	Type of Service	
Origin Point	Loose Sack	Containerized
Atlanta	-1.88681	-13.92982
Boston	-2.76906	-5.76914
Cleveland	-6.55869	-3.31143
Denver	-1.88118	-6.52904
Dallas/Ft. Worth	-2.49213	-10.43473
Detroit	-2.41454	-8.86267
Newark	-1.69706	-1.86677
New York-Kennedy	-1.76288	-3.07705
Los Angeles	-1.95935	-5.84351
Minneapolis	-2.80426	-3.72580
Chicago-O'Hare	-3.33218	-15.64017
Portland	-1.58988	-3.68895
Seattle	-1.73881	-2.31735
San Francisco	-4.02041	-2.54078
San Juan	-2.53856	-4.63075
Sacramento	-2.90853	-10.25611
St. Louis	-4.45354	-3.31143
Avg	-2.26970	-3.88397

By using Equations 9 through 12, the own-price elasticities for loose-sack and containerized air freight service for each AMF in the sample were computed and are presented in Table 1. For every AMF except three, the own-price elasticity for containerized service was more responsive than that for loose-sack service. The three exceptions are the Cleveland, San Francisco, and St. Louis AMFs. In the consideration of all AMFs, the average own-price elasticity for containerized service of -3.88397 was more responsive than the average of -2.26970 for loose-sack service. Further, note that the own-price elasticity for both air freight services is responsive for every AMF.

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