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 break-even 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 (AMP) 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 AMP 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 AMP variable-cost function. For the AMPs 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 AMP (where capital is the fixed input) may be expressed as

\[ \text{VC} = \text{VC}(W_{Ai} + W_{Lk}, Q, \bar{F}_m) \]  

where

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

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 AMP. 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:

\[
\ln \text{VC} = a_0 + \sum_{i=1}^{m} \ln W_{Ai} + \sum_{k=1}^{n} B_{ik} \ln W_{Lk} \\
+ \gamma \ln Q + \sum_{m} \ln \bar{F}_m \\
+ \sum_{i} A_{ik} \ln W_{Ai} \ln W_{Lk} + \sum_{i} B_{i1} \ln W_{Ai} \ln Q \\
+ \sum_{k} D_{ik} \ln W_{Lk} \ln Q + \sum_{m} G_{im} \ln \bar{F}_m \ln Q \\
+ \sum_{m} P_{km} \ln \bar{F}_m \ln \bar{F}_m + \sum_{i} F_{km} \ln W_{Ai} \ln \bar{F}_m \\
+ \sum_{i} H_{ij} \ln W_{Ai} \ln W_{Aj} + \sum_{j} I_{jk} \ln W_{Lk} \ln W_{Lj} \\
+ \sum_{m} N_{mi} \ln \bar{F}_m \ln \bar{F}_m + (1/2) J(\ln Q)^2 \\
+ (1/2) [M_{ii}(\ln W_{Ai})^2 + (1/2) G_{kk}(\ln W_{Lk})^2] \\
+ (1/2) [P_{mm}(\ln \bar{F}_m)^2] i \neq j, j \neq s, m \neq r
\]  

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:

\[
\frac{E_{Ai}}{\text{VC}} = 3\ln W_{Ai}/3\ln W_{Ai} = a_1 + \sum_{k} A_{ik} \ln W_{Lk} + B_{i1} \ln Q \\
+ \sum_{m} E_{im} \ln \bar{F}_m + H_{ij} \ln W_{Aj} + M_{ij} \ln W_{Ai}
\]  

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

From Shepherd's lemma (3) the input share Equation 3 may be interpreted as a derived demand equation for a given AMP for freight service of the ith type. This interpretation follows, because \(E_{Ai}\) may be alternatively expressed as \(W_{Ai} X_{Ai}^{b}\) where \(X_{Ai}^{b}\) 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 con-
sidered—loose sack and containerized. However, the
incorporation of containerized service in this study
greatly reduced the size of the sample, because rela-
tively 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 air mail (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 contain-
erized 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 in-
put is included. Finally, because two types of air
freight service are being analysed, 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:

$$S_{AI} = a_i + A_i\ln W_i + B_i\ln Q$$
$$+ H_i\ln W_{AI} + M_{ij}\ln W_{Ai}$$
(4)

where $W_i$ is the average wage rate per hour incur-
ered 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 con-
versely.)

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:

$$a_{LS} + a_C + \beta = 1$$
(5)

$$b_{LS} + b_C + b_L = 0$$
(6)

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

where $\beta$ is the intercept parameter in the labor in-
put 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 neces-
sary to impose symmetry restrictions on $M_{ij}$. Spe-
cifically:

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

Because the input share Equation 4 is not a di-
rect 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
($e_{LS}$) and containerized ($e_C$) air service can be
derived for a given USPS AMF by using the fol-
lower relationships:

$$e_{LS} = (M_{LS,LS}/S_{AI,LS}) + S_{AI,LS} - 1$$
(9)

$$e_C = (M_{C,C}/S_{AI,C}) + S_{AI,C} - 1$$
(10)

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

$$S_{AI,LS} = -0.4428 + 0.0786 \ln W_{LS}$$
$$(-0.02308) (2.3462)$$

$$+ 0.0027 \ln Q + 0.0185 \ln W_{AI,LS}$$
$$+ 0.0971 \ln W_{AI,LS}$$
$$R^2 = 0.2488$$
$$(-3.1884)$$

$$S_{AI,C} = -0.4260 + 0.0458 \ln W_{AI}$$
$$(-0.02906) (2.1307)$$

$$+ 0.0070 \ln Q + 0.0185 \ln W_{AI,LS}$$
$$+ 0.0844 \ln W_{AI,LS}$$
$$R^2 = 0.1456$$
$$(-3.2744)$$

($t$-Statistics are given in parentheses.)

The signs of the coefficients in Equations 11 and
12 agree with a priori expectations with the possi-
ble exception of the wage variable ($\ln W_i$). The
positive sign for the wage coefficient in both equa-
tions indicates that as the average wage rate for
labor increases, the proportion of variable cost al-
lotted 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 ser-
dvice (as a percentage of total variable cost) than
relatively smaller facilities, it therefore follows
that the sign of the wage coefficient would be posi-
tive. 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 vari-
ables are significant at the 0.01 and 0.10 levels,
respectively. Note that the sign of $\ln W_{AI,C}$ in
the loose-sack input share and the sign of $\ln W_{AI,LS}$
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 service to be feasi-
bile 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

<table>
<thead>
<tr>
<th>Origin Point</th>
<th>Loose Sack</th>
<th>Containerized</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta</td>
<td>-1.88681</td>
<td>-13.92982</td>
</tr>
<tr>
<td>Boston</td>
<td>-2.76906</td>
<td>-5.76914</td>
</tr>
<tr>
<td>Cleveland</td>
<td>-6.53869</td>
<td>-3.31143</td>
</tr>
<tr>
<td>Denver</td>
<td>-1.88118</td>
<td>-6.52904</td>
</tr>
<tr>
<td>Dallas/Ft. Worth</td>
<td>-2.49213</td>
<td>-10.43473</td>
</tr>
<tr>
<td>Detroit</td>
<td>-2.41454</td>
<td>-8.86267</td>
</tr>
<tr>
<td>Newark</td>
<td>-1.69706</td>
<td>-1.86677</td>
</tr>
<tr>
<td>New York-Kennedy</td>
<td>1.76288</td>
<td>-3.07075</td>
</tr>
<tr>
<td>Los Angeles</td>
<td>-1.95935</td>
<td>-5.84351</td>
</tr>
<tr>
<td>Minneapolis</td>
<td>2.80426</td>
<td>-3.72580</td>
</tr>
<tr>
<td>Chicago-O'Hare</td>
<td>-3.32118</td>
<td>-15.64017</td>
</tr>
<tr>
<td>Portland</td>
<td>-1.58988</td>
<td>-3.68895</td>
</tr>
<tr>
<td>Seattle</td>
<td>-1.73881</td>
<td>-2.31735</td>
</tr>
<tr>
<td>San Francisco</td>
<td>-4.02041</td>
<td>-2.54076</td>
</tr>
<tr>
<td>San Juan</td>
<td>-2.53856</td>
<td>-4.63057</td>
</tr>
<tr>
<td>Sacramento</td>
<td>-2.90833</td>
<td>-10.25611</td>
</tr>
<tr>
<td>St. Louis</td>
<td>-4.45374</td>
<td>-3.31143</td>
</tr>
<tr>
<td>Avg</td>
<td>-2.26970</td>
<td>-3.88397</td>
</tr>
</tbody>
</table>

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.

### REFERENCES


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