An Economic Framework for Modeling Mail Processing Costs

Mark J. Roberts
Department of Economics
The Pennsylvania State University
University Park, PA 16802

March 2006

Goals of this paper

1. Extend the model of labor demand presented in May 2002 to incorporate categories of mail that differ in the amount of processing (depth of sort) they receive.

2. Compare this model with the framework used by the USPS, most recently in R2005-1, USPS-T-12. Identify the role of underlying assumptions about the technology.

3. Estimate the new model using MODS data. Measure and interpret the output elasticities of labor demand for letters and flats.

4. Present recommendations for future efforts to model labor demand.

Theoretical Model of Labor Demand in Mail Sorting Operations

Processing is separable by mail shape. Develop the model for letter sorting.

Plant Outputs: Arriving mail is a mix of unsorted and presorted pieces
Dispatched mail is a mix of different levels of sorting

Define categories of mail representing combinations of level of preparation and level of dispatch.
Each category can require different processing and different labor and capital inputs.

Outputs are the *number of letters* in each category.

Example: Two categories of processing - Initial sort and Final sort

Output 1: L_I - the number of letters receiving the initial sort

Output 2: L_F - the number of letters receiving the final sort

Plant output is the bundle (L_I, L_F)

Production of the Output Bundle (L_I, L_F) Utilizes:

Labor in Manual sorting (M_L)
Labor in Automated Operations (A_L)
Capital Stock of Automated Machinery (K_L)

Short-Run Demand Functions for Labor: M_L and A_L

1) Manhours in manual operations: $M_L(WA_L/WM_L, K_L, L_I, L_F)$

2) Manhours in automated operations: $A_L(WA_L/WM_L, K_L, L_I, L_F)$

Interpretation: Manhours in each letter-sorting operation depend on

- the relative wages of the two groups of workers,

- the capital stock in the automated operation,

- the total number of letters receiving each type of sorting.

Points to notice:

- The model used in Roberts (2002) is the special case where plant output is the total number of sorted letters, $L = L_I + L_F$

- There is an output elasticity (variability) of each labor demand with respect to *each output*.

Manual labor: $\eta_M^I = \left(\dfrac{\partial \ln M_L}{\partial \ln L_I}\right)$ and $\eta_M^F = \left(\dfrac{\partial \ln M_L}{\partial \ln L_F}\right)$

Automated labor: $\eta_A^I = \left(\dfrac{\partial \ln A_L}{\partial \ln L_I}\right)$ and $\eta_A^F = \left(\dfrac{\partial \ln A_L}{\partial \ln L_F}\right)$

- Elasticity of *total labor use* with respect to an increase in *each output* is a labor-share weighted sum over the two groups of labor:

L_I output: $$\eta^I = \theta_M \eta_M^I + \theta_A \eta_A^I$$

L_F output: $$\eta^F = \theta_M \eta_M^F + \theta_A \eta_A^F$$

Useful in measuring the marginal cost of an increase in L_I and marginal cost of an increase in L_F.

- Elasticity of *total labor use* in letter sorting with respect to an equal proportional increase in *both outputs* is the unweighted sum over the two output elasticities:

Letters: $$\eta = \eta^I + \eta^F$$

Extension to Multiple Automated Technologies
(i.e. OCR, MPBCS, and DBCS in letter sorting)

Labor demand equation for each automated operation (and manual)

Capital stock in *each automated operation* will enter *every* labor demand. This is necessary to capture substitution among different generations of automated equipment.

A Comparison with the USPS Methodology

Assume

1) There is a single output, L = number of sorted letters. This allows us to isolate assumptions about the technology.

2) There is a single rate class of mail. This allows us to separate assumptions about the technology (cost drivers) from assumptions used to allocate costs across rate classes (distribution key).

3) General production function for sorted letters has the form:
$$L = L(M_L, A_L, K_L)$$

USPS methodology makes two additional assumptions about the production function:

Assumption 1 (Separability): Each sorting operation can be viewed in isolation from others. Each sorting operation has a unique output or "cost driver" that varies with total volume of letters L.

Implied Labor Demand Equations - labor in a sorting operation only depends on wages, capital input, and cost driver *in that operation*.

manhours in manual operations $M_L (WM_L, D^M(L))$

manhours in automated operations $A_L (WA_L, K_L , D^A(L))$

Implication for the Marginal Cost of a Letter

General Model:

$$\frac{\partial C^L}{\partial L} = \left(\frac{C^L}{L}\right)(\theta_M \eta_M + \theta_A \eta_A)$$

θ_M and θ_A are shares of labor costs for each operation (observable)

η_M and η_A are labor demand elasticities w.r.t. letter volume L (estimated econometrically in Roberts (2002 and 2005) using FHP in the plant as the measure of L)

Separable Model:

$$\frac{\partial C^L}{\partial L} = \left(\frac{C^L}{L}\right)(\theta_M \varepsilon_M \delta_M + \theta_A \varepsilon_A \delta_A)$$

ε_M and ε_A are labor demand elasticities w.r.t. the cost drivers D^M, D^A (estimated econometrically in USPS-T-12 using TPF in an operation as the cost driver)

δ_M and δ_A are elasticities of the cost drivers w.r.t. letter volume L (not observable).

Assumption 2 (Proportionality): The cost driver in each sorting operation is proportional to the volume of letters L:

$$D^M(L) = \alpha^M L \quad \text{and} \quad D^A(L) = \alpha^A L.$$

Benefits of this assumption

It implies $\delta_M = \delta_A = 1$. If you can measure the cost drivers D^M and D^A, you can measure marginal cost of a letter without measuring the volume of letters L.

Cost of this assumption

It implies that the manual and automated sorting operations are used in *fixed proportions* to each other. Each one unit increase in L results in α^M more units of manual sorting and α^A more units of automated sorting. This eliminates substitution between manual and automated sorting operations.

Measuring the Cost Drivers

Is TPF in a sorting operation a good measure of the cost driver? No

1) Does not satisfy the proportionality assumption. Tables 1 and 2

   TPF_j / L is not a constant, but varies across plants and time depending on the whole set of technologies and inputs used in the plant.

2) Not an output measure

   TPF_j is proportional to *hours of machine time* used in the operation.

   TPF_j is a measure of the *capital input* used in the operation.

Conclusions:

1) USPS model of labor demand places strong restrictions on the nature of input substitution, particularly between sorting operations. The restrictions are inconsistent with the substitution of automated operations for manual operations over time.

2) Even given these restrictions, the elasticities estimated by regressing labor hours on TPF in a sorting operation are not measures of the output elasticities (ε) needed to measure marginal cost.

Table 2

Ratio of TPF $_j$ / FHP$_{letters}$
(for all plants using sorting operation *j* during the time period)

Year: quarter	Manual	MPBCS	DBCS	OCR
Median Across Plants				
1999:1	.147	.389	1.245	.254
2000:1	.134	.326	1.309	.242
2001:1	.126	.246	1.434	.233
2002:1	.107	.226	1.492	.220
2003:1	.095	.221	1.556	.220
2004:1	.080	.190	1.599	.194
Inter-Quartile Range Across Plants				
1999:1	.069	.246	.378	.078
2000:1	.065	.267	.393	.083
2001:1	.052	.255	.405	.087
2002:1	.052	.260	.368	.089
2003:1	.051	.273	.362	.092
2004:1	.046	.265	.333	.098

An Application of the Model of Labor Demand with Multiple Outputs (L_I, L_F)

Letter Sorting Operations: Manual, OCR, MPBCS, DBCS

Multiple plant outputs:

- L_I measured as FHP in outgoing sort operations (FHP_{OUT})

- L_F measured as FHP in incoming sort operations (FHP_{IN})

Measured with disaggregated MODS data. Summarized in Table 3

Other control variables:

- relative wage in automated vs. manual operations

- capital stocks in OCR, MPBCS, DBCS operations

- technology dummy variables indicating if MPBCS or DBCS technology is present in the plant.

- year dummy variables

Econometric Methods (explained in Roberts (2002)):

- Fixed Effects/Instrumental Variables estimator

- IV's are FHP_{OUT} and FHP_{IN} for flats.

Similar model estimated for flat sorting operations: manual, FSM881, FSM1000, and AFSM.

Table 3

FHP Counts for Incoming and Outgoing Sorting Operations
(Totals over 294 plants with full reporting, millions of pieces)

Year: quarter	Letters			Flats		
	FHP_{IN}	FHP_{OUT}	Share of FHP_{IN}	FHP_{IN}	FHP_{OUT}	Share of FHP_{IN}
1999:1	25,715	13,508	.656	4,731	1,143	.805
2000:1	27,147	13,433	.669	4,870	1,151	.809
2001:1	28,222	13,154	.682	5,064	1,127	.818
2002:1	27,588	12,501	.688	5,124	1,038	.832
2003:1	27,945	12,082	.698	5,463	1,005	.845
2004:1	28,116	11,600	.708	5,494	936	.854

Brief Summary of Empirical Results

Letters (Table 4)

- Output elasticities for manual, OCR, and DBCS are sensible. The response to a one percent increase in total output is .91 in manual and OCR and 1.21 in DBCS. MPBCS estimates are low and some insignificant.

- Much higher output elasticities for incoming sorting than outgoing which partially reflects larger volume in incoming.

- Capital in “own” operation raises labor use. Capital in “other” operations lowers labor use.

- Technology dummies indicate that DBCS use lowers labor use in manual and OCR, but not always statistically significant.

- Relative wage has the correct sign and is significant

- Time dummies reflect the reduction in manual, OCR, and MPBCS labor demand over time and increase in DBCS.

Flats (Table 5)

- Output elasticities for manual sorting are smaller than Roberts(2002). A one-percent increase in total output raises manual labor use by .60 percent

- Output elasticities for AFSM are much larger, .791 for incoming flats and .218 for outgoing implying a total output response of 1.0.

- Output elasticities w.r.t. FHP_{OUT} are not very precisely estimated.

- Capital in "own" operation raises labor use (except for AFSM). Capital in "other" operations lowers labor use.

- Technology dummies indicate the automated operations are substitutes for each other and for manual sorting.

- Relative wage has the expected sign but not significant

- Time dummies indicate the reduction in manual and FSM881, an increase followed by a decrease in FSM1000. Mixed pattern in AFSM.

Table 4

Labor Demand Coefficients: Letter Sorting Operations

FE/IV estimator

(standard errors in parentheses)

	Manual	OCR	MPBCS	DBCS
log (FHP_{IN})	.869 (.091)*	.703 (.225) *	.076 (.514)	1.100 (.130)*
log (FHP_{OUT})	.045 (.020)*	.207 (.046) *	.243 (.082) *	.111 (.028)*
Capital MPBCS	1.811 (.366)*	-.550 (.802)	49.83 (1.679)*	-.614 (.523)
Capital DBCS	- .312 (.102)*	-.842 (.222) *	-4.655 (.460) *	.910 (.145) *
Capital OCR	-1.162 (.248)*	2.045 (.550) *	-4.999 (1.127) *	-1.019 (.354)*
TECH MPBCS	-.018 (.012)	-.018 (.029)	n.a.	-.055 (.017) *
TECH DBCS	-.309 (.082)*	-.526 (.376)	n.a.	n.a.
Relative Wage	.647 (.029)*	-.228 (.065) *	-.389 (.145) *	-.289 (.041)*
Dummy 2000	-.168 (.009) *	-.018 (.022)	-.229 (.049)*	.090 (.014) *
Dummy 2001	-.357 (.012) *	-.082 (.028) *	-.271 (.062)*	.121 (.017) *
Dummy 2002	-.494 (.011) *	-.108 (.027)*	-.310 (.059) *	.155 (.016)*
Dummy 2003	-.668 (.012) *	-.155 (.028) *	-.354 (.060) *	.177 (.017)*
Dummy 2004	-.800 (.014) *	-.289 (.035)*	-.509 (.074) *	.154 (.020)*
Intercept	-.132 (.344)	-1.785 (1.011)	-.042 (2.100)	-2.327 (.508)*
$\hat{\sigma}$	.170	.367	.725	.242
R^2	.845	.764	.389	.885
Sample size	6812	6257	5690	6812
Hausman Test Statistic (p-value)	5.98 (.003)	4.48 (.011)	5.07 (.006)	39.77 (.000)

* Reject that the coefficient is equal to zero at the .01 significance level with a two-tailed test.

Instrumental variables used are log(FHP_{IN}) for flats and log(FHP_{OUT}) for flats

Table 5

Labor Demand Coefficients: Flat Sorting Operations

FE/IV estimator

(standard errors in parentheses)

	Manual	FSM881	FSM1000	AFSM
log (FHP_{IN})	.526 (.140)*	.723 (.081)*	.651 (.206)*	.791 (.085) *
log (FHP_{OUT})	.078 (.073)	-.017 (.070)	-.088 (.085)	.218 (.027) *
Capital FSM881	-.756 (1.412)	11.909 (1.995)*	-6.644 (1.711) *	-.016 (.628)
Capital FSM1000	-5.579 (1.303)*	-.970(1.386)	17.155 (1.727)*	-.788 (.568)
Capital AFSM	-.833 (.308)*	-16.329(3.352) *	-.731 (.390) *	-.562 (.138)*
TECH FSM881	-.012 (.039)	n.a.	-.134 (.053)	-.093 (.016)*
TECH FSM1000	-.758 (.038)*	-.158 (.041)*	n.a.	-.035 (.022)
TECH AFSM	-.594 (.062) *	-.761 (.070)*	-.889 (.085)*	n.a.
Relative Wage	.072 (.077)	-.110 (.069)	-.019 (.149)	-.112 (.072)
Dummy 2000	-.060 (.027)*	-.053 (.012)*	.084 (.036)*	n.a.
Dummy 2001	-.124 (.034)*	-.081 (.018)*	.259 (.049) *	n.a.
Dummy 2002	-.225 (.045)*	-.191 (.032)*	.468 (.070)*	n.a.
Dummy 2003	-.218 (.051) *	-.526 (.046)*	.191 (.079)*	.044 (.019) *
Dummy 2004	-.247 (.053)*	n.a.	-.183 (.081)*	-.057 (.019)*
Intercept	1.156 (.342)*	.901 (.210)*	.333 (.557)	.100 (.259)
$\hat{\sigma}$	.555	.198	.652	.140
R^2	.223	.801	.392	.884
Sample size	5064	2085	3980	2055
Hausman Test Statistic (p-value)	5.00 (.007)	0.97 (.381)	2.48 (.084)	38.27 (.000)

* Reject that the coefficient is equal to zero at the .01 significance level with a two-tailed test.
Instrumental variables used are log(FHP_{IN}) for letters and log(FHP_{OUT}) for letters

Table 7

Output Elasticities of Labor Demand by Shape of Mail
(Standard Errors in Parentheses)

	FHP_{IN}	FHP_{OUT}	Total FHP
Letters	.890 (.079)	.100 (.016)	.990 (.081)
Flats	.655 (.070)	.049 (.035)	.704 (.079)

Compare the last column - elasticity of total labor use w.r.t. a 1percent increase in total volume for each shape - with Roberts (2002)

Letters: .951 (s.e.=.023) to 1.025 (.071) depending on estimator/model

Flats: .838 (.046) to .956 (.029) depending on estimator/model

Recommendations for Future Modeling of Mail Processing Labor Demand

1) Theoretical model used in the USPS studies needs to be generalized

2) Data on mail volume must be incorporated into the empirical analysis

3) Endogeneity of FHP continues to be important and requires more exploration of alternative instrumental variables. Must recognize the imprecision in the estimates.

4) Full set of model results needs to be presented and discussed.

5) Capital data requires more study and explanation.

6) A standardized, core set of plants should be identified and used in the empirical analysis. Sample selection based on computer edits for outliers should be minimized and underlying data subjected to more rigorous examination for unusual cases.

7) The importance of the systematic quarterly variation in mail volume and labor use needs to be thoroughly studied. How the quarterly variation is used in estimation matters substantially to the results.