Estimates of U.S. Postal Price Elasticities of Demand Derived from a Random-Coefficients Discrete-Choice Normal Model

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1 INTRODUCTION

Reliable estimates of demand parameters, particularly own-price and cross-price elasticities, are essential for many applications of economic theory to issues of postal regulation. However, conventional econometric approaches typically fail to produce complete and consistent estimates of these elasticities. The failure occurs because the demand equations for a conventional model typically include each product's own-price but exclude the prices of most of the possible postal substitutes. Two recent examples of models fit to U.S. data that truncate the price variables in this way are by Pearsall (2011) and Thress (2012).

In this chapter we present a table of own-price and cross-price elasticities for selected U.S. postal services taken from a complete matrix of consistent estimates of price elasticities for 15 categories of U.S. postal services for the fiscal year (PFY) 2011. They were produced by fitting a model using an econometric method that derives from the Random-Coefficients Discrete-Choice Logit model and estimation methodology of Berry, Levinsohn and Pakes (BLP 1995, Nevo 2000a and Nevo 2000b). To our knowledge, the BLP/Nevo approach has not previously been tried in postal economics.[ii]

The BLP/Nevo model is attractive because the elasticities derived from their model are capable of representing any demand behavior, yet they are sufficiently restricted that the estimates usually conform well to *a priori* expectations of signs and magnitudes. However, the standard BLP/Nevo methodology is computationally challenging. Our Random-Coefficients Discrete-Choice Normal model replaces the demographics variables of the BLP/Nevo model with their principal components. The random elements of the coefficients are then assumed to be drawn independently from Normal distributions. This change both simplifies the computations and increases their accuracy so effectively that our model can be fit with just a small fraction of the effort typically required by the BLP/Nevo methodology. A companion paper, Cigno *et al* 2012, provides a detailed explanation of the technical aspects of our model and estimation method.

Our estimates indicate that conventional econometric demand models severely underestimate the price elasticities of postal products. For example, conventional methods yield own-price elasticities for Single-Piece First-Class Letters, Flats and Parcels of around -0.25; our comparable estimate is -0.85. Our estimates are exploratory and experimental at this point in our research and should not to be considered definitive. Important refinements remain to be made to the modeling before the results can be relied upon in policy decisions.

Our model has been fit using two alternative measures of postal prices: average revenue per piece (RPP) and fixed-weight index (FWI) prices. Price elasticities and cross-price elasticities have been derived from the parameter estimates for both RPP and FWI prices. The price elasticities with respect to the RPP indices are larger in magnitude than the elasticities with respect to the FWI prices. This confirms and extends an earlier finding that revenues per piece are generally less than unit elastic with respect to the U.S. postal tariff (see Pearsall 2005).

This paper will proceed by outlining in section 2 the basic model underlying the application, including the conceptual indirect utility equation and its distribution assumptions. The specific definitions of postal products, measures of their hedonic characteristics, household demographics variables and other variables used to capture changes in postal market conditions are described in section 3. We then present and discuss our equation fits and the estimates of U.S. postal price elasticities in sections 4 and 5. Our results demonstrate that we have found a practical method for estimating the complete matrix of price elasticities of U.S. mail products. We provide suggestions for future postal modeling efforts along the line established by our model and estimation method in section 6.

2 THE MODEL

To correctly represent the effects of substitution possibilities and complementarities among the relevant products in a differentiated product market, the price of each product should appear in every demand equation of a conventional econometric model. The United States Postal Service (USPS), like other posts, offers a wide array of postal products and services, some of which are close substitutes for each other. As a result, the number of cross-price elasticities required to describe demand, except at a highly aggregated level, is necessarily large. Postal prices are geographically uniform and tend to be highly correlated over time. Consequently, the equations used to describe demand must be overly restrictive with respect to the price variables in order to avoid near multicollinearity when fit by standard econometric methods. In conventional postal econometric modeling, each equation is usually specified with its own-price but without the entire set of cross-prices. With these restrictions the econometrics yields an incomplete and inconsistent set of estimated parameters including the price elasticities.

A potential solution to the problem exists in the general form of a Random-Coefficients Discrete-Choice Logit Model. The past decade of empirical research in industrial organization has been dominated by the estimation of such models following the method of Berry, Levinsohn, and Pakes (BLP 1995). Their model is founded in individual choice behavior yet can be fit with only market-level price and share data in combination with observable product characteristics, population demographics and, when necessary, an effective set of instrumental variables. Most recent applications of the BLP methodology have followed the "Practitioners Guide" and have used the routine developed by Nevo (2000a and 2000b).

In this paper, we harness a model similar to the BLP/Nevo model that we call the Random-Coefficient Discrete-Choice Normal model, to estimate own and cross-price elasticities of the U.S. Postal Service. Our application is fit using annual U.S. Postal Service volumes, prices, hedonic mail properties, aggregate demographic and economic variables. A series of exponential trends and dummy variables that describe exogenous influences on U.S. postal markets such as the introduction of new services and the entry of competitors is also incorporated. The fitted parameters of the model apply directly to linear functions describing the indirect utility resulting from the purchase of a small additional quantity of each postal service by a single U.S. household.

Following BLP/Nevo, we define the household indirect utility from the purchase and consumption of one additional unit of each of several postal products plus an "outside good". The outside good allows for the possibility that the household may not purchase an additional unit of any of the named products.

$$U_{ij} = \xi_j + \left(Y_i + C_i - P_j\right)\left(\alpha + \Pi_y D_i\right) + X_j(\beta + \Pi_x D_i) + Z_j\gamma_j + \varepsilon_{ij} \qquad (1)$$

Eqn (1) describes indirect utility in every time period (or market) *t=1,…,T*, for every household *i=1,…,I* , and for every product *j=1,…,J*, including the outside good, *j*=0. To simplify notation, the time period index, *t*, has been dropped. The vector X_j contains the *x* hedonic properties of product *j*, with $X_0 = 0$. D_i is a random vector of length d of the demographics characteristics of household *i*. D_i includes both observable and unobservable characteristics and is mean-centered over the population, allowing us to interpret β as an x-vector of mean responses of the household to changes in the hedonic properties of the products.

Eqn (1) is a linear indirect utility function with random coefficients and two mean-centered disturbances. In particular, ξ_j is a disturbance to the mean indirect utility from purchasing one unit of product *j*, and ε_{ij} is a disturbance to the individual household's indirect utility from the purchase. The other terms represent the gains and losses to household *i* by purchasing and consuming an additional unit of product *j*.

A gain in utility occurs when a household consumes product *j* and is captured by the term $X_j(\beta + \Pi_x D_i)$. A loss in utility arises because the act of purchasing requires expenditures equal to each product's price. This loss is captured by $\left(Y_i + C_i - P_j\right)\left(\alpha + \Pi_y D_i\right)$. Y_i is household income and C_i is the accumulated consumer surplus derived from the household's current levels of consumption of the J products. The purchase of an additional unit of product *j* reduces the household's income and consumer surplus by P_j (with $P_0 = 0$ for the outside good). The monetary loss is converted to a utility loss when it is multiplied by the household's marginal utility of income, $(\alpha + \Pi_y D_i)$. $(\alpha + \Pi_y D_i)$ is a scalar random coefficient which combines the mean response to income changes, α, with a component that depends on the d-vector, D_i, of demographic characteristics. $(\beta + \Pi_x D_i)$ is a vector of similar random coefficients.

Finally, the term $Z_j\gamma_j$ represents exogenous effects that may either increase or decrease indirect utility in ways that are unrelated to changes in the properties of the products or the demographics characteristics of the households. In particular, Z_j is a vector of exogenous effects in the market for product j (with $Z_0 = 0$ for the outside god), and γ_j is the associated vector of non-random coefficients. In our application, Z_j often contains dummy variables and exponential trends inserted to capture the effects of either structural changes that have occurred in the U.S. postal market or changes in U.S. Postal Service product offerings.

The household indirect utility function together with the mechanics of preference in a discrete-choice framework and a few distributional assumptions implies an associated market share. We solve this model numerically according to the algorithm described in our companion paper Cigno *et al* 2012. Fitting the model ensures that simulated market shares do not differ noticeably from observed aggregate market shares. In addition, analytic demand elasticities are derived from the market share equations employing information specific to a time period or market. In this sense, all elasticities depend upon the values of the demographic variables, product characteristics, and external effects used to compute them.

3 THE DATA

We fit the model using two different measures of U.S postal prices. The first fit uses fixed-weight index (FWI) prices taken from worksheets accompanying an econometric demand model submitted by the USPS to the U.S. Postal Regulatory Commission (PRC) (see Thress 2012). The second fit uses revenues per piece (RPP) calculated from quarterly Revenue, Pieces and Weights (RPW) reports from USPS. Both FWI prices and RPP were converted to constant 2005 dollars using the implicit deflator for real GDP.

Table 1 describes the taxonomy of these models. Listed in the table are the 15 USPS product categories, the variables for price (P) and product properties (X), the demographic characteristics of households (D), and the effective dates and product associations for the exponential trends and other market influences (Z). The models were fit to a 40-year time series of observations corresponding to postal fiscal years from PFY 1972 to PFY 2011.

Most of the product categories we use are U.S. mail classes and subclasses that have existed since 1972. The presort categories for First-Class Letters (2) and Cards (4) did not exist until PFY 1976. Express mail (6) also begins with PFY 1976. Standard Carrier-Route (10) begins with PFY 1979. The shares model representing the early years was solved for only those products that existed. Finally, the shares for the outside good are derived from the shares of the other products.[iii]

Market shares, prices and weights per piece were all measured in scaled units. The units were chosen so that a scaled unit of every product except the outside good (0) and penalty, franked and free mail (14) required the same expenditure at average prices over the sample period. The scaled unit for products 0 and 14 is a single average piece. Using scaled units reduces computational error when solving the shares model and allows us to treat the mean disturbance, ξ_j, as homoscedastic but does not alter the estimates of coefficients and elasticities.

The model requires a set of hedonic properties of the mail. To this end, we have included in X_j a subset of the hedonic properties identified in Fenster *et al* (2007). Our source for the values of the hedonic properties is the more recent analysis found in Pearsall and Trozzo (2011). We include in X_j the weight per piece, a measure directly reported by USPS in its quarterly RPW reports. Also in X_j is a presortation index representing the number of sort passes on standard USPS sorting equipment left to be done by USPS for a particular class of mail. A high presort index indicates a greater number of sorts that the mail must undergo. A lower presort index indicates mail that has undergone some amount of worksharing before being delivered, or drop shipped, to the Postal Service. A distance index in X_j corresponds to the average distance traveled according to mailing zones and destination entry levels. In addition to the hedonic indices, we have included a set of shape variables (proportions of letters, cards, flats and parcels for each mail category) to measure the effect of mail shape on household utility, and a dummy variable identifying domestic mail auxiliary services.

Table 1

Definitions of Products and Variables

j	Product (Postal Service Categories)
0	Outside Good
1	First-Class Single-Piece Ltrs, Flats, & Pcls
2	First-Class Presort Ltrs, Flats, & Pcls
3	First-Class Single-Piece Cards
4	First-Class Presort Cards
5	Priority Mail
6	Express Mail
7	Periodicals In-County
8	Periodicals Outside County
9	Standard non-Carrier-Route Ltrs, Flats & Pcls
10	Standard Carrier-Route Ltrs, Flats & Pcls
11	Parcel Post and Parcel Select
12	Bound Printed Matter
13	Media and Library Mail
14	Penalty, Franked and Free Mail
15	Domestic Mail Services ex Evps & Box Rents

	Price (P) and Properties of Mail (X-vector)	
P	FWI	Fixed-Weight Index, or
	RPP	Revenue per Piece
X	Std. Wgt/Pc	Weight per Piece in 2011, or
	Wgt/Pc	Weight per Piece
	Letters	Proportion of Letters
	Cards	Proportion of Cards
	Flats	Proportion of Flats
	Parcels	Proportion of Parcels (large and small)
	Presort	Number of USPS Machine Passes to Sort
	Distance	Log of Number of Miles to Destination
	Service	Dummy for Domestic Mail Services

Demographic Variables (D-vector)	
hhadults	Adults per Household (22+ years of age)
gdp per hh	Real Gross Domestic Product per Household (Chained 2005 Dollars)
chg gdp per hh	Annual Change in Real GDP per Household (Chained 2005 Dollars)
net worth per hh	Real net Worth per Household (Chained 2005 Dollars)
broadband	Proportion of Households with Broadband Access
unemployment rate	Unemployment Rate
linear trend	Linear Trend from 1970 to 2012

Service Innovations and Market Conditions (Z-vector)

Effective Date	Products	Exponential Trend Description
07/06/1976	1,3	Start of presort discounts for bulk entry First-Class mail presorted to the 3/5 digit ZIP code level.
03/21/1981	1,2,3,4,9	Start of presort discounts for bulk entry First-Class mail presorted by carrier route.
02/03/1991	1,2,3,4	Start of discounts for bukl entry First-Class mail with preprinted barcodes.
07/01/1996	1,2,3,4,7,9,10	Effective date of mail reclassifications and changes for automation resulting from MC95-1.
05/24/1997	15	Effective date for MC96-3 reclassification of special (auxiliary) services.
04/03/1988	4,10	Start of discounts for bulk mail with extended ZIP code addressing.
02/03/1991	11	Introduction of parcel select service and discounts for parcels drop shipped.
01/07/2001	5,6,9,11	Effective date of miscellaneous changes resulting from the R-2000 rate case.
07/06/1981	7,8,10	Separation of In/Out-county periodicals. Start of Carrier-Route discounts for Standard mail.
02/17/1985	12,13	USPS allowed fliers and advertisements to be bundled with catalogues mailed at BPM rates.
05/14/2007	1,2,12	Effective date of changes affecting parcels resulting from the R-2006 rate case.
01/28/1979	9	Start of presort discounts for bulk entry Standard (Third Class) mail presorted to 3/5 digit level.
01/10/1999	9,15	Effective date of miscellaneous changes resulting from the R-97 omnibus rate case.
09/13/1975	5	USPS introduces Express mail service.
02/03/1991	5	Up to two pound Priority Mail envelope level rate for anywhere in the U.S.
01/01/1995	5	Priority Mail rates are leveled up to 5 lbs.
01/01/1979	6	Federal Express enters the express mail delivery market.
03/21/1981	6	USPS introduces customer pickup service for Express Mail
04/03/1988	9	5-digit barcode discount introduced for Standard mail

Source/Date	Products	Other Variable Description
USPS	5	UPS Coverage of Lower 48 States
USPS	5	Minimum Weight for Priority Mail
	9,10	Election Year Fraction
USPS	11	UPS Man-Days Lost to Strikes (Normalized)
07/06/1976	12	Bound Pprinted Matter Definition Expanded
05/29/1978	12	Bound Printed Matter Pound Rates in Effect
01/01/1993	12	Sears Catalog Discontinued
11/21/1993	13	Library Rate Rule Change

Except for weight per piece in the RPP model, all of the measurements of hedonic properties are based upon the U.S. mail stream during PFY 2009. The two applications differ slightly with respect to the treatment of weight per piece. For the FWI application weights per piece are standardized for all periods using the most recent (2011) RPW values. For the RPP application weights per piece are variable and are calculated from the RPW reports for each postal fiscal year. Otherwise, the vector X_j does not change over the sample. The seven demographics variables listed in Table 1 were all suggested by conventional econometric studies of U.S. postal demand conducted by Pearsall (2005 and 2011) and Thress (various years, most recently 2012). Quarterly time series from 1971 to 2012 are readily available at the national level for all of these variables. The quarterly time series were aggregated and averaged by PFY. "Real" GDP and Net Worth per household are measured in thousands of 2005 dollars.[iv]

Finally, we have included a set of mostly exponential trend variables to account for exogenous influences on U.S. postal markets. These were selected by scanning the equations fit by Pearsall (2011) and selecting the exponential trends and other variables that appeared in these demand equations with statistically significant coefficients. The exponential trends were recalculated for the PFYs using the rates of adjustment re-estimated for the PRC by Pearsall in 2012. Exponential trends were first employed to control for the effects of product innovations and other market interventions in Pearsall (2005)

4 RESULTS

Coefficient estimates and t-values for the mean responses of indirect utility to changes in the properties of the products using FWI prices are shown in Table 2. Each response is *ceteris paribus* and must be considered separate from other responses. The extreme t-values for many of the estimated coefficients is primarily a reflection of the exactness of the fit.

Table 2: Mean Responses of Indirect Utility, Fixed-Weight Index Prices

P, X-vector	FWI	Std Wgt/Pc	Letters	Cards	Flats	Parcels	Presort	Distance	Service
	-Alpha (P)	*Beta (x1)*	*Beta (x2)*	*Beta (x3)*	*Beta (x4)*	*Beta (x5)*	*Beta (x6)*	*Beta (x7)*	*Beta (x8)*
Coefficient	-2.5173	1.5007	5.2114	7.9249	3.8575	7.9460	-1.2740	0.0775	2.3103
t-value	-24.5561	13.3440	65.0547	76.6796	34.2338	69.1366	-41.3386	4.5147	32.5296

Price affects indirect utility with a negative sign, implying, as expected, that consumers lose utility with a higher postal tariff.

The remaining coefficient estimates describe the effects of the hedonic properties on mean indirect utility. Regardless of shape, household utility depends positively on the average weight per piece, indicating that households place a higher value on services that permit heavier mailings. The four coefficients for shapes show the relative utility to the mean household of service for differently shaped pieces. Cards and Parcels are the most highly valued, and Flats are the least valued.

The negative coefficient on the presortation index reflects a preference for mail that may be workshared as opposed to single-piece mail which cannot be. Recall that our presort index reflects the amount of sorting left to be done by USPS. Our result may seem counter-intuitive when considering household utility, however, “households” encompasses all mail recipients and senders, including bulk mailers. U.S. bulk mailers are offered discounted rates and other advantages based on the level of presortation preformed before the mail is entered into the USPS mail stream. Presortation allows for an efficient division of mail preparation tasks between USPS and the mailers themselves. Presortation also brings with it many other advantages including bulk entry, simplified weight-based payment, faster service and qualification for a variety of other discounts including many discounts for automated addressing and drop shipping. Therefore, a preference for work shared mail reflects a preference for mail that is eligible, versus mail that is ineligible, for efficient processing, access to better service and a discounted tariff.

Although distance enters positively into the household indirect utility, the relatively low magnitude of the estimate and its t-value suggests that the distance that a piece will be transported is a hedonic characteristic of low importance to consumers. We have no *a priori* expectation for the sign of the dummy variable identifying domestic mail ancillary and other services.

There are over 25 different exponential trends and other exogenous variables included to account for various structural changes in the U.S. postal market. Table 3, based on our fit using FWI prices, highlights only a few statistically significant parameters to illustrate the importance of exogenous effects on U.S. postal markets.

Table 3: (Selected) Estimated Exogenous Effects on the Market, FWI

Exp. Trend from 03/21/1981	**Coefficient**	**t-value**
First-Class Single Piece Letters	1.0209	7.4088
First-Class Single Piece Cards	0.3706	2.3038
First-Class Workshared Letters	-0.0135	-0.1633
First-Class Workshared Cards	0.3427	3.3216
Express Mail	-0.3399	-2.3300
Standard Non-carrier Route	0.1362	0.8956
Exp. Trend from 07/01/1996	**Coefficient**	**t-value**
First-Class Single Piece Letters	0.8090	6.5072
First-Class Single Piece Cards	-0.2354	-1.9292
First-Class Workshared Letters	-1.0209	-8.2249
First-Class Workshared Cards	-2.0719	-16.9811
Periodicals Within County	-0.1439	-2.2648

Standard Non-carrier Route	-0.2687	-1.9526
Standard Carrier Route	-0.5520	-8.0119

March 21, 1981 marks the start of presort discounts for bulk entry Standard (formerly Third Class) mail presorted to the 3 and 5 digit levels. Our estimates indicate that this change positively affected household utility for First-Class Mail products. On July 6, 1981, the separation of In-County Periodicals from Outside-County Periodicals was implemented, which increased household indirect utility for all Periodicals. July 1, 1996 was the effective date for mail reclassifications and changes that reconfigured automation-based discounts. Modeling this resulted in mean household effects with very high t-values for eight different products.

In general, the estimates and t-values for the coefficients of the variables in the vectors, Z_j, do a remarkably precise job of separating variables that are statistically important from those that are not. The pattern of t-values is unlike the pattern one would get from a conventional econometric fit. Many of the estimated components are statistically significant at extremely high levels. An examination of all estimated exogenous effects reveals that others are quite close to zero, and that there are surprisingly few coefficients with t-values in the middle, with magnitudes in the ambiguous range of one to two. The high t-values confirm previous findings of shifts in utility due to these effects.

5 ESTIMATED PRICE ELASTICITIES

Table 4 shows a selection of estimates of own-price and cross-price elasticities based on the FWI prices. Own-price elasticities are shown along the diagonal; the off-diagonal elements display the cross-price elasticity of demand for products listed down with respect to the prices of products listed across. The right columns show respectively the sum, by product, of the own-price and all cross-price elasticities using FWI and, for illustrative purposes, RPP.

Overall, our estimates of price elasticities are larger in magnitude than the estimates that the USPS and the PRC have customarily relied on to recommend and set postal rates. Consider the elasticity of First-Class Single-Piece Letters, Flats, and Parcels with respect to its FWI price. Our estimate is -0.846. While this still reflects an inelastic aggregate demand, it is much higher than previous elasticity estimates. For example, the most recent estimate from USPS of this own-price elasticity is -0.189.[v]

Nominal postal prices have changed infrequently, but usually in concert, after a period of public consideration and due process dictated by U.S. postal law. Since 2006, postal rates have been tied to CPI-based class-level price caps imposed by the Postal Accountability and Enhancement Act (PAEA). As a result, the movements of all real postal prices are highly correlated over time.

Table 4: Own-Price and Cross-Price Elasticities Using Fixed-Weight Index Prices, PFY 2011

	Demand for Product (listed down)	Own-Price or Cross-Price Product (listed across)														
		1	2	3	4	7	8	9	10	11	12	13	14	15	FWI Sum	RPP Sum
1	First-Class Single-Piece Ltrs, Flats, & Pcls	-0.846	0.147	0.005	0.006	0.001	0.018	0.134	0.050	0.045	0.006	0.004	0.000	0.068	-0.285	-0.763
2	First-Class Presort Ltrs, Flats, & Pcls	0.137	-0.878	0.006	0.007	0.001	0.021	0.152	0.057	0.052	0.007	0.005	0.000	0.079	-0.268	-0.492
3	First-Class Single-Piece Cards	0.258	0.326	-2.288	0.024	0.005	0.064	0.313	0.137	0.140	0.022	0.019	0.000	0.192	-0.557	-1.105
4	First-Class Presort Cards	0.214	0.263	0.016	-1.646	0.003	0.046	0.249	0.106	0.107	0.016	0.013	0.000	0.147	-0.292	-0.328
7	Periodicals In-County	0.290	0.367	0.030	0.030	-2.920	0.080	0.356	0.162	0.171	0.029	0.026	0.000	0.228	-0.871	-1.040
8	Periodicals Outside County	0.225	0.279	0.017	0.018	0.004	-1.549	0.265	0.113	0.114	0.017	0.014	0.000	0.157	-0.142	-0.811
9	Standard non-Carrier-Route Ltrs, Flats & Pcls	0.178	0.212	0.011	0.013	0.002	0.033	-1.131	0.083	0.083	0.012	0.009	0.000	0.113	-0.251	-0.467
10	Standard Carrier-Route Ltrs, Flats & Pcls	0.193	0.232	0.013	0.015	0.003	0.039	0.217	-1.441	0.094	0.014	0.011	0.000	0.126	-0.338	-0.543
11	Parcel Post & Parcel Select	0.199	0.241	0.014	0.016	0.003	0.041	0.226	0.097	-3.516	0.015	0.012	0.000	0.133	-2.364	0.045
12	Bound Printed Matter	0.238	0.290	0.020	0.022	0.005	0.057	0.276	0.125	0.131	-2.013	0.017	0.000	0.171	-0.454	-0.316
13	Media & Library Mail	0.269	0.336	0.026	0.027	0.006	0.070	0.324	0.147	0.155	0.026	-3.549	0.000	0.205	-1.709	-1.960
14	Penalty, Franked and Free Mail	0.275	0.343	0.028	0.028	0.007	0.074	0.330	0.153	0.162	0.027	0.024	0.000	0.212	1.920	2.334
15	Domestic Mail Services ex Evps & Box Rents	0.197	0.239	0.013	0.015	0.003	0.040	0.224	0.095	0.095	0.014	0.011	0.000	-1.548	-0.452	0.782

The postal demand models currently in use in the United States mostly include just own-prices in the demand equations, and are fit to postal time series. When these equations are fit the own-prices become proxies for the movements, not only of each product's own-price, but also for movements in the prices of the product's postal substitutes and complements. These movements are nearly proportionate to movements in the own-price of the postal products themselves. The conventional econometric own-price elasticity represents (approximately) the sum of the own-price elasticity and all of its postal cross price elasticities. This, in effect, masks the true own-price elasticity of each postal product. To see this effect one need only examine the sums of own-price and cross-price elasticities in the next to the last column of Table 4. These sums resemble conventional own-price elasticities. The sum for First-Class Single-Piece Letters, Flats and Parcels, -0.285, is not much different from the USPS estimate of -0.189. The USPS underestimate of the own-price elasticity is approximately equal to the combined cross price elasticities of First-Class Single-Piece Letters, Flats and Parcels with respect to the prices of all other categories of mail. Our estimates suggest that conventional methods have seriously underestimated virtually all of the own-price elasticities for U.S. postal services.

The cross-price elasticity estimates in Table 4 reflect sensible substitution patterns amongst the products. For First-Class Single-Piece Letters, Flats, and Cards, the cross-price elasticity with respect to the price of First-Class Presort Letters, Flats, and Cards is positive and small, 0.147, suggesting that these goods are substitutes. Similarly, the cross-price elasticity with respect to Standard non-Carrier-Route Letters, Flats, and Parcels is 0.134. However, due to content restrictions for Periodicals mail, it would be a near impossibility for a First-Class Single-Piece letter to be sent as an In-Class Periodical, and indeed the associated cross-price elasticity, 0.001, is virtually nonexistent. Likewise, it would be nearly impossible for a piece of In-County Periodical mail to be diverted to the First-Class Single-Piece Cards subclass, and indeed, this estimated cross-price elasticity, 0.030, is negligible. Conversely, the cross-price elasticity for In-County Periodical subclass with respect to First-Class presort is 0.367 and with respect to Standard non-Carrier-Route mail is 0.356. The cross-price elasticity with respect to First-Class single-piece is 0.290 and with respect to Standard Carrier-Route Letters, Flats, and Parcels is 0.162. For the In-County Periodicals subclass, these cross-price elasticities reflect the most-likely substitute mail sub-classes. Due to mail preparation requirements and distribution densities, an In-County Periodical is much more likely to convert to presort First-Class or regular Standard.

Finally, based on the estimates seen in the last two columns of Table 4, we make the observation that the elasticities with respect to the FWI are smaller in magnitude than are the elasticities with respect to the RPP. The mathematical relationship between the elasticities that underlies this conclusion is

$$\frac{\partial \text{Volume}}{\partial \text{RPP}} \frac{\text{RPP}}{\text{Volume}} = \frac{\left[\frac{\partial \text{Volume}}{\partial \text{FWI}} \frac{\text{FWI}}{\text{Volume}}\right]}{\left[\frac{\partial \text{RPP}}{\text{FWI}} \frac{\text{FWI}}{\text{RPP}}\right]}$$

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When the elasticity of RPP with respect to the FWI price is less than one, the demand elasticity with respect to RPP exceeds the demand elasticity with respect to the FWI price.

This confirms and extends an earlier finding in Pearsall (2005) that revenues per piece are less than unit elastic with respect to the U.S. postal tariff as represented by the FWI prices. USPS tariffs that apply to broadly-defined mail categories are actually quite complex. Consequently, when the tariff changes, mailers are able to re-optimize the structure of their mailings, either by reducing content or by otherwise adjusting shapes, weights, and/or worksharing. In the face of increased rates this usually results in an increase in RPP that is smaller than the increase in the FWI price. This less-than-unit-elastic relationship between RPP and FWI helps to explain why both the PRC and USPS tend to over-estimate the changes in postal revenues from higher rates.

6 FURTHER RESEARCH

This application to postal services of our Random-Coefficients Discrete-Choice Normal model and our method of estimation can be further refined. For example, we specified the model using mail class definitions chosen to ease the use of postal data assembled by PFY from 1972 to 2011. Alternatively, the same model could be fit using quarterly data and the post-2006 definitions of mail classes that arose from the Postal Accountability and Enhancement Act (PAEA).

Our finding that conventional models underestimate postal price elasticities depends very much on the selection of product categories for our model. Our division of postal traffic into 14 mail and one service categories is not particularly fine. In fact it was chosen to provide a convenient example for the model and estimation methodology. USPS accounting supports much finer divisions of both mail volumes and postal ancillary services. As the mail stream and service transactions are disaggregated we would expect to find that our own-price elasticities will increase in magnitude. This should happen because disaggregation will tend to introduce products that are ever closer substitutes. Ideally, our model should be refit using product definitions that reflect the level of aggregation found in postal price decisions. This level is much finer than the 15 products we have used in our initial research.

It may be desirable to include a broader set of demographic variables and/or harness a suitable household-level sample to better estimate the variance-covariance matrix used to calculate the principal components. We have also employed only a subset of the hedonic properties found underlying the U.S. tariff by Fenster *et al* (2007). Further explorations may suggest some extensions to the subset that we chose. Also, the low t-values of many of the estimates of the coefficients included in the vectors $\gamma_1,..,\gamma_J$ indicate that the model can be fit just about as well using a shorter list of exogenous market effects.

The effect of the regulatory environment on rates and fees is an important aspect of our research that needs further study.[vi] To simplify the method of estimation, we omitted the use of instrumental variables and assumed that all postal prices are exogenous. Between 1970 and 2006 the nominal rates were predetermined by a regulatory process; since 2006, they have been linked to the Consumer Price Index under a formula stipulated by Congress. All econometric demand studies of U.S. postal volumes to date have treated postal rates as error-free. The Generalized

Method of Moments is an estimation method that avoids this probably-incorrect assumption. It can be applied to our model, provided a set of suitable instrumental variables can be identified. Possible data that could be used as effective instruments include unit costs, productivity measurements, and contract labor rates.

Finally, the efficiency of our estimation methodology can be improved by adding a second stage. The first stage would remain the least-squares methodology described in Cigno *et al* (2012). The residuals from the first stage would then be used to estimate the variance-covariance matrix of the mean disturbances. The second stage would be to refit the model with the estimation methodology modified to Generalized Least Squares.

7 CONCLUSION

Our estimates of price elasticities are markedly different from those that are produced by conventional econometric methods. The estimates suggest that U.S. postal products are much more sensitive to selective price changes than conventional demand models predict. Our estimates of own-price elasticities using FWI prices range from -0.8 to -3.5, with most in the elastic range. We have also indirectly confirmed an earlier finding that revenues per piece are generally less than unit elastic with respect to the prices in the U.S. postal tariff. The implications for postal pricing and regulation are potentially significant.

Our estimates should be regarded as the early results of an initial exploration. Nevertheless, they stand as a demonstration that a new and effective method has been found to estimate a full set of own-price and cross-price elasticities for postal services.

NOTES

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[ii] This omission may partly be explained by the extreme computational demands of the BLP/Nevo estimation methodology. A thorough survey of modern econometric models of demand behavior may be found in Nevo (2011). This paper also contains an extensive bibliography of the literature regarding the Random-Coefficients Discrete-Choice Logit model.

[iii] The largest combined volume of mail pieces and postal service transactions per household in a single PFY, 1933.65, occurred in PFY 2000. Product shares, including the share for the outside good, were calculated for all PFYs using 2000 as the total number of potential pieces and transactions per household per year.

[iv] The variance-covariance matrix of the demographics variables was estimated from their quarterly series in the absence of a suitable household-level sample. The roots and matrix of characteristic vectors were computed and used with the demographics vectors, D, to calculate the vectors of principal components. All seven principal components were used to fit the models.

[v] See Thress (2012).

[vi] Virtually everything said here about prices also applies to weights per piece.

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