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U.S. POSTAL SERVICES AS COMPOSITE GOODS WITH HEDONIC PROPERTIES[*]

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[*] **The views expressed in this paper are those of the authors and do not necessarily represent the opinions of the Postal Rate Commission**.

1. INTRODUCTION

In this paper we treat U.S. postal services as composite goods with hedonic properties such as shape (letter, card, flat or parcel), weight-per-piece, distance to be transported, time-to-delivery (as a measure of service quality), presortation level, automation preparation (prebarcode, ZIP+4 addressing), size of mailings, etc. This contrasts with the conventional treatment of postal services found in recent demand studies. These studies treat postal services as collections of similar goods with cross-elastic demands.[1] Mail categories such as First-Class single-piece letters and Standard Regular Rate Enhanced Carrier Route mail are regarded as aggregations of services with distinct but inter-related demand functions, and with prices that are predetermined by the monopoly supplier, the United States Postal Service (USPS).

An alternative approach begins by fitting hedonic price equations and leads, eventually, to hedonic demand models such as those found in the work of Rosen (1974) and others. A hedonic price equation relates the postage rate that arises from the application of a postal tariff to the hedonic properties of the piece. The hedonic price equation becomes, in effect, an analytic functional representation of the tariff. Rosen showed that when there are many buyers and sellers, the partial derivatives of the hedonic price equation act as equilibrating prices. As buyers and sellers respond to these hedonic prices by bidding and offering goods with alternative amounts of the hedonic properties, the market reaches an equilibrium described by the hedonic price equation. In the case of a postal market, however, there is only one seller, so the hedonic price equation becomes a representation of the single supplier's administered

[1] Virtually all recent research has followed the conventional treatment with the primary goal of estimating price elasticities. Nankervis and Rodriquez (1995), Nikaki (1997), Nankervis, Carslake, and Rodriquez (1999), Florens, Sarach, and Toledano (2002) have estimated the demand for postal products using aggregate data from the UK, Finland, the UK, and France, respectively. Thress (2005) and Pearsall (2004) have used USPS time-series data to fit conventional demand models while Wolak (1997) has used microeconomic data derived from the U. S. census.

tariff and the hedonic prices describe the marginal rates customers are charged per piece for varying the amounts of the hedonic properties of their mailings.

Formally, we denote the hedonic price equation as $P = f(X)$ where X is a real-valued vector of hedonic properties and P is the postage that results when the postal tariff is applied to a piece of mail with the characteristics defined by X. $f(X)$ is assumed to be differentiable with respect to the elements of X. Its partial derivatives are the hedonic prices. These are denoted by the vector function $P_x(X) = \nabla f(X)$. If f is a homogenous function then $P_x(X)$ determines P for any X, otherwise, the hedonic price vector may be augmented with the residual $R(X) = f(X) - X \times P_x(X)$ to obtain a set of hedonic prices that completely describe the postal tariff. The hedonic price functions $P_x(X)$ and the residual $R(X)$ are predetermined functions of X and can be regarded as exogenous in the same way that postal rates are regarded as exogenous in conventional demand studies.

Our research has identified hedonic properties that define the structure of the tariff for domestic mail. We have found indices for measuring most of these properties and have developed an effective method for specifying and fitting the hedonic price equation as a differentiable function of the indices. We have used data from the United States Postal Service (USPS) to construct the indices and employed them to fit hedonic price equations for every tariff for domestic mail from 1969 to 2006. The high statistical quality of the estimates support the notion that U. S. postal tariffs are closely based upon the hedonic properties of the mail stream and that the tariffs have generally succeeded in presenting customers with hedonic prices that are consistent over the entire spectrum of postal services.[2]

2. BACKGROUND

Over time the U. S. postal tariff has evolved into an extremely complex and detailed system of rates, surcharges and discounts. The postal regulations that prescribe the application of the tariff to qualified mailings and mailers are equally

[2] A set of Lotus 1-2-3 worksheets were created to develop the hedonic indices, construct data sets, fit the hedonic price equations and graph the results in various ways. These worksheets may be retrieved from the PRC web site at www.prc.gov.

complex. Together they make it virtually impossible to discover, by simply inspecting the tariff, how much is actually charged at the margin for many of the basic hedonic properties of the mail stream. Yet having this information for proposed tariffs is essential for efficient rate design.

The basic principle that underlies the design of an efficient postal tariff is that the hedonic price equation, before it is subject to any markups, should be identical to the Service's variable cost function. Another way to express this principle is that the hedonic prices before the application of mark ups should equal the marginal costs to USPS of producing additional amounts of each of the hedonic properties at every point on the hedonic price equation.[3]

Our methodology for fitting hedonic price functions makes it possible for rate designers at the USPS and the PRC to apply this principle with far greater precision and consistency than has been possible in the past. The methodology yields hedonic price equations that accurately represent the tariff without a markup. So the pre-markup hedonic prices can be compared directly to postal marginal costs. The methodology is simple and can be applied successively within the processes that are currently used to design and refine proposed postal tariffs. In this role, the methodology would supplant a collection of rules of thumb that rate designers presently rely upon to estimate the hedonic rates that are implicit in a postal tariff.

The weight per piece of Standard mail illustrates how the methodology can be applied. The current postal tariff actually contains a parallel system of minimum piece rates and compound piece and pound rates for Standard letters and flats. The regulations prescribe the higher of the postage rates that result from the two systems. There are destination entry discounts that differ both by piece and by pound, and the regulations impose minimum total weights for mailings and have other complex provisions that relate to weight.[4] The piece and pound rates are all different for non-automated presorted mail, automated presorted mail and carrier-route presorted mail. The rates for regular and nonprofit mailers are also different, and the differences go

[3] The variable cost function and the hedonic price equation must both be defined for the same indices of hedonic properties.

[4] One of these provisions is positively mind-bending: *"Letters that weigh more than 3.3 ounces but not more than 3.5 ounces pay the nonletter piece and pound rate but receive a discount off the piece rate equal to the applicable*

beyond the use of different markup ratios for the two subclasses. There is no simple rule that a rate designer can apply to this system of charges to estimate the marginal charge for the weight per piece of Standard mail implicit in the tariff.

However, retrieving hedonic prices with our methodology is straightforward. The hedonic price equation is refit to the proposed tariff exactly as we shall describe for past tariffs, and the result is used to compute the hedonic prices without the subclass markups. The result can be graphed for Standard Mail and/or for any of its subclasses and rate categories to exhibit the relationship between weight per piece and the hedonic price implicit in the proposed tariff.

3. HEDONIC INDICES FOR U.S. POSTAL SERVICES

A difference between the rates charged for two distinct pieces of mail is ultimately attributable either to a difference in the hedonic properties of the two pieces, to a difference in the markups applied to derive the rates from cost per piece, to a mechanical feature of the tariff such as rounding to the nearest cent for a weight or distance step, or, to an inconsistency in the rate design.

Modern postal tariffs for U. S. domestic mail are complex structures. Rates, surcharges, discounts and the accompanying rules rarely apply to a single hedonic property of a piece of mail. Most commonly, the rate for a piece is the result of the interplay of several hedonic properties. Often, the hedonic properties are embedded in the tariff in ways that are peculiar to USPS, e.g., 5-digit presort.

The complexity of the tariff is considerably reduced if we can identify and measure a short list of hedonic properties. The indices that we have evolved for this purpose after a considerable mount of testing are for weight per piece; presortation; the quality of service based on the average days to delivery; preparation for automated and mechanized processing; the distance traveled from origin to destination; destination entry and the size of the average permit holder's annual mailings. Our efforts to define indices for other properties, most notably indices for shape and palletization, were less successful. Therefore, shape, palletization and several other properties are represented in the hedonic price regressions using dummy variables.

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nonletter minimum piece rate minus the applicable letter minimum piece rate corresponding to the correct presort

The indices are defined in ways that are universally applicable. For example, 3-digit presorting has no exact counterpart in the mail streams and tariffs of any country other than the U. S. So we have avoided using 3-digit presorting directly as the basis for defining a hedonic property of the mail stream. Instead, the value of our index for presorting is based on the number of divisions resulting from a sort and can be applied to any national mail stream with presorted mail.

The same indices of hedonic properties are used to fit the hedonic price equations for all rate regimes. These indices were refined and evaluated by fitting and refitting the hedonic price equation for the tariff that resulted from the R2001-1 postal rate proceeding. This was done using a sample with mail flows and hedonic properties derived from a detailed sampling of the mail stream performed by USPS in 2004 and provided to the PRC during the R2005-1 general rate proceeding. Some of the indices, such as weight per piece and distance traveled, are obvious selections as indices. Some, such as the size of a permit holder's annual mailings, were discovered to be important as the result of our experimentations. Many of the indices, such as those for presortation, automation and destination entry, were chosen after we had explored a number of alternative formulations.

Weight per Piece: The weight per piece index is directly measured and regularly reported by USPS in quarterly Revenue, Pieces and Weight (RPW) reports. Weight per piece served as its own index in our estimates of the hedonic price equations.

Service: The delivery service index is a measure of the speed of delivery for the various classes and subclasses of U.S. mail. Ideally a delivery service benchmark should be independent of the distance traveled. However, no such measurement exists for USPS delivery performance. Instead, the time taken by USPS to deliver mail is reported in the form of broad class and subclass averages that are not standardized to compensate for differences in the distances traveled. Consequently, we settled upon an index of delivery service that uses only the national averages by subclasses and several First-Class rate categories for delivery times for 2004 as shown in Appendix Table 1.

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tier."

Presortation: Postal tariffs since 1976 have included discounts for mail presorted to levels that correspond to the major levels that are found in the USPS processing and distribution network. These levels are denoted as “basic”, “3-digit”, “5-digit”, “carrier-route”, etc. in the RPW reports. Mail that receives a discount for destination entry must also be presorted at least to the corresponding level of entry. Presorting was reduced to a single index using the “bundle number”. The bundle number is the number of separate piles that would be produced by sorting a large quantity of mail to a specific distribution level. The bundle numbers for each presort level are shown in Appendix Table 1. The presortation index is based upon a fairly simple observation about how sorts are performed. Suppose that a large quantity of mail is to be sorted down to N delivery points by a machine that is capable of sorting a stream of mail M ways in a single pass. In addition, suppose that the mail has already been presorted into S bundles. In order to finish sorting the mail, each bundle would have to be passed through the machine a number of times X that can be approximated by solving the equation $(N/S)=M^X$ and rounding the result up to an integer. The equation suggests an index for presortation based upon a “machine” that sorts mail into a number of piles that equals the number of delivery points on an average postal route. Our presortation index is calculated from the formula $X=\ln(N/S)/\ln(M)$ where $N=122{,}363{,}316$ (the number of delivery points in the USPS network); $M=520.24$ (the average number of delivery points per route); and S is the bundle number from Appendix Table 1.

Distance: Postal tariffs for domestic mail include zoned rates for Parcels and Periodicals but not for First-Class or Standard mail which consists mostly of pieces that are small, light and flat. The zones run from east to west and were originally intended to represent about one day’s surface travel time. Recent tariffs also include discounts for destination entry for several classes and subclasses. Mail that is drop shipped to locations that are close to the delivery point travels less over the USPS transportation network. So, part of a destination entry discount is a rebate for shortening the distance. Our estimates of the average distances traveled corresponding to the zones and destination entry levels are shown in Appendix Table 1. The distances for the zones are average miles reported by Federal Express for transporting USPS mail under contract. The distances for the various drop ship levels were derived by regressing

USPS data for transportation costs for Periodicals on the Fed Ex distances and dummy variables for the different destination entry levels. Distances for the destination entry levels were then inferred from the estimated coefficients of the dummy variables. The index is the logarithm of the ratio of distance to the average distance for a local package delivery (12.84 miles).

Automation: Current and past postal tariffs have often included discounts intended to encourage large mailers to address their mail in ways that facilitate mechanized and automated processing. Originally, these discounts rewarded mailers for adding a ZIP+4 code to the address on each piece of mail. These discounts have now been completely supplanted by discounts for prebarcoding. In First-Class, the automation discounts have been partially extended to single-piece mail by means of a discount for qualified business reply (QBRM) letters and cards. Automation preparation is indexed on a sliding scale from zero (no preparation), to one (complete prebarcoding). Automation index values for ZIP+4 and QBRM mail were interpolated based upon a comparison of the discount to the discount for prebarcoding on a comparable piece of mail. *Destination Entry:* Recent postal tariffs include rates and discounts for destination entry at several levels of the USPS distribution system. These levels are bulk mail centers (BMC), area distribution centers (ADC), sectional center facilities (SCF) and delivery distribution units (DDU). Mail that is drop shipped to these locations is cheaper for USPS to deliver for several reasons. It is necessarily presorted at least to the entry point level, it travels a shortened distance through the postal transportation system and it avoids being transshipped through several hubs in the USPS distribution system. From a customer's viewpoint the most important aspects of destination entry may be the number of USPS locations to which he must, in effect, run his own delivery system and the reduction in delivery time he can achieve by drop shipping his mail closer to its destination. The bundle number for presorting is also the number of drop ship points for the corresponding destination entry level. Our index for destination entry is the logarithm of the bundle number.

Customer Size: Postal tariffs contain many rates and discounts that are available only to large mailers. This occurs, first, because mailers must pay fees, meet special standards for address hygiene, and make mailings that pass a size threshold in order to

qualify for these rates and discounts, and, second, because the fees and the costs of compliance are usually not worth the expense for a small mailer. In this way the size of a postal customer's mailings may create a difference in the rates for otherwise equivalent pieces of mail. Our index of customer size is derived from permit and volume data published by the PRC in the R2001-1 Recommended Decision. Appendix Table 1 shows the numbers of transactions in the form of fees, permits, and mailing certificates that are acquired by mailers to qualify for various special rates and discounts within each category. The customer size index is the logarithm of the volume of mail per transaction divided by the annual number of single-piece First-Class letters and cards per delivery point.

The indices described above, and presented in Appendix Table 1, do not exhaust the list of hedonic properties that are rewarded or penalized in a typical tariff for domestic mail. For example, the physical volume of a piece is an important factor in transportation costs and the physical dimensions of a piece are likely to determine if the piece can or cannot be processed by mechanized or automated equipment. Consequently, the postal code regulates the dimensions of pieces that are eligible for specific rates and the tariff typically sets different rates for letters, cards, flats and/or parcels, and imposes additional charges for pieces that are nonstandard or non-machinable.

4. HEDONIC PRICE EQUATION REGRESSION RESULTS

USPS instituted sixty different domestic mail tariffs between July 1969 and January 2006. This number far exceeds the number of occasions over this time period when the PRC recommended changes in postal rates. The large number of changes in the tariff occurred because USPS typically follows the practice of introducing new rates in several stages.

We have estimated hedonic price equations for each of the sixty different tariffs using a single large representative sample of domestic mail. We extracted information for representative pieces with diverse average characteristics and known billing determinants from USPS samplings of the mail stream (Loetscher 2005) and from billing determinants (Thress 2005) for the year 2004. The data provide a highly detailed picture of the mail stream with respect to First-Class and Standard mail, and a somewhat less detailed picture for Periodicals and other subclasses. The sample data were reaggregated to obtain observations that represented collections of mail with distinct characteristics, such as single-piece, non-permit-imprinted, non-QBRM, standard-shaped, machineable, First-Class letters, weighing between 1.5 and 2 ounces. The resulting sample consisted of 2086 observations encompassing all categories of domestic mail except Penalty mail and Free mail. Appendix Table 2 presents the number of observations for several broad categories of mail along with various proportions and average hedonic index values. Each of the observations in the sample corresponds to at least 10,000 pieces of mail in 2004.

The values of the indices of hedonic properties along with the values for dummy variables representing mail shape and other hedonic properties were calculated for each data point. The values of the explanatory variables for the hedonic price equations were derived from these index and dummy variable values and did not change for the rate regimes except for the omission of the observations for Express Mail for rate regimes prior to 10 September 1977.

The USPS data was sufficiently detailed to enable us to estimate billing determinants for every data point in the sample. Postage rates were calculated for each of the sixty rate regimes by applying the tariff for the regime to the billing determinants for the observations. A comparison of the calculated revenues per piece for the rate

regime in effect in 2004 with the average revenues per piece from the USPS First-Class and Standard mail sampling data usually revealed a near-perfect agreement. Nevertheless, the ratios from the 2004 sample were used to correct the calculated revenues per piece.

Postal rates are partly the result of subclass markup ratios set by the PRC in omnibus rate proceedings. The markups are expressed as ratios of the average revenue per piece to the average attributable cost per piece for each subclass. The markups are needed to obtain a postal tariff that will collect sufficient revenue to cover all costs and to meet other requirements established by Congress. The markup ratios used by the PRC to construct a tariff have varied from rate case to rate case for reasons that generally have little to do with the hedonic properties of the mail stream. The subclass markups applied by the PRC to obtain the rates it recommended in the R2001-1 Decision are shown in Appendix Table 2.

For this research we have represented postal revenues per piece as the product of a markup ratio and an underlying pre-markup hedonic price that is solely a function of the hedonic properties of the mail. The markup ratios that the PRC has applied with each of the 13 omnibus rate proceedings since 1969 and for the mail reclassification of MC93-1 have been extracted from the Commission's Recommended Decisions and used to back the markups out of the calculated rates prior to fitting the hedonic price equations. The markup ratios used on any rate regime are taken from the most recent prior PRC Recommended Decision.

The equation form we use to fit the hedonic price equations is an abbreviated translog with many dummies among the explanatory variables and several omissions among the squares and cross-products of the logged variables. The equations contain nearly complete collections of squared terms and cross product terms for the indices of hedonic properties. The inclusion of cross product terms involving the dummy variables and proportions has been much more sparing to preserve degrees of freedom and to avoid multi-colinearity. Squared terms are always divided by two in order to facilitate the calculation of the derivatives and the construction of the hedonic prices. Since the translog is a general-purpose form, the quality of the hedonic equation fit is overall

evidence of the hedonic basis and consistency of the tariff and the residuals from the fit will reveal how precisely the tariff applies to specific types of pieces.

The hedonic price equations are fit using two specific forms that differ only with respect to the exclusion of three regressors for Express Mail from the equations fit for rate regimes prior to the introduction of Express Mail service on 10 September 1977. The fitted hedonic price equation for the rate regime installed on 16 July 2003 is shown in Appendix Table 3. This is the tariff recommended by the PRC in its R2001-1 Recommended Decision. The dependent variable for the equation is the natural logarithm of the calculated postage divided by the subclass markup. Postage rates for all of the hedonic price regressions are measured in current dollars. The intercept is omitted because the equation includes dummy variables for a complete list of shapes: letters, cards, flats, small parcels and large parcels. The natural logarithm of weight per piece and its square also do not appear alone for the same reason. Instead, weight per piece and its square are interacted individually with the shape dummies. A parcel is considered “small” if it is a piece of First-Class mail, Standard mail or a Periodical. It is considered “large” if it is a Priority, Express or Package Service piece. All of the indices for hedonic properties, except the index for automation preparation, appear in the equation as natural logarithms. None of the other explanatory variables appear in logged form.

To obtain an equation specification that could be fit closely to the data set, we found that it was necessary to include several variables that are not measures of hedonic properties of the mail. The observations for First-Class mail include points for halved weight brackets up to 4 ounces. The estimated rates for the two halves of the bracket are always the same so when an equation is fit through this data the lower half-bracket point will fall above the fitted curve and the upper half-bracket point will fall below. These offsetting errors can be mostly eliminated by adding to the equation a dummy variable defined as 1 = lower bracket half, -1 = upper bracket half and 0 = not a halved bracket.

A dummy variable was added to distinguish between zoned and un-zoned rates. Zoned rates progress with distance travelled, while un-zoned rates do not. The rates for Periodicals, Priority Mail, Express Mail, Parcel Post and Bound Printed Matter (BPM)

vary according to the number of zones crossed by the piece. The rates for all other categories of mail are not zoned in this way. Flat-rated Priority and Express mail pieces are considered zoned.

In order to get uniformly good estimates, Express Mail was distinguished from other mail with respect to weight per piece and distance travelled. This was done by adding a dummy variable for Express Mail and interacting the dummy with weight per piece and the distance index. The terms that were added are the same ones that are omitted from the equations prior to 9 October 1977.

Some of the tariffs for Periodicals apply only to the advertising portion of the weight of the piece, or connect discounts to "editorial" content. Advertising is not really a hedonic property of a piece. Rather, the tariff links the markup on a periodical to the periodical's commercial content. The subclass markup ratios we have used to eliminate the markup from the estimated postage rates do not reflect this linkage, so the ratio of advertising to total weight has been included as a variable for periodicals and is set to zero for all other kinds of mail.

The hedonic price equations are fit to the elements of the data set using weighted least squares. The use of weighted least squares allows us to apply all of the standard statistical tests for significance and goodness-of-fit to the estimated equations. The observation weight μ_t for a data point t is derived from the volume of pieces V_t according to the formula $\mu_t = 0.5\left(N \Big/ \sum_i \sqrt{V_i} \right)\sqrt{V_t} + 0.5N$, where N is the number of observations in the data set and V_t is the number of pieces for the data point t in the mail stream in 2004. The formula produces a set of weights that sum to N, so the weight μ_t may be viewed as the number of observations for which the observation t serves as a proxy. The minimum value for any weight is 0.5. This ensures that the fitted hedonic price equation will continue to reflect the tariff even in cases where the tariff applies to very little mail. The weights increase proportionately with the square-root of volume to a maximum value of approximately 24.5. When the hedonic price equations are fit using weights that vary according to this formula, they produce very accurate predictions of revenue per piece for all of the observations that represent large volumes of mail.

As an exercise in curve fitting the method works quite well for the rate regime that was in effect in 2004. This can be seen from the R-square of 0.99711 and from the standard errors shown in Appendix Table 3. The standard error declines as the weight for an observation changes from $\mu_t = 0.5$ to $\mu_t = 24.5$. The standard error for an unusual piece of mail like a 50 lb package for delivery by Parcel Post is around .34421 current dollars per piece. The standard error for a more average piece, such as a 2 to 2½ ounce non-automated 3/5-digit presorted Standard Nonprofit Rate flat, is about 0.17210 dollars per piece. The standard error for the most common piece of mail, a single-piece ½ ounce First-Class letter, is only 0.00702 dollars per piece.

Goodness-of-fit statistics were calculated for the estimated hedonic price equations for all sixty rate regimes. Remarkably, the R-square statistics are about the same for all of the fitted equations. However, the standard errors for an average data point (observation weight = 1.0) for the rate regimes of the early 1970s are about 50 percent higher than the errors for the rate regimes since 2001. Therefore, the statistical quality of the estimated equations deteriorates gradually as we regress back over time. Nevertheless, the precision of the estimates demonstrates that the tariffs for domestic mail have historically been both hedonically based and internally consistent. The estimated hedonic price equations all successfully relate postal rates to the same hedonic properties of the mail stream. The high precision of the estimates is possible only because rate designers were generally successful in replicating the same relationship of rates to hedonic properties over all classes, subclasses and categories of domestic mail, except Express mail.

The t-values in Appendix Table 3 show that the hedonic variables and dummies that we have selected, the indices that we have devised for the hedonic properties, the translog form for the hedonic price equation and the weighted least squares estimator all worked well together to explain the rates that resulted from the tariff of 16 July 2003. This is also generally true for the other rate regimes. All of the hedonic indices and dummy variables are associated with several regressors with statistically significant t-values. This means that all of the hedonic indices and variables make a statistically significant contribution to the fitted hedonic price equation. It is particularly noteworthy that so many of the regressors constructed as squares and cross-products have

coefficients with high t-values. This means that we can rule out the possibility that a simpler equation form, omitting many of these terms, would be nearly as effective as the chosen translog.

The large number of cross-products with significant coefficients also means that the hedonic price equations are generally not separable with respect to the hedonic properties. The economic explanation for this finding is that the relationship of postal rates to the hedonic properties of the mail is complex. As a consequence, we cannot view postal rates as a simple arithmetic or geometric sum of a collection of hedonic functionals, each dealing exclusively with one of the hedonic properties.

5. PROPERTIES OF THE FITTED EQUATIONS

Simply inspecting the estimated coefficients of the fitted translog equations is usually insufficient to determine if the hedonic prices conform to expectations regarding signs and magnitudes. Translogs are difficult to evaluate in this respect because the relevant properties of the equation are almost always the result of interactions among several coefficients. This usually makes the hedonic prices functions of the indices and other terms in the hedonic price equations.

A practical, but not very scientific, way to deal with the problem is to chart the fitted equations and their derivatives, and then to inspect the charts visually. Figures 1, 2 and 3 illustrate how this was done for the fitted hedonic price equations. This particular set of figures was drawn for a hypothetical composite piece of mail that has the characteristics of an average piece of mail in 2004. The values of the dummy variables and the hedonic properties for this hypothetical piece can be found on the lines for “All Categories” in Appendix Table 3. Figures similar to Figures 1, 2 and 3 have been drawn for all of the hedonic properties for which we have indices, for 39 categories of mail, and for 13 representative rate regimes.[5] While an inspection of all of these graphs certainly produced some surprises, on the whole the hedonic prices that emerge from our fits of the hedonic price equations conform well to our expectations regarding signs and magnitudes.

[5] Readers wishing to examine any of these figures may do so by generating them using a Lotus 1-2-3 worksheet that we have constructed partly for this purpose. The worksheet and a file with a more extensive set of illustrative graphs is posted on the PRC web site at www.prc.gov.

The bundle number for an average piece of mail in 2004 was 1,117. This means that a large quantity of the composite pieces would have been presorted into an average of 1,117 divisions prior to mailing. We can see from Appendix Table 1 that this is a finer presort than a 3-digit presort but is not as fine as a 5-digit presort. It is roughly the minimum level of presorting that would be needed for destination entry at a delivery unit (DDU). The value of the presortation index for such a presort is about 1.85. A higher level of presorting leads to a lower value of the index and vice versa.

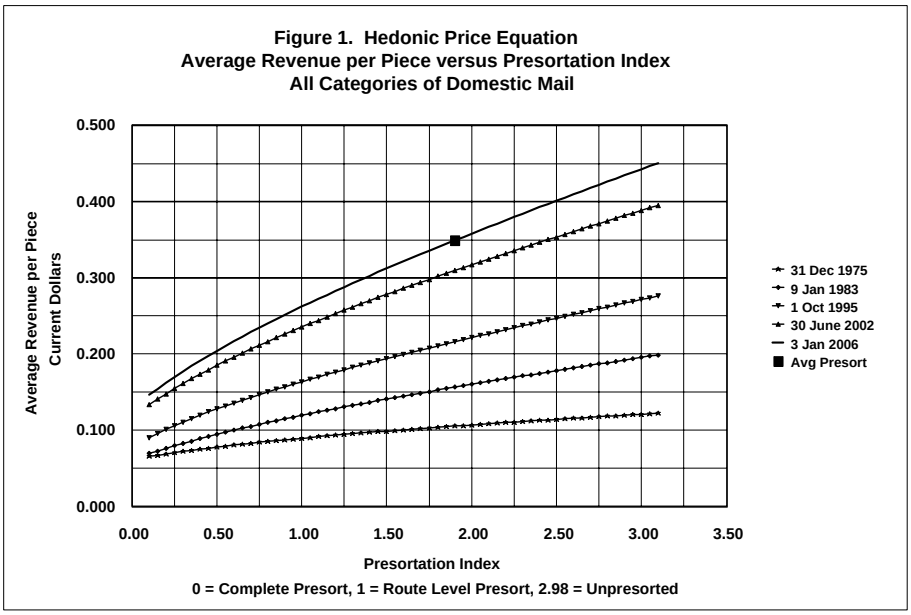


Figure 1 shows how postal rates varied with the hedonic index for presortation for five selected rate regimes from 1975 to 2006. The predicted average revenue per piece is shown on the vertical axis and the presortation index is shown along the horizontal axis. Each of the curves in Figure 1 is taken from the hedonic price equation for a single tariff. The curves are identified by the installation dates of the tariffs shown in the legend on the right side of the figure. For example, the black curve represents the present USPS tariff for domestic mail. This tariff was installed in two stages following the Recommended Decision of the PRC in October 2005. The second stage of the installation occurred on 3 January 2006. The square black mark on this curve shows the current postage and the presortation index value for an average piece of domestic mail.

The curve for each regime was constructed by evaluating the fitted hedonic price equation over a range of presort index values and then multiplying the result by the average markup for the rate regime. For example, the curve for the rate regime that was installed in 30 June 2002 was constructed by evaluating the regression equation shown in Appendix Table 3 for values of the presortation index ranging from 0 to 3, calculating the predicted pre-markup rates by taking the anti-logarithm, and then multiplying the result by the average markup from the PRC's R2001-1 Recommended Decision.

The hedonic price equations for more recent tariffs lie above the earlier ones because current-dollar postal rates have generally risen over time. All of the curves slope upwards reflecting the fact that all but the first of the tariffs offered discounts to large mailers for presorting certain kinds of mail. The slopes become more pronounced as USPS increased the existing discounts and added new discounts for more kinds of presorting and more subclasses.

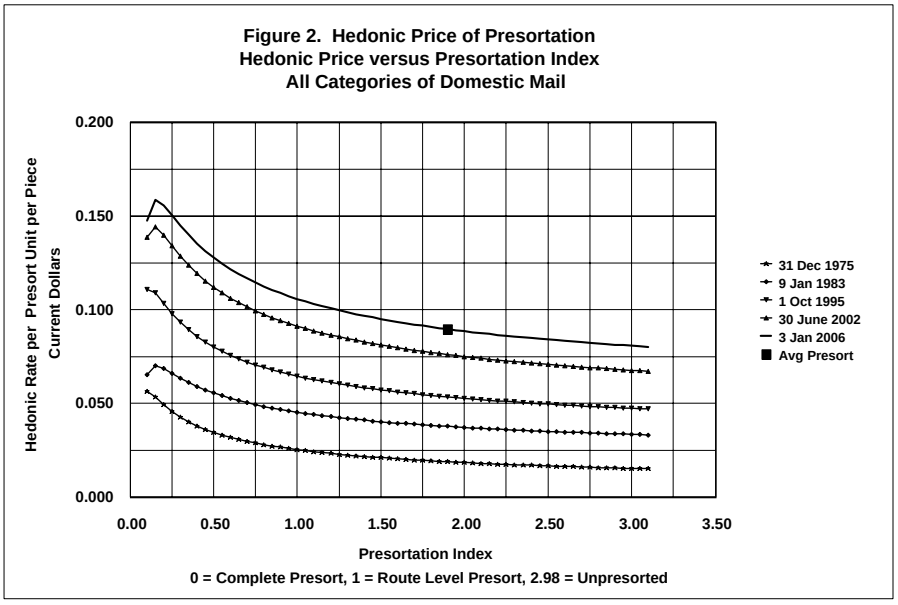
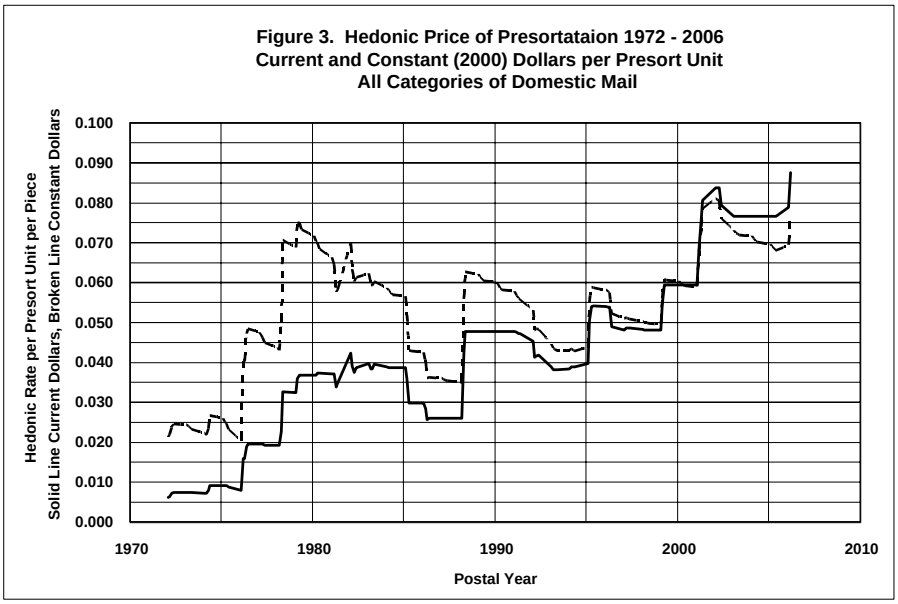


Figure 2 shows the hedonic price of presorting for the various rate regimes as a function of the presort level. These hedonic prices are computed by evaluating the partial derivatives of the hedonic price equations with respect to the presortation index. The derivatives are then multiplied by the rate regime's average markup ratio for all categories of mail. Any point on one of the curves in Figure 2 shows the slope of the

hedonic price equation at the corresponding point in Figure 1. Figure 2 shows that the hedonic rate for presortation has risen rapidly since discounts for presorting were first offered to some First-Class mailers in 1976. The curve for the rate regime of 30 December 1975 does not lie flat at the bottom of the graph because the translog equation cannot precisely represent such a line, and also, because the tariff of the time included rates that would have implicitly provided a small reward for mail that was presorted as it was in the samples and billing determinants of 2004. The curve for 9 January 1983 shows how the hedonic price rose as the result of the installation of presort discounts for most large First-Class and Third-Class mailers. Thereafter, the hedonic prices rose only in gradual steps until the rate regime of 30 June 2002 when they were again raised substantially. The hedonic price for presorting in the current rate regime is shown by the black line in Figure 2. As we would expect, these hedonic prices are the highest in current dollars.



It is worth noting that the curves in Figure 2 do not approximate flat lines. Instead, they all exhibit negative slopes. This means that the relationship between postal rates and the index for presortation is non-linear. Increases in presorting are rewarded more highly for mail that is already presorted.

Figure 3 shows how the hedonic price of presortation has varied over time both in current and in constant (year 2000) dollars deflated with the implicit GDP deflator. All

sixty of the fitted hedonic price equations are used to derive the hedonic price of presortation at the average 2004 level of the index. The graph was constructed by joining the hedonic prices from the equations in a continuous quarterly time series from 1972 to 2006. The hedonic price of presortation for a piece with the average characteristics of the 2004 mail stream has risen considerably since the early 1970s, however, we can see that most of the real increase occurred between 1975 and 1980. Since then, the constant dollar hedonic price has exhibited roughly the same saw tooth time path that is exhibited by postal rates generally.

The indices of hedonic properties, the specific form of the fitted hedonic price equations and the weight calculation for our applications of weighted least squares were the result of a series of experiments with alternatives. In most respects the impression left by these experiments is that the fitted hedonic price equations are robust. Minor changes in variable definitions, the specific form of the translog and the weights formula have almost no effect on the way that the equations and the derived hedonic prices appear in the figures.

6. CONCLUSION

For this paper we have adopted the view that a piece of mail is a composite bundle of hedonic properties. Our econometric research has succeeded in identifying and measuring these properties. The results obtained are striking in several ways. First, they provide important insights into the implicit valuations of product features embodied in postal rates. Second, the hedonic prices/valuations obtained have been quite stable over three decades. Third, variations in estimated hedonic prices over time often correlate with corresponding innovations in product features and regulatory decisions. Of course, the indicated stability of these hedonic prices over time may only indicate that the regulatory process has produced stable implicit valuations of postal product features. While this does not allow us to draw efficiency inferences about postal rate setting over the period, it does display the consistent structure of implicit valuations of features embodied in postal products resulting from the process. Equally important, our research provides an essential first step to the use of hedonic demand

models for regulated markets extending the results of Rosen (1974) and others for competitive markets.

APPENDIX

Table 1: Indices for Selected Hedonic Properties of U.S. Domestic Mail

Delivery Service Standard

Class	Category	Index (Days)
First-Class	SP Ltrs	1.6600
	SP Cards	1.5325
	SP Flats	2.1675
	SP Pcls	2.5475
First-Class	Presort Ltrs	2.2325
	Presort Cards	2.1750
	Presort Flats	2.5775
	Presort Pcls	2.3575
Periodicals	All Mail	4.2310
Standard	All Mail	7.0210
Priority	All Mail	2.0800
Express	All Mail	1.0000
Package	Parcel Post	4.3650
Services	BPM	3.9825
	Media Mail	4.7900
	Library Rate	3.7825

Presortation

Sort Level	Bundle Number	Index
None	1	2.9776
BMC	21	2.4908
Mixed AADC	133	2.1956
ADC/AADC	133	2.1956
SCF	286	2.0732
3 -Digit	930	1.8847
3/5-Digit	930	1.8847
DDU	1,031	1.8682
Counties	3,143	1.6900
5-Digit	37,159	1.2950
Routes	235,204	1.0000
Basic Car-Rte	2,352,040	0.6318
High Density CR	29,400,500	0.2280
Saturation CR	110,126,984	0.0168
Delivery Point	122,363,316	0.0000

Distance Transported

Zone/Facility	Distance	Index
Delivery Point	1.00	0.0000
DDU	1.15	0.0536
SCF	2.40	0.3427
BMC	4.23	0.5651
Local	12.84	1.0000
Zone 1	15.46	1.0729
Zones 1&2	62.47	1.6199
Zone 2, 1-3	109.48	1.8397
Zone 3	260.34	2.1791
Zone 4	514.86	2.4463
Zone 5	807.28	2.6225
Zone 6	1166.00	2.7666
Zone 7	1588.07	2.8876
Zone 8	2577.86	3.0774
Zone 9	5000.00	3.3370

Automation Preparation

Addressing	Shape	Index
Common	All	0.0000
ZIP+4	Letters	0.1596
	Cards	0.2000
QBRM	Letters	0.4054
	Cards	0.8333
Prebarcoded	All	1.0000

Destination Entry

Dropship	Bundle Number	Index
None	1	0.0000
BMC	21	3.0445
ADC	133	4.8903
SCF	286	5.6560
DDU	1,031	6.9383

Size of Customer Mailings per Permit

Class	Category	Fee Type	Transactions	Volume/Trans.	Index
First-Class	Single-Piece	Delivery Point	122,363,316	1.00	0.0000
First-Class	Regular Ltrs	Certificate	2,531,643	1.10	0.0990
	Presort Ltrs	Presort	3,280	2675.55	7.8919
	Regular Cards	Certificate	141,904	5.40	1.6855
	Presort Cards	Presort	200	2672.20	7.8907
	Auto Ltrs	Presort	44,194	2675.81	7.8920
	Auto Cards	Presort	2,242	2675.94	7.8921
Periodicals	Within County	Application	249	8479.31	9.0454
	Regular Rate	Application	2,072	8488.69	9.0465
	Nonprofit	Application	566	8482.35	9.0457
	Classroom	Application	17	8498.44	9.0476
Standard	Reg Presort	Presort	3,666	2770.57	7.9268
	Reg Auto	Presort	38,560	2770.54	7.9268
	Reg ECR	Presort	29,571	2770.52	7.9268
	NP Presort	Presort	68,006	80.80	4.3919
	NP Auto	Presort	295,795	80.80	4.3919
	NP ECR	Presort	99,084	80.80	4.3919
Priority		Certificate	141,757	20.56	3.0231
Express				1.00	0.0000
Package	Parcel Post	Certificate	13,378	68.10	4.2209
Services	BPM	Certificate	21,214	68.63	4.2287
	Media Mail	Certificate	5,718	80.55	4.3889
	Library Rate	Certificate	975	41.67	3.7297

Table 2: Average R2001-1 Markup and Hedonic Index Values for U.S. Domestic Mail

	No. of Data	Proportions by Shape					Proportions of Pieces		
Mail Catagory	Points	Letters	Cards	Flats	Sm. Pcls	Lg. Pcls	Non Std.	Palletized	Unzoned
All Categories	2086	70.45%	2.65%	25.46%	0.53%	0.91%	0.44%	2.95%	94.61%
First-Class Letters	307	94.54%	0.00%	4.94%	0.53%	0.00%	0.72%	0.00%	100.00%
First-Class Cards	31	0.00%	100.00%	0.00%	0.00%	0.00%	0.00%	0.00%	100.00%
Priority Mail	240	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%
Express Mail	105	0.00%	0.00%	0.00%	0.00%	100.00%	0.00%	0.00%	0.00%
Periodicals	86	1.86%	0.00%	98.12%	0.02%	0.00%	0.00%	66.20%	0.00%
Standard Regular Mail	390	56.24%	0.00%	43.05%	0.71%	0.00%	0.15%	0.00%	100.00%
Standard Non-Profit Mail	337	76.11%	0.00%	23.77%	0.12%	0.00%	0.64%	0.00%	100.00%
Package Services	590	0.00%	0.00%	19.97%	0.00%	80.03%	1.78%	0.00%	16.79%
Unzoned Mail	1071	74.38%	2.80%	22.16%	0.56%	0.10%	0.46%	0.00%	100.00%
Zoned Mail	1015	1.54%	0.00%	83.37%	0.01%	15.08%	0.19%	54.77%	0.00%

	R2001-1	Wgt./Pc.	Ppn. of Wgt.	Service	Automation	Presort	Distance	Drop Ship	Cust. Size
Mail Catagory	Markup	Ounces	Advertising	Avg. Days	Prebarcode	Bundle No.	Miles	Locations	Vol/Trans
All Categories	1.705	1.922	1.86%	4.448	0.6236	1,117	60.35	6.34	2,139
First-Class Letters	1.920	0.751	0.00%	1.989	0.4906	37	197.83	1.00	1,370
First-Class Cards	1.426	0.136	0.00%	1.876	0.4887	38	646.49	1.00	1,432
Priority Mail	1.595	27.518	0.00%	2.080	0.0000	1	361.32	1.00	21
Express Mail	1.840	9.955	0.00%	1.000	0.0000	1	287.86	1.00	1
Periodicals	1.008	7.124	41.69%	4.231	0.4241	133,559	33.95	27.23	8,487
Standard Regular Mail	1.699	1.994	0.00%	7.021	0.7913	34,897	15.70	44.78	2,771
Standard Non-Profit Mail	0.951	1.150	0.00%	7.021	0.7785	3,925	28.80	12.11	81
Package Services	1.237	46.269	0.00%	4.221	0.2657	450	123.82	19.65	70
Unzoned Mail	1.740	1.320	0.00%	4.471	0.6377	921	61.43	5.92	1,861
Zoned Mail	1.081	12.468	34.49%	4.040	0.3756	33,076	44.21	21.32	7,029

Table 3: Hedonic Price Equation Regression Example Results

Rate Regime Installation Date	16 July 2003	Standard Error (Observation Weight = 0.5)	0.34421
Correlation Coefficient (R-Squared)	0.99711	Standard Error (Observation Weight = 1.0)	0.17210
Number of Data Points	2086	Standard Error (Observation Weight = 24.5)	0.00702

Variable	Estimate	t-value	Variable	Estimate	t-value	Variable	Estimate	t-value	Variable	Estimate	t-value
X0	0.0603	12.26							X7*X14	0.0513	8.08
X1	-1.0411	-4.47	W*X1	0.2112	8.88	X1*W*W/2	0.2152	19.58	X11*X11/2	0.1233	10.56
X2	-1.4673	-6.40	W*X2	-0.0541	-1.10	X2*W*W/2	0.1810	3.82	X11*X12	-0.0088	-0.93
X3	-0.8495	-3.60	W*X3	0.1622	5.99	X3*W*W/2	0.2648	26.15	X11*X13	-0.0165	-2.77
X4	-0.6232	-2.59	W*X4	0.3234	6.97	X4*W*W/2	0.0796	3.62	X11*X14	-0.0017	-0.56
X4L	1.1843	4.35	W*X4L	0.1305	2.36	X4L*W*W/2	0.0950	8.02	X12*X5	-0.1420	-3.71
X5	0.0746	0.30	W*X5	0.1756	6.36	X6*X5	1.0087	5.32	X12*X9	-0.1815	-11.56
X6	-0.3901	-1.74	W*X6	-0.1356	-18.38	X6*X6/2	0.0066	0.03	X12*X10	-0.0954	-3.10
X7	0.0033	0.02	W*X7	0.0329	3.80	X6*X7	-0.0864	-1.81	X12*X12/2	0.0544	6.30
X8	-0.3891	-1.75	W*X8	-0.1535	-1.57	X6*X11	0.2379	5.83	X12*X13	0.0050	1.14
X9	1.1473	12.10	W*X9	0.1350	6.99	X6*X12	0.0386	2.23	X12*X14	0.0192	8.25
X10	1.9069	7.92	W*X10	-0.2472	-8.92	X6*X13	0.0456	1.48	X13*X3	-0.0235	-5.12
X11	0.2048	2.34	W*X11	-0.0331	-8.81	X6*X14	-0.0257	-1.66	X13*X4L	0.1301	6.41
X12	-0.2998	-5.36	W*X12	0.0193	6.04	X7*X7/2	-0.5494	-1.79	X13*X8	0.3393	5.16
X13	-0.1161	-1.86	W*X13	-0.0240	-9.14	X7*X11	-0.1145	-3.59	X13*X13/2	-0.0364	-8.87
X14	-0.2516	-9.86	W*X14	0.0008	0.50	X7*X12	0.0033	0.17	X13*X14	0.0134	6.09
X15	0.0968	3.35	W*X15	0.1075	1.99	X7*X13	-0.0101	-0.81	X14*X14/2	0.0372	5.17

Symbol	Description
Y	Natural Logarithm of the Postage Rate in cents divided by the subclass markup ratio.
W	Natural Logarithm of Weight per Piece in Ounces based upon either the FY 2004 mail samplings or billing determinants
X0	Dummy Variable for a Halved one-ounce rate bracket (1 = lower 1/2, -1 = upper Half, 0 = unhalved bracket).
X1	Share of Letters as a fraction of total pieces.
X2	Share of Cards as a fraction of total pieces.
X3	Share of Flats as a fraction of total pieces.
X4	Share of Small Parcels as a fraction of total pieces.
X4L	Share of Large Parcels as a fraction of total pieces.
X5	Share of Nonstandard and/or Nonmachinable pieces as a fraction of total pieces.
X6	Natural Logarithm of a Delivery Service Index based upon the average number of days to delivery.
X7	Automation share as a fraction of total pieces based upon an index of postal addressing standards.
X8	Share of pieces that are eligible for a pallet discount.
X9	Dummy Variable for mail that is subject to an unzoned tariff (1 = unzoned tariff, 0 = zoned tariff).
X10	Dummy Variable for Express Mail.
X11	Natural Logarithm of a Sortation Index based upon the number of presortation divisions.
X12	Natural Logarithm of a Distance Index based upon the miles between processing centers.
X13	Natural Logarithm of a Drop Ship Index based upon the number of destination entry locations.
X14	Natural Logarithm of a Customer Size Index based upon the number of pieces mailed by permit holders.
X15	Ratio of Advertising Weight to Total Weight for Periodicals (zero for other mail classes).

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