Hedonic regression models using in-house and out-of-house data

Two data sources used by the Bureau of Labor Statistics to create hedonic regression models have their own distinct advantages and disadvantages; the Bureau performs research on each data source in an effort to meet its current and ever-evolving future needs

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The research leading up to the publication of this article was conducted under the CPI initiative to expand the scope of developing hedonic regression models for quality adjustment purposes to more items within the CPI market basket. The primary focus of the article is to provide a detailed analysis of the hedonic modeling process and to illustrate the characteristics of two data sources the Bureau of Labor Statistics has chosen to utilize in its ongoing research on hedonic-based quality adjustment methods.

Early research by BLS personnel and a significant portion of the current research done by the CPI staff in this area rely upon the existing sample of CPI data for the creation of hedonic regression models.[1] When it was recommended that the Bureau expand its use of hedonic models for quality adjustment purposes to more items within the CPI, situations arose in which the existing sample size of the items chosen were deemed insufficient to support the creation of hedonic models. To alleviate this problem, supplemental samples were designed and collected exclusively for hedonic modeling purposes.[2] Despite the Bureau's having full control over this type of sample data, such an "in-house" prescription was not seen as a cure-all, because designing and collecting these data exhausts many BLS resources. Accordingly, the Bureau was led to investigate the use of hedonic models created with market data purchased from private firms that specialize in collecting point-of-sale observational data.[3] Purchased, or out-of-house, data offer many enhancements over in-house data, but are costly and have their own sets of limitations.

With home-based telephones (corded or cordless), the Bureau has an opportunity to compare the process and results of using both in-house and out-of-house data in the creation of hedonic regression models. This article discusses the issues of data quality, the specification of a model, and the application of hedonic quality adjustments to substitutions in the CPI sample. Empirical evidence and quantitative data support the topics addressed. The next section examines the characteristics of the data. Following that section, the results of the models are presented, and a discussion illustrates how they could have been used in quality-adjusting substitutions in the CPI. The final section is a follow-up of what has changed with the data and presents a brief conclusion.

The data

Sources. The price data used in the analysis that follows were collected by BLS data collectors for the CPI and by the NPD Group, a private firm that collects and sells point-of-sale marketing information. The CPI sample consists of price data for home-based telephones from the official CPI sample and a specially designed supplemental research sample that was created and collected in order to increase the robustness of the existing sample to facilitate hedonic modeling research. CPI statisticians drew the supplemental sample

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on the basis of current CPI sampling procedures. The CPI sample is designed to be representative of consumer spending habits and is distributed across the country and across all types of retail outlets. The NPD Group sample is a collection of point-of-sale data for home-based telephones from various partnered retail outlets from across the country. The Bureau purchased these data from NPD to explore the use of out-of-house data in developing hedonic regression models. NPD offers point-of-sale data for a wide range of consumer goods and services. Most of the company's clients are private firms that use the sales data to make marketing decisions.

Sample design. All of the price data for this study were collected in August and September of 2000. It was during these months that the Bureau was able to collect its supplemental sample. The agency purchased roughly 2 years of telephone data from the NPD Group, but in order to make timely comparisons with the CPI sample, only data from the aforementioned months were used in the upcoming analysis.

The CPI sample consists of price quotes, each of which represents a single item sold in a retail outlet. Each quote consists of the item's listed price at the time of collection, a description of the item's physical characteristics, and information about where the item is sold. Under current CPI sampling procedures, data collectors initiate price quotes by using a multistage probability selection technique. The probabilities of selecting items for pricing are proportional to the sales of the items. A slightly augmented item selection procedure was followed in pricing the supplemental sample. In this procedure, data collectors were told how many cellular, corded, and cordless telephones to price in each outlet. Respondents in the outlet were asked to rank unique model numbers according to their sales figures and the length of time they had been available for sale in the outlet. Unique models that were both good sellers and fairly recent arrivals to the outlet were chosen for the sample.

The supplemental sample added 398 observations to the existing 115 observations from the official CPI sample. BLS data collectors were unable to collect 21 percent of the supplemental sample. The final sample consisted of 314 supplemental observations and the 115 observations from the official CPI sample, for a total of 429 observations.

Telephones are included in the *information and information processing* CPI expenditure class (coded EE). Specifically, telephones represent one cluster in the entry-level item (ELI) category *telephones, peripheral equipment, and accessories* (EE041). This cluster includes both home-based telephones and cellular telephones. After observations for cellular telephones and observations with duplicate model numbers from within a unique retail outlet were excluded, the CPI sample for home-based telephones totaled 261 observations.

The NPD sample is a collection of aggregated and average-priced point-of-sale observations representing a group of unique product model numbers. Specifically, data are collected in various cooperating retail chain outlets. NPD classifies these outlets by type, or "channel," and then aggregates the data across channels to arrive at a national estimate of the average price for each unique product model number for which data are collected.[4] Each observation includes an average price (total expenditures for a unique product model number, divided by total number of units of that model sold) and information on the item's physical characteristics. NPD has more than 400 participating retail partners that provide the market data it sells. This group of retailers includes department stores, mass merchants, specialty stores, and other venues. Because the data are collected from transactions, they represent actual consumer purchases in those retail outlets which cooperated with the survey.

As stated earlier, the Bureau purchased approximately 2 years of monthly point-of-sale data for corded and cordless telephones from NPD, but only data from August and September of 2000 were used in this study. The combined sample of those 2 months for both corded and cordless telephones consisted of 669 observations.

The NPD sample was further reduced by eliminating observations pertaining to unique product model numbers collected in August when data on those same numbers also were collected in September. Unique product model numbers with data for only August or only September were kept in the sample. After these reductions, the final data set totaled 371 NPD observations.

Cleaning. Cleaning the data sets was a tedious exercise, but one that had to be regarded with importance. The CPI sample was cleaned by attempting to match the descriptions of all collected manufacturer model numbers with descriptions found on manufacturers' Internet Web sites. Corrections were made to the data when inconsistencies were found. Not all model numbers were capable of being verified through the manufacturers' sites, however. Because old models are discontinued and replaced by new models every few months, it becomes difficult to find data for older model numbers after a long time has passed since their discontinuation. For those model numbers for which primary data were not available, credible secondary Internet Web sites were used for verification.

A unique characteristic of the CPI data is that they contain information about the type of business or retail outlet where the data were collected. The variable that gives this information is included in many hedonic regression models created by the CPI. Its primary use is as a control variable to account for the effects that varying business practices may have on the price of goods offered in an outlet. Each type of business category is assigned a code that BLS data collectors use to classify the retail outlet in which data are collected. Inconsistencies and coding errors between the classifications and actual retail outlet names were evaluated and corrected as needed.

Cleaning the NPD data was surmised to be a task less tedious than cleaning the CPI data. The reasoning behind this assumption begins with the fact that describing the characteristics of an item correctly is difficult, given the diversity of work each CPI data collector is responsible for, the complexity of the data collection forms, the variety of the items themselves, and the paucity of knowledgeable respondents within outlets. The CPI data thus needed to be reviewed. By contrast, the NPD Group is a company whose business is collecting and selling market data. The accuracy of the NPD data is improved by electronic scanners in the retail outlets that supply data to the company. These scanners record price and quantity information, along with a minimal amount of characteristic information in the form of SKU numbers (unique identifying numbers manufacturers assign to their products). NPD maintains a library of SKU's and characteristic information on each one. Some degree of quality control is employed by NPD in packaging the company's data. Collecting and maintaining data in this way would seem to result in fewer errors in the measurement of characteristic variables.

To test this theory, a random sample (5 percent of the total) was generated from each "precleaned" data set, and the item descriptions of those model numbers were checked against either manufacturers' information or information from credible secondary sources. The following tabulation of the quality of the samples before cleaning shows the results of this analysis (entries are percentages):

Item descriptions	*CPI, 5 percent,* n = *14*	*NPD, 5 percent,* n = *18*
Correct	36	82
Missing or incorrect specifications	43	12
Could not verify	21	6

Because more than 80 percent of the NPD sample had correct descriptions, compared with roughly one-third of the CPI sample, verifying each model number in the NPD sample might have proven inefficient and unwise. Accordingly, another element of the NPD sample was selected for investigation: the description field.

Found in the NPD sample purchased by the Bureau, the description field consists of a highly general description of each unique model number. The latter is likely to be a product identifier used by the manufacturer or retailer. A random selection of model numbers was cross-checked by comparing the information in the description field with the item's actual description. The consistency between the two was similar enough to justify simply verifying the item description by consulting the description field for all the model numbers in the sample.

The NPD sample had to be further reduced after the initial cleaning phase. A total of 10 unique product model numbers had no price, rendering them unsuitable for modeling purposes. Seven model numbers were for items that were outside the scope of the CPI and therefore were ineligible for pricing.[5] Finally, two model numbers had average prices that were well below average for the types of telephones they represented. After deletion of those 19 unique model numbers, the final NPD sample stood at 352.

Market and product background. The market for home-based telephones is an established, mature market. Most consumers who have such telephones already have replaced their old ones with more technologically advanced models as they arrive in the marketplace (for example, corded to cordless or analog cordless to digital cordless phones). Consumers routinely accept new generations of advanced technology, and a few premium features are well known and valued by consumers. Manufacturers of home-based telephones bundle the different varieties of their product with features the consumer is thought to value.

Corded telephones allow for a clear, static-free conversation, but lack the convenience and mobility of a cordless telephone. Still, many people choose to keep corded telephones in their homes because they are inexpensive and reliable. Consumers of cordless telephones are met with a wide variety from which to choose. The most basic and inexpensive type of cordless telephone is the 46- to 49-MHz analog phone. For more security, 900-MHz analog telephones are available, although they provide less clarity and security than their 900-MHz digital counterparts. Home-based telephones underwent a substantial technological improvement in 1995 with the introduction of digital spread-spectrum (DSS) technology. This feature allows the signal to randomly jump channels, making it less susceptible to interference and eavesdropping. As the popularity of cordless telephones grew, the 900-MHz frequency range became overcrowded. In response, the Federal Communications Commission opened up the 2.4-GHz frequency to cordless telephones in 1998, whereupon the operating range of such telephones increased substantially.[6] However, even though the capability of a telephone to function at larger bandwidths is a valued characteristic, it is not as valuable as the ability to operate through DSS technology. While there are fewer signals to interfere with in the higher frequencies and the operating range is increased, without DSS technology interference and decreased security can still be problematic.[7] 5.8-GHz technology was not available during the period covered by this study, but has recently become available in the U.S. market for cordless phones.

Home-based telephone manufacturers will typically produce many models of a telephone, with each model including certain valued features. For example, a manufacturer may produce four types of 900-MHz digital phones: a basic model, a digital phone with caller ID, a digital speakerphone with caller ID, and a digital speakerphone with caller ID and a digital answering machine. It is presumed that the prices of these different telephones will become progressively higher as each additional feature is added to the basic model.

Comparing the samples. A closer look at the CPI and NPD data sets reveals a similar distribution in the number of observations of each type of telephone. Chart 1 shows the distribution of unique model numbers for each type of telephone by the percent of each sample. Four different samples will be analyzed in this section: the CPI, the unweighted NPD, the quantity-weighted NPD (NPDQ), and the value-weighted NPD (NPDV).[8] In the August and September 2000 data set, most of the cordless telephones operate at 900 MHz. This type of telephone was, and still is, very popular. Corded telephones account for a large percentage of each sample, a fact that is interesting because the NPD sample for corded telephones is collected independently of the company's sample for cordless telephones and the NPD samples reflect transaction spending behaviors by consumers. In contrast, the CPI substitution procedure of pricing another item of similar quality when the original item is no longer available could result in a biased sample consisting of a disproportionate number of corded telephones or older generations of cordless telephones that are available for sale, but of which few are actually sold. However, because of the similarities in the percentages of each type of telephone in the CPI and NPD samples, it appears that the sample is unbiased toward any one type of telephone. Another point of interest is that the percentage of 2.4-GHz DSS telephones in the CPI sample is more than twice as large as the percentage of those telephones in the NPD and NPDQ samples, but less than the percentage in the NPDV sample. The reason for these disparities could be that the CPI sample is disproportionately representing a new good. It is also important to note that the CPI sample had no 2.4-GHz analog telephones and the NPD sample had no 2.4-GHz digital telephones. Whether these omissions will result in any specification bias is unclear.

Overall, a priori expectations of the average prices of telephones were met. The newer, more sophisticated telephones clearly have higher average prices than the older telephones. Chart 2 shows the distribution of average prices by type of telephone for all samples. The average price of each type of telephone is usually higher in the CPI sample. This pattern is expected, because the Bureau collects list-price data for the CPI sample whereas NPD collects transaction prices, which usually are lower than list prices. The NPDV sample has a slightly higher average price than the NPDQ sample for each type of telephone. This difference has implications in the debate over whether to use quantity weighting or value weighting. Erwin Diewert suggests that quantity weighting tends to give too little weight to high-priced models and too much weight to less expensive models that have fewer newer characteristics.[9]

Another perspective from which to compare the similarities between the CPI and NPD samples is to examine the distribution of brand names and unique model numbers found in those samples. The final CPI sample of 261 observations contains 18 brand names and 156 unique model numbers. The final NPD sample of 352 observations contains 22 brand names and 352 unique model numbers.[10] In total, 13 brand names and 67 model numbers were common to both samples.

Quality characteristics. Three unique value-adding characteristics of the CPI and NPD data sets are of particular interest to the analysis presented. The first is the vintage variable found in the NPD sample. The vintage represents the date each unique model number first appeared in the sample. It marks the introduction and prevalence of new, innovative technologies in the telephone market. The vintage variable is useful because it makes it possible to observe the changing prices of models over time. As stated earlier, only data for August and September of 2000 were used for this study, but approximately 2 years of telephone data were purchased from NPD. Looking at data over this longer period may reveal trends in the pricing behavior over the product life cycle.

Chart 3 graphs the average vintage (or age) and the average (unweighted) price of each type of telephone. Vintage is measured by the number of months each model number has been in the sample. Newer model numbers will have lower vintage values. Model numbers that were introduced in September 2000 have a vintage value of unity. The vintage values were averaged for each type of telephone. In this small sample of data, it is apparent that those telephone models which are likely to have the lowest vintage values (the 2.4-GHz models) and the most advanced features (the DSS models) also have the highest average prices. The vintage variable has many uses as a diagnostic tool and may indeed be valuable in modeling the NPD data.

Another valuable feature of the NPD sample is the ability to weight each model number in it by either the quantity of units sold or the value of expenditures on that model number. As illustrated earlier in chart 2, the average prices of the various types of telephone can differ under all three weighting methods, a feature whose implications will be examined later in the article.

It seems clear that, by the nature of the NPD data, a weighted sample would be preferred over an unweighted sample. Unweighted, the NPD sample is simply an equally weighted list of model numbers; weighted, however, it becomes a more informative sample, indicating consumers' preferences for telephones. The importance of weighting is obvious in the case of the 46- to 49-MHz telephones: as shown in chart 1, this type of telephone represents a sizeable percentage of the unweighted NPD sample, but its presence in the weighted sample is minuscule. The opposite is true with the 900-MHz analog telephones, whose impact in the weighted sample is far greater than in the unweighted sample.

The CPI sample does not weight quantity or expenditure data, but it is designed in a manner that gives more popular models a greater chance of being included in the sample. It could be argued that this is a satisfactory weighting method, but it is unlikely that it is as capable of tracking consumer spending preferences as accurately as the electronic scanners found in the checkout lines of NPD's retail partners.

Chart 1. **Percent of sample by type of telephone for each sample**

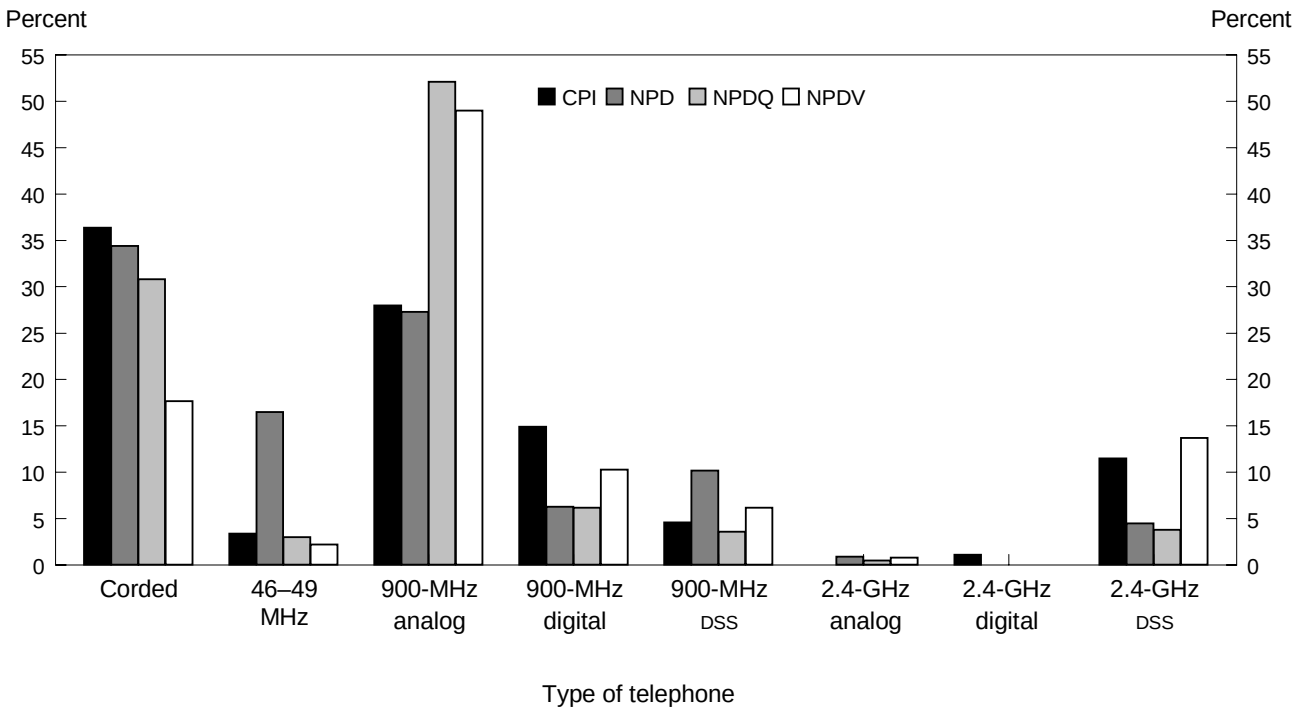


Chart 2. **Average prices of telephones by type for each sample**

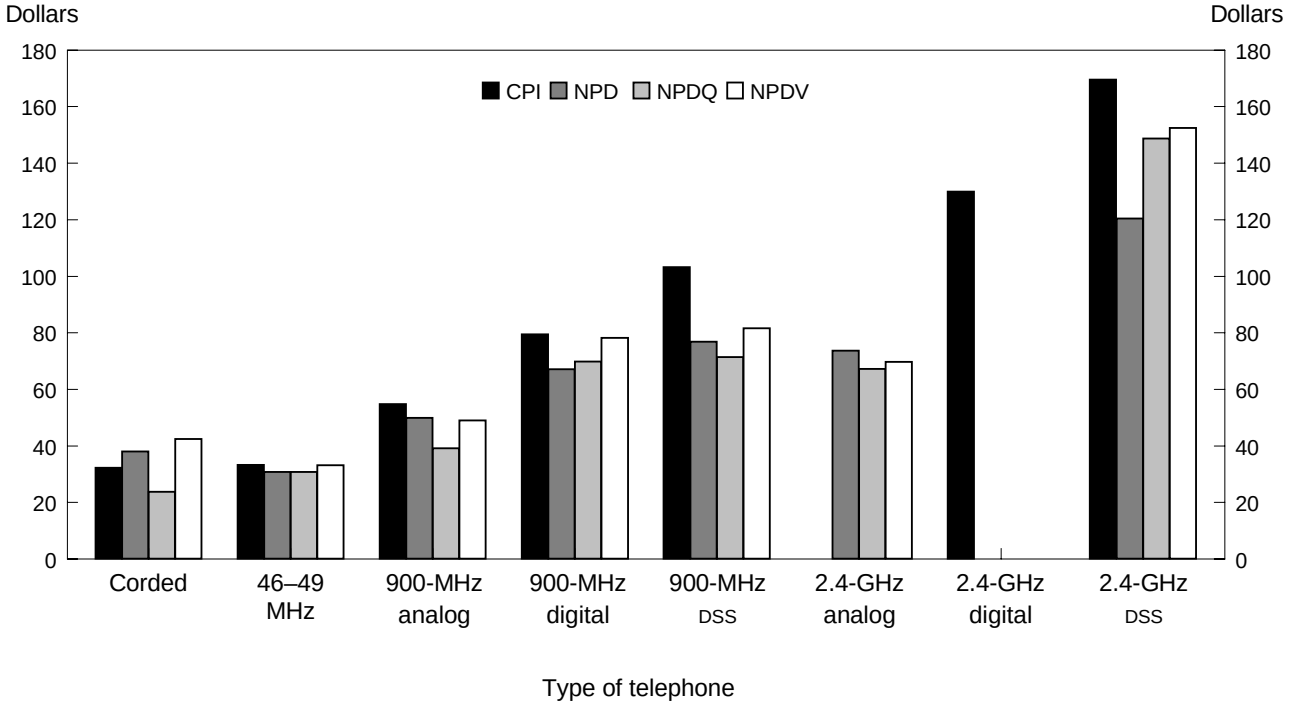
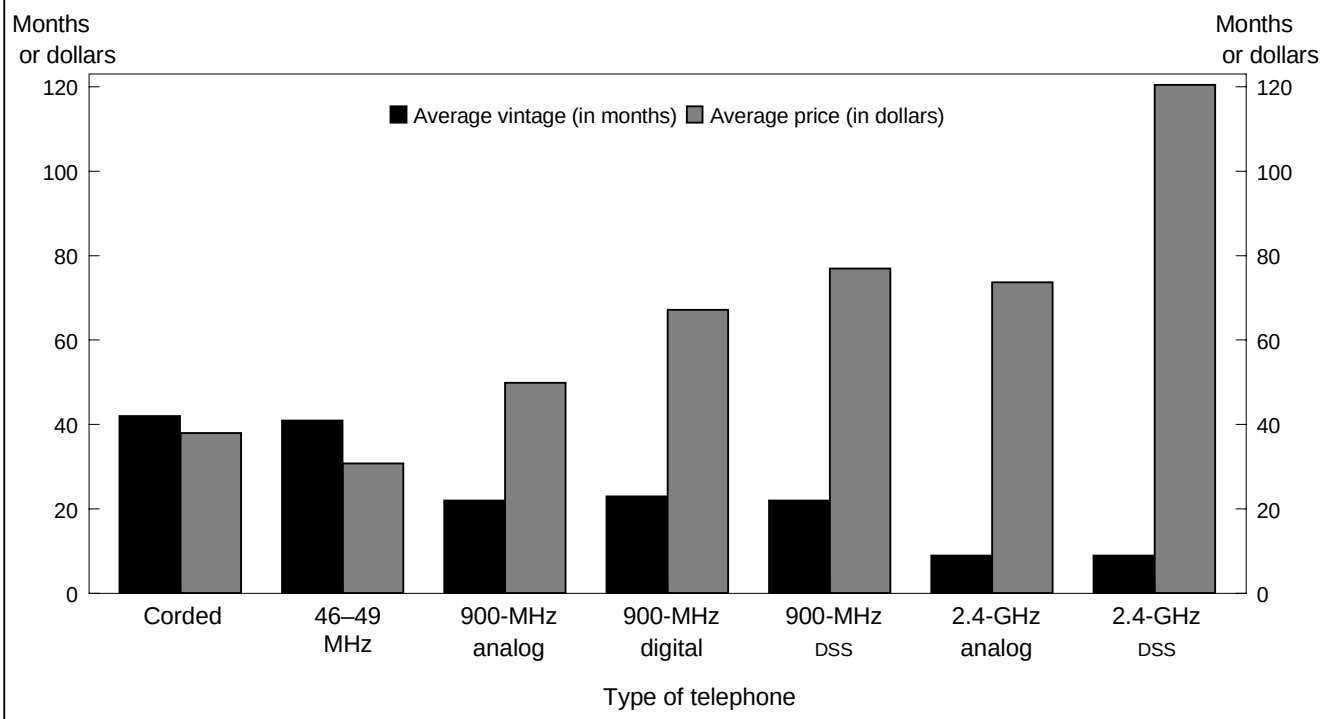


Chart 3. Average vintage and average price for types of telephone, NPD sample[1]



[1] There are no 2.4-GHz digital telephones in the NPD samples.

The final quality characteristic worth mentioning is the set of control variables available in the CPI sample. The CPI uses the list price advertised for each type of telephone at the time the data are collected. CPI data collectors report that price and indicate whether it was classified as a sale price or a regular price. This information is used as a control variable in some hedonic models employed by the CPI to control for the negative effect sale price indicators have on prices, other things being equal.

The CPI also includes information on the types of retail outlets in which the data are collected. This feature of the CPI sample is important, because it aids in controlling for the effects each type of retail outlet may have on the price of the items offered there. Usually, when these control variables are included in hedonic models, the resulting parameter estimates are logical and in accordance with a predicted order of relative value.

The last control variable of note in the CPI sample is that indicating the region and city size for each observation. The CPI divides the United States into four regions, and the cities in which the Bureau collects data are assigned one of three size labels based on their populations. Variables for region and city size are used to control for the possible effects location may have on the price of goods sold. The usefulness of the geography variables is difficult to quantify, but they do aid in minimizing the unexplained variation in those price-determining variables which are being estimated.

Data reservations. Despite the number of positive attributes associated with both data sets, four lingering reservations about the data deserve attention:

- The representativeness of the samples
- The absence of area, outlet (or channel), and type-of-price indicators from the NPD sample
- The quality of the characteristic data
- The age of the data

The discussion of the representativeness of the data is best addressed by splitting it into two issues. The first is whether the data are representative of the market for home-based telephones. Mary Kokoski, Keith Waehrer, and Patricia Rozaklis note that, because the NPD sample is not collected under the probability sampling procedures that are used for the CPI sample, the relative degrees of representation of specific models in the respective samples are different.[11] The NPD sample is capable of reflecting changes in consumer purchasing habits, because it is a measure of actual telephone purchases. In this regard, the NPD sample could be more representative of the market for telephones than the CPI sample, which has the potential to be skewed toward older models due to the CPI's procedure that instructs data collectors to substitute an item of similar quality when the one they were originally pricing becomes unavailable.[12] As shown in

chart 1, however, such a concern over representativeness is not entirely warranted in this situation, because the CPI and NPD samples are fairly similar in their distribution of the various types of telephone.

The second issue with regard to representativeness has to do with where the data are collected. The outlets from which the Bureau collects price quotes for the CPI differ from those sampled by NPD, thus affecting both the product mix and prices. The CPI data are collected in a wide variety of retail outlets across the country. These outlets, which represent answers by respondents of the Consumer Expenditure Survey to questions about where they make their purchases, are chosen through statistical sampling procedures.[13] NPD, by contrast, collects its data from retail outlets it has partnerships with. This approach introduces some bias into the NPD sample, because some types of retail outlets may not be represented in the national sales figures NPD produces. In particular, the Bureau is aware that certain major discount department stores do not contribute data to NPD. The exclusion of important retailers from the NPD sample is a critical shortcoming of the NPD data.

The second reservation regarding the data—the absence of area, outlet, and type-of-price indicators from the NPD sample—deals with factors that contribute to the quality of the models. Each price quote in the CPI is accompanied by information stating where it was collected. This information consists of the specific outlet name, a type of business classification code, and the size and region category of the city in which the quote was collected. The information is converted into variables that control for the effects different types of business practices and geographic locations may have on the product mix and price. Such control usually helps minimize the variation in parameter estimates for price-determining characteristics in the model. The NPD sample does not have any control variables; therefore, even if the NPD sample happened to be collected in the same mix of retail outlets that the CPI sample used, there would still be no way of accounting for the effects of geography and outlet characteristics in regression models constructed from NPD data.

The NPD sample also lacks a sale or markdown price indicator. Unlike the CPI sample, the NPD sample uses an aggregated average price of the units sold for a unique model number in the outlets that supply data to NPD. Such an average, however, is a national average and has no indication of whether the units were sold at a sale price or a regular price. Because items sold at a sale price generally are of a lower price than other items of similar quality, all other things being equal, it is appropriate to control for the effects of sale prices in the regression model through the use of a dummy variable.

The third reservation about the data concerns the quality of characteristic data. Well-defined characteristic data are essential to creating reliable models. CPI researchers spend considerable amounts of time and resources preparing and cleaning the data they use for modeling. The NPD characteristic data were defined more precisely than the CPI characteristic data. However, it may be unwise to assume that NPD data for all other goods would be of the same level of quality as the telephone data. By the same token, while the CPI sample for telephones was not as well defined, CPI data for other goods may be of a more acceptable quality. More importantly, the collection of CPI data is under the control of the Bureau and is capable of being manipulated in order to increase the quality of the data. CPI data collectors can be directed as to what data to collect, and data collection forms can be updated to capture innovations and other valuable quality characteristics. The Bureau forgoes this level of involvement with NPD data.

Besides having this obvious concern about the accuracy of each data set, analysts may worry about the possibility that the definitions, categories, and quality characteristics identified by both data sets will differ from one another. Because hedonic models created with NPD data could eventually be used to make quality adjustments to CPI data, the variables denoting quality characteristics in those models would need to be similar enough to the specifications found in the CPI data for the desired quality adjustments to be made. For the most part, the CPI and NPD data are fairly similar, although there are a few differences worth mentioning in the subsequent discussion of the hedonic models.[14]

The last major reservation about the data has to do with their age. Both samples represent data from August and September of 2000. The CPI sample was cleaned for this study during the first half of 2002, and the NPD sample was cleaned during the first quarter of 2003. Given the amount of time between collection and cleaning, difficulty arose in verifying the descriptions of each model number through Internet sites. Many model numbers were either no longer current or completely out of production by the time the data were cleaned. Also, the telephone market has changed considerably since 2000. 2.4-GHz telephones are far more prevalent now, and new technologies are available. Accordingly, using hedonic models created with old data to quality-adjust substitutions in current samples is questionable, especially because the market for telephones is so different now from what it was then. If the coefficients of the variables were created from current data, they would likely be quite different from what they were a number of years ago.

Model specification

The first step in building the hedonic model is creating variables from the telephone data. Dummy variables were constructed for all characteristic data, except for the vintage variable in the NPD models. Vintage is a continuous variable, and its parameter estimate must be multiplied by the age of the unique model number (in months) to be interpreted correctly.

Once the variables are created, a functional form for the regression model is chosen and the model is specified on the basis of a priori assumptions about price-influencing characteristics. The most common functional form recommended in the

hedonic literature is the semilogarithmic form.[15] This form is preferred because it fits the data particularly well and because the coefficient estimates generated from the model can be interpreted as being the proportion of a good's price that is directly attributable to the respective characteristics of that good. The semilogarithmic form is given by the equation

$$\ln p_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \ldots + \beta_n X_{ni} + \mathring{a}_i,$$

where $\ln p_i$ is the natural logarithm of the price of each good, β_j is the coefficient of the characteristic variable X_j, and $\mathring{a}_i$ is the error term. The value of β_0 is interpreted as the value of the base good without any of the quality characteristics that add value to or subtract value from that good.[16] The dependent variable is defined differently in both samples: for the CPI sample, it is the list price collected for each observation; the NPD sample uses the average transaction price of each unique model number.

As stated earlier, the NPD sample is capable of being weighted by the quantity of units sold or by the value of expenditures for each model number. Given this capability, regression models were calculated for the earlier mentioned four different data sets: the CPI sample, the unweighted NPD sample (NPD), the NPD sample with value weighting (NPDV), and the NPD sample with quantity weighting (NPDQ).

Preliminary models. A set of preliminary models, each of which included only variables for the types of telephones, a variable controlling for prices collected on sale, and a continuous variable for vintage produced the results shown in table 1. The order of the relative values of the coefficients for the telephone-type variables matches a priori expectations. All of the cordless types of telephone are of greater value than the corded telephones. Cordless 46- to 49-MHz analog telephones are statistically insignificant in all models except the NPDQ. The other cordless types of telephone are in an expected order, with 2.4-GHz DSS types having the largest coefficient in all models. The CPI sample did not have any 2.4-GHz analog telephones, and the NPD, NPDV, and NPDQ samples did not have any 2.4-GHz digital telephones. The sign on the coefficient for the sale price variable in the CPI model is negative, meeting a priori expectations, but the variable is statistically insignificant. The sign on the coefficient for the vintage variable is negative, also meeting expectations, and is statistically significant in all three of the NPD models.

Final models. Additional characteristic variables were included in the final models, along with a few brand-name variables. Control variables for the type of business, the region, and the size of the city in which the data are collected were included in the final CPI model. The final models yielded the results shown in table 2.

Other than the variables for the type of telephone and the brand name, only the caller ID, handset keypad, and dual keypad characteristic variables appear in all four models. The caller ID variable is statistically significant in all models, and its coefficient values in the CPI, NPDV, and NPDQ models are similar. The same is true for the keypad placement variables. Corded telephones with keypads only on the handset are typically featureless and inexpensive, which explains the negative sign on the coefficient of the associated variable. By contrast, cordless telephones with keypads on both the base unit and the handset are generally more sophisticated than those with keypads only on the handset, resulting in large positive coefficients for this variable.

Other characteristic variables are similar, but not exactly the same, in all models. For example, the speakerphone feature variable applies only to corded telephones in the CPI model, but only to corded telephones without three or more line capabilities in the NPD models. Multiple line capability also is modeled differently in the various models. In the CPI model, the variable for multiple line capability does not distinguish between telephones with exactly two lines and telephones with three or more lines. By contrast, the NPD models make this distinction. Still, the variable for two line capabilities in the NPD models does not apply to telephones with conference call capability, and the variable for three or more lines applies only to corded telephones.

Some characteristic variables are unique to one data set. For instance, the CPI model includes a variable for telephones with digital answering machines attached. Oddly, there are no variables for these types of telephones in the NPD sample. The NPD models, however, include variables for conference call and

Table 1. Preliminary models

Variable name	CPI	NPD	NPDV	NPDQ
Intercept	[1]3.236	[1]3.647	[1]3.839	[1]3.263
	(–.0542)	(–.0874)	(–.0845)	(–.0653)
Corded	Base	Base	Base	Base
Cordless 46–49 MHz	…	…	…	…
	.157	–.028	–.087	[1].304
	(–.1829)	(–.0978)	(–.1799)	(–.1473)
Cordless 900-MHz analog	[1].697	[1].304	.101	[1].418
	(–.0827)	(–.0897)	(–.0783)	(–.0623)
Cordless 900-MHz digital	[1]1.103	[1].653	[1].655	[1]1.039
	(–.1004)	(–.1451)	(–.1033)	(–.1099)
Cordless 900-MHz DSS	[1]1.392	[1].796	[1].602	[1]1.011
	(–.1614)	(–.1209)	(–.1253)	(–.139)
Cordless 2.4-GHz analog	([2])	[1].703	.500	[1]1.002
	…	(–.3618)	(–.2883)	(–.3444)
Cordless 2.4-GHz digital	[1]1.492	([2])	([2])	([2])
	(–.3074)	…	…	…
Cordless 2.4-GHz DSS	[1]1.885	[1]1.122	[1]1.271	[1]1.786
	(–.1104)	(–.1712)	(–.1011)	(–.1358)
Sale price	–.155	([2])	([2])	([2])
	(–.0921)	…	…	…
Vintage	([2])	[1]–.008	[1]–.012	[1]–.008
	…	(–.0016)	(–.0018)	(–.0013)
Adjusted R^2	.586	.344	.551	.546
F value	53.56	27.35	62.43	61.36
Number of observations	261	352	352	352

[1] Statistically significant at the $p = .05$ level.
[2] Not in model.

Table 2. Final models

Variable name	CPI	NPD	NPDV	NPDQ
Intercept	[1]3.157	[1]3.101	[1]3.014	[1]2.857
	(.0725)	(.0997)	(.0718)	(.0615)
Corded	Base	Base	Base	Base
	…	…	…	…
Cordless 46–49 MHz	.105	[1].213	[1].202	[1].205
	(.1236)	(.0959)	(.0940)	(.0830)
Cordless 900-MHz analog	[1].545	[1].507	[1].491	[1].488
	(.0718)	(.0959)	(.0711)	(.0605)
Cordless 900-MHz digital	[1].758	[1].783	[1].696	[1].642
	(.0881)	(.1334)	(.0796)	(.0765)
Cordless 900-MHz DSS	[1]1.044	[1]1.060	[1].964	[1].949
	(.1106)	(.1129)	(.0808)	(.0819)
Cordless 2.4-GHz analog	([2])	[1]1.073	[1]1.083	[1]1.207
	…	(.2595)	(.1237)	(.1527)
Cordless 2.4-GHz digital	[1].861	([2])	([2])	([2])
	(.1978)	…	…	…
Cordless 2.4-GHz DSS	[1]1.413	[1]1.211	[1]1.420	[1]1.466
	(.0891)	(.1533)	(.0826)	(.0951)
Sale price	–.070	([2])	([2])	([2])
	(.0585)	…	…	…
Vintage	([2])	[1]–.004	–.001	.0001
	…	(.0012)	(.0008)	(.0007)
Digital answering machine	[1].406	([2])	([2])	([2])
	(.0549)	…	…	…
Speakerphone (corded)	[1].235	([2])	([2])	([2])
	(.0796)	…	…	…
Speakerphone (not three-line capable)	([2])	[1].379	[1].334	[1].276
	…	(.1054)	(.0784)	(.0681)
Conference call (not three-line capable)	([2])	[1].453	[1].657	[1].706
	…	(.1129)	(.0723)	(.0751)
Intercom (not dual keypad)	([2])	.134	.040	.074
	…	(.1223)	(.0512)	(.0900)
Clock radio	([2])	[1].677	[1].565	[1].587
	…	(.1407)	(.0903)	(.0853)
Caller ID	[1].456	[1].330	[1].466	[1].504
	(.0449)	(.0554)	(.0233)	(.0259)
Two-or-more-line capability	[1].420	([2])	([2])	([2])
	(.0811)	…	…	…
Two-line capability (no conference calls)	([2])	[1].451	[1].509	[1].506
	…	(.0868)	(.0418)	(.0616)
Three-or-more-line capability (corded)	([2])	[1]1.860	[1]1.759	[1]1.783
	…	(.1597)	(.0864)	(.1046)
Keypad on handset only (corded)	[1]–.312	[1]–.317	[1]–.424	[1]–.414
	(.0794)	(.1597)	(.0785)	(.0621)
Keypad on base and handset (cordless)	[1].274	[1].224	[1].305	[1].341
	(.0665)	(.0716)	(.0308)	(.0437)
Corded handset on base (cordless)	([2])	–.122	–.133	–.178
	…	(.3171)	(.0962)	(.1417)
Extra-handset capability (cordless)	([2])	.334	–.055	–.151
	…	(.2374)	(.0628)	(.1223)

Table 2. Continued—Final models

Variable name	CPI	NPD	NPDV	NPDQ
Headset style design	([2])	[1].905	[1].799	[1].824
	…	(.1377)	(.0674)	(.1051)
Headset jack	([2])	.075	[1].105	[1].154
	…	(.0700)	(.0285)	(.0336)
Brand B	Base	Base	Base	Base
	…	…	…	…
Brand C	[1].200	[1]–.154	–.036	[1].087
	(.0595)	(.0753)	(.0384)	(.0396)
Brand A	[1].189	.142	[1].182	[1].294
	(.0726)	(.0789)	(.0421)	(.0487)
Brand M	[1]–.851	([2])	([2])	([2])
	(.1522)	…	…	…
Brand H	–.098	[1]–.161	[1]–.243	[1]–.153
	(.0752)	(.0724)	(.0314)	(.0303)
Brand G	–.092	[1]–.216	[1]–.233	[1]–.110
	(.0787)	(.0815)	(.0386)	(.0450)
Brand F	.021	[1]–.263	[1]–.205	[1]–.083
	(.1008)	(.1045)	(.0345)	(.0377)
Brand N	([2])	[1]1.010	[1]1.000	[1]1.088
	…	(.1823)	(.3014)	(.3524)
Audio/video store	Base	([2])	([2])	([2])
	…	…	…	…
Full-price department store	[1]–.140	([2])	([2])	([2])
	(.0743)	…	…	…
Discount appliance store	[1]–.196	([2])	([2])	([2])
	(.0735)	…	…	…
Discount department store	[1]–.289	([2])	([2])	([2])
	(.0551)	…	…	…
Warehouse	[1]–.330	([2])	([2])	([2])
	(.0679)	…	…	…
Midwest region	[1].104	([2])	([2])	([2])
	(.0477)	…	…	…
C-sized city	[1]–.414	([2])	([2])	([2])
	(.1076)	…	…	…
Adjusted R^2	.852	.693	.940	.922
F value	60.62	31.49	210.94	160.58
Number of observations	261	352	352	352

[1] Statistically significant at the $p = .05$ level.
[2] Not in model.

intercom capabilities, clock radio units, headset jacks, and headset-style designed telephones. Generally, the values of these variables are statistically significant and have the expected signs on the coefficients.

Two variables unique to the NPD samples have values that are not statistically significant in the final NPD models, but that should be noted because of their significance in the current market for telephones. Three cordless telephone models include a corded handset on their base unit, and four cordless telephone models are capable of adding extra cordless handsets to their operation. Telephones with either of these features had average prices 2 to 3 times greater than prices for those without the

features, yet, because relatively few of these telephones were sold, they were not statistically significant in the models.

A comparison of the adjusted R^2 values from each model reveals some interesting results. First, the unweighted NPD model has a much lower adjusted R^2 value than do the value- and quantity-weighted models. This is expected, because, in general, weighted regressions produce much better fits. Of the two weighted models, it is unclear which is preferred. The argument by Diewert that quantity weighting ignores higher priced models with innovative features in favor of lower priced models with fewer advanced features[17] is not fully realized, because both models have the same number of characteristic variables with statistically significant values and the quantity-weighted model actually has one more brand-name variable with a value that is statistically significant. In fact, most of the variation in the coefficients of these two models appears to be found in the brand-name variables. Variations in the coefficients of other variables appear negligible.

The other point of interest is the adjusted R^2 value of the CPI model. Comparing adjusted R^2 values from two different models is not econometrically sound, but if the values are compared in terms of how well each model explains the variation in its own data set, then it is fair to comment on the results. Under this analytical framework, it is interesting to note that the CPI model explains more of the variation in its data set than the unweighted NPD model does in its data set, while the weighted models explain more variation in price than the other two do.

Experimental models. To compare the samples further, experimental models were run on modified data sets consisting of the observations for unique model numbers common to the CPI and NPD samples.[18] As stated earlier, there were 67 unique model numbers common to both samples. These model numbers represent 118 observations in the CPI sample and 67 observations in the NPD samples. Because the data sets consist of the common model numbers, the experimental models are specified with the same variables, which represent the quality characteristics present in the 67 common model numbers. These quality characteristics are found to be most consistently statistically significant in the final models in table 2. Variables for 12 of the 13 brand names common to all of the data sets also were included.[19] The experimental models yielded the results shown in table 3.

The variables for the type of telephone and many of the feature variables remain very strong in these models. Two exceptions are the variables for handset placement, which are significant in the final models, but not in the experimental models. Also, although many of the telephone type and feature variables are significant, there are large differences in the parameter estimates for these variables. For example, the parameter estimates for cordless 900-MHz digital telephones range from 0.730 to 0.933, and the parameter estimates for the speakerphone feature range from 0.302 to 0.498. There is also much variation in the statistical

Table 3. Experimental models

Variable name	CPI	NPD	NPDV	NPDQ
Intercept	[1]3.124	[1]3.08	[1]3.144	[1]3.121
	(.1255)	(.1823)	(.2086)	(.1635)
Corded	Base	Base	Base	Base
	…	…	…	…
Cordless 46–49 MHz	.221	[1].528	.463	[1].497
	(.1944)	(.2269)	(.2396)	(.1908)
Cordless 900-MHz analog	[1].645	[1].617	[1].569	[1].571
	(.1073)	(.1646)	(.2045)	(.1550)
Cordless 900-MHz digital	[1].920	[1].933	[1].760	[1].730
	(.1290)	(.2287)	(.2220)	(.1947)
Cordless 900-MHz DSS	[1]1.277	[1]1.084	[1].964	[1].981
	(.1272)	(.1653)	(.2149)	(.1822)
Cordless 2.4-GHz DSS	[1]1.460	[1]1.611	[1]1.403	[1]1.407
	(.1476)	(.2148)	(.2132)	(.1854)
Caller ID	[1].480	[1].377	[1].499	[1].506
	(.0585)	(.0843)	(.0437)	(.0510)
Two-or-more-line capability	[1].388	[1].478	[1].518	[1].452
	(.1147)	(.1648)	(.1032)	(.1480)
Speakerphone	[1].302	[1].414	[1].482	[1].498
	(.1103)	(.1680)	(.2209)	(.1695)
Conference call capability	.078	.087	.125	.211
	(.1588)	(.3543)	(.3751)	(.4098)
Keypad on handset only (corded)	–.158	–.242	–.221	–.193
	(.1010)	(.1737)	(.2099)	(.1543)
Keypad on base and handset (cordless)	–.180	–.308	–.253	–.176
	(.1288)	(.2036)	(.2240)	(.1868)
Brand A	.005	.1040	.0750	–.001
	(.1083)	(.1374)	(.0811)	(.0948)
Brand B	Base	Base	Base	Base
	…	…	…	…
Brand C	–.023	–.112	–.144	–.141
	(.1093)	(.1441)	(.0743)	(.0807)
Brand D	–.053	–.074	–.053	–.040
	(.2783)	(.3121)	(.1629)	(.3325)
Brand E	–.155	–.050	–.189	–.174
	(.2820)	(.2993)	(.1960)	(.2477)
Brand F	–.177	–.243	[1]–.368	[1]–.372
	(.1282)	(.1785)	(.0667)	(.0709)
Brand G	[1]–.359	[1]–.291	[1]–.405	[1]–.396
	(.1137)	(.1427)	(.0681)	(.0809)
Brand H	[1]–.400	[1]–.373	[1]–.583	[1]–.595
	(.1204)	(.1544)	(.0630)	(.0660)
Brand I	[1]–.499	–.266	[1]–.500	[1]–.501
	(.2229)	(.2609)	(.1423)	(.1114)
Brand J	–.516	–.130	–.269	–.254
	(.2901)	(.2993)	(.1509)	(.1842)
Brand K	[1]–.547	–.175	[1]–.272	–.262
	(.1570)	(.1893)	(.1062)	(.1368)
Brand L	[1]–.753	[1]–.628	[1]–.735	[1]–.738
	(.1691)	(.2232)	(.1656)	(.1159)
Adjusted R^2	.8834	.8447	.9688	.9542
F Value	41.28	17.31	94.24	63.46
Number of observations	118	67	67	67

[1]Statistically significant at the $p = .05$ level.

significance of, and parameter estimates for, the brand-name variables.

The adjusted R^2 values of the experimental models are quite high. As suggested earlier, they are highest in the weighted models, with the CPI model and the unweighted NPD model following after.

Quality adjustment results

To assess the usefulness of a hedonic model for home-based telephones, the model's parameter estimates were applied to home-based telephone substitute price quotes (items selected by CPI data collectors to replace previously collected items that are no longer available) with quality changes. Substitutions from the months of May and June 2003 were chosen for this exercise. There were 18 home-based telephone substitutions during those 2 months. In the published index, 22 percent of the substitutions were compared directly with the previous item. The price changes for the remaining noncomparable substitutions were imputed, or "linked," essentially by assuming them to be the same as the elementary item price change for the same geographic area that month.[20]

The comparability decisions of the 18 substitutions were reassessed on the basis of the four hedonic models. Nearly 67 percent of the substitutions underwent quality changes that could be adjusted for with the use of one of the hedonic models. After the reassessment was complete, 39 percent of the substitutions were adjusted with the CPI model, 28 percent were adjusted with the NPD models, and 33 percent of the prices were directly compared under all four models.[21] The remaining substitutions (28 percent under the CPI model and 39 percent under the NPD models) were deemed noncomparable, and the price changes would have been imputed with the link method. The substitution comparability ratio (the ratio of directly compared and quality-adjusted substitute quotes to the total number of substitute quotes) jumped from 22 percent in the published index to 72 percent under the CPI model and 61 percent under the NPD models. Most of the quality adjustments were calculated for changes in the caller ID variable and brand-name changes, and most of the noncomparable substitutions had unadjustable quality changes, such as an expandable phone system capability and extra handsets included with the system. Table 4 summarizes the specification and quality changes that occurred in the substitutions.

The hedonic models were analyzed further through a comparison of the unweighted mean price changes for the home-based telephone substitutions in the published index with the mean price changes for the quality-adjusted substitutions. The mean price change for directly compared substitutions increased dramatically after the reassessment. These substitutions were primarily those wherein only the model number, with or without additional minor price factors, changed. The mean price changes for the quality-adjusted substitutions were mostly negative, with an average downward price change (across all models) of 4.7 percent. The overall mean price change for all substitutions with comparisons (directly compared and quality-adjusted) varied greatly, with the largest difference occurring between the unweighted NPD model and the weighted NPD models. Table 5 compares the mean price changes of the home-based telephone substitutions under the published CPI with those calculated in the four hedonic models.

Table 4. Specification and quality changes in substitution price quotes

Type of change	Number of occurences
Specification change	
Model number change or other, minor specification change	6
Change in quality	12
Quality Change[1]	
Type	4
Brand	4
Digital answering machine	1
Speakerphone	2
Keypad on base and handset (dual keypad)	4
Two-line capability	1
Caller ID	4
Expandable phone system	4
Extra handset(s) included	4
Headset included	1

[1] For each specification listed, more than one could have changed for a given substitution.

On average, there were only nine home-based telephone substitutions each month. The small proportion of substitution price quotes for home-based telephones in the item index limits the impact of quality-adjusting the CPI for home-based telephones. Also, because cellular telephones account for roughly 40 percent of the entire telephone sample used in index calculations, the effect of quality-adjusting only home-based telephones is marginal. Aside from these points, however, applying any one of the home-based telephone models significantly decreases the number of noncomparable (imputed) substitution price quotes, the fewer of which exist in the index, the more likely it is that the index will measure true price change over time.

What's changed?

Since the data presented in this article were collected, new 5.8-GHz telephones have entered the market and the prices of older types of telephones have fallen. New innovations, accompanied by decreasing prices, have nearly driven 46–49-MHz telephones out of existence. Consumers seem to be accepting new technology, such as the 2.4-GHz models, and

Table 5. Mean price changes of substitution price quotes

Total substitutions (= 18)	Published CPI		CPI quality-adjusted index		NPD quality-adjusted index		NPDV quality-adjusted index		NPDQ quality-index adjusted	
	Number	Mean price change (percent)	Number	Mean price change (percent)	Number	Mean price change (percent)	Number	Mean price change (percent)	Number	Mean price change (percent)
Substitutions with comparison (nonlink)	4	–0.65	13	1.48	11	3.19	11	–0.34	11	–0.97
Directly compared substitutions	4	–.65	6	5.74	6	5.74	6	5.74	6	5.74
Quality-adjusted substitutions	0	…	7	–2.17	5	.14	5	–7.62	5	–9.02
Noncomparable (linked)	14	…	5	…	7	…	7	…	7	…

are benefiting from the lower prices. Clear evidence of this trend can be found by comparing the CPI sample in September 2000 with the CPI sample in June 2003.[22] Chart 4 compares the percentage of the sample each type of telephone accounts for, and chart 5 compares the average prices of each type of telephone.

Expandable telephone systems and telephones sold with two or more handsets are becoming very popular, as evidenced by the number of substitute price quotes having those characteristics. The impact of the popularity of cellular telephones on the home-based telephone market is also of interest. Some consumers are now choosing cellular telephones as their primary communication device and abandoning their home-based telephone service altogether.

With regard to changes in the data sources, the CPI sample has grown dramatically since September 2000. The size of the sample for telephones increased from 115 observations in September 2000 to 290 in June 2003, with the number of home-based telephones increasing from 84 to 167 observations. The 2003 figures for home-based telephones are large enough to support the creation of hedonic models without the aid of supplemental samples.

Since September 2000, NPD's data on cordless telephones has changed to include 2.4-GHz digital models and 5.8-GHz models. This modification leads to the assumption that NPD's sample now includes model numbers of those types of telephone. NPD also has improved its control methods for its consumer electronics data and now offers a variety of data delivery options that may be of interest to the Bureau.[23]

AN ARGUMENT CAN BE MADE FOR AND AGAINST the use of either of the two data sources examined in this article in creating hedonic regression models. The CPI sample is relatively small and is not the best item-oriented representation of consumer purchases. Moreover, its characteristic data are not as well defined as the NPD characteristic data. The CPI sample is, however, more representative of the entire market for telephones than are any of the NPD samples, because it includes many more retail outlets than those samples do and because the Bureau has direct control over data collection and maintenance of the CPI sample.[24] In addition, the results of the study presented indicate that the CPI model can be used to make quality adjustments more often than any of the NPD models can. In comparison, NPD data offer a large, representative sample of actual consumer preferences, contain accurate characteristic data, and have options for weighting the data, but suffer a bias in retail outlet representation. Further, the Bureau has little oversight in the upkeep of NPD data. An ideal research sample would meld the coverage and manageability of the CPI sample with the accuracy and robustness of the NPD sample.

In this research, the age of the data examined is somewhat of a cause for concern, because applying the models discussed to quality-adjusting substitutions used in calculating the CPI may not now be appropriate. Doubtless, the parameter estimates of the telephone characteristics have changed as prices for telephones and the value consumers place on quality features have changed since the data were collected. Further research is recommended to determine whether using the by-now-outdated model for quality adjustment is preferable to simply linking substitutions with quality change. Aside from this issue, however, the challenging characteristics of the data sources still exist, and the benefits of each sample continue to define its appeal to researchers.

Currently, BLS researchers still use NPD data in hedonic research studies, and new methods of model creation and application are being considered.[25] The Bureau continues to rely on CPI data to create hedonic models that are used to adjust the prices of apparel items. As the course of BLS hedonic research continues to be charted, the future data needs of the Bureau will evolve, perhaps rendering one data source more suitable than another. Until a single source of satisfactory data is found for its research needs, the Bureau will likely further explore the use of other data providers, in addition to continuing to use its own in-house data. □

Chart 4. **Percent of CPI sample by type of telephone, September 2000 and June 2003**

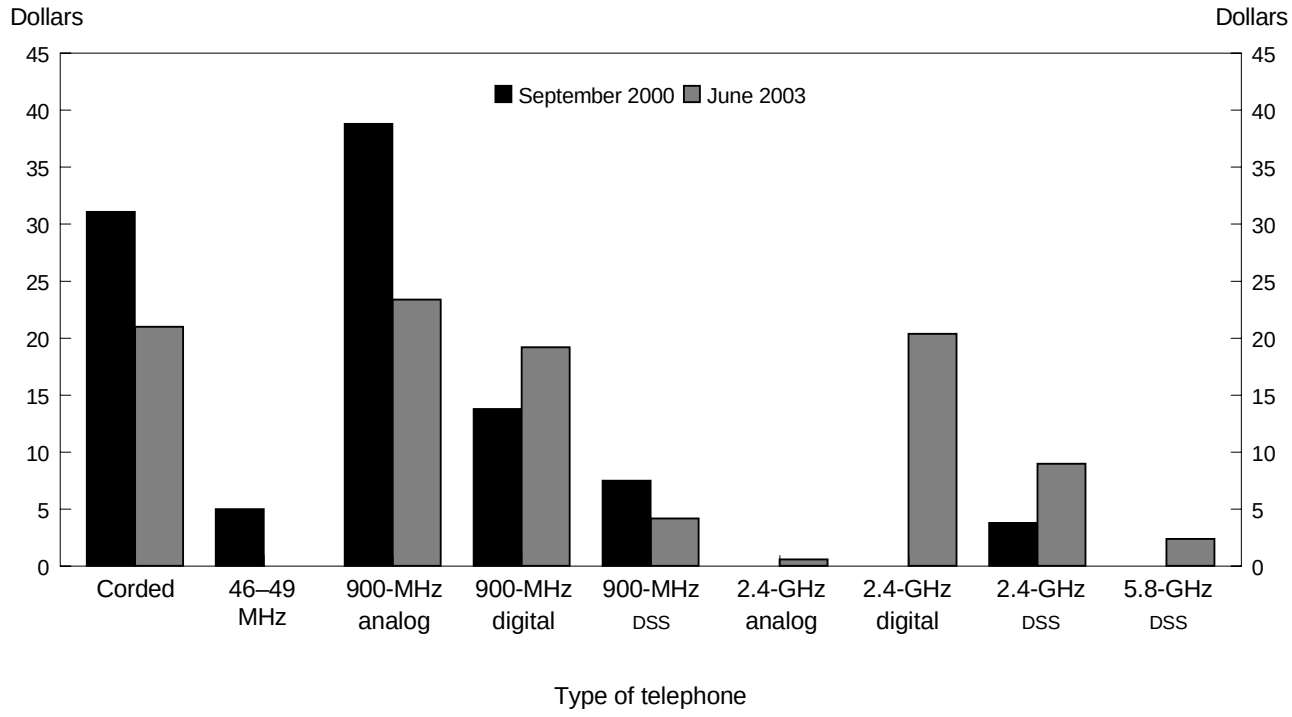
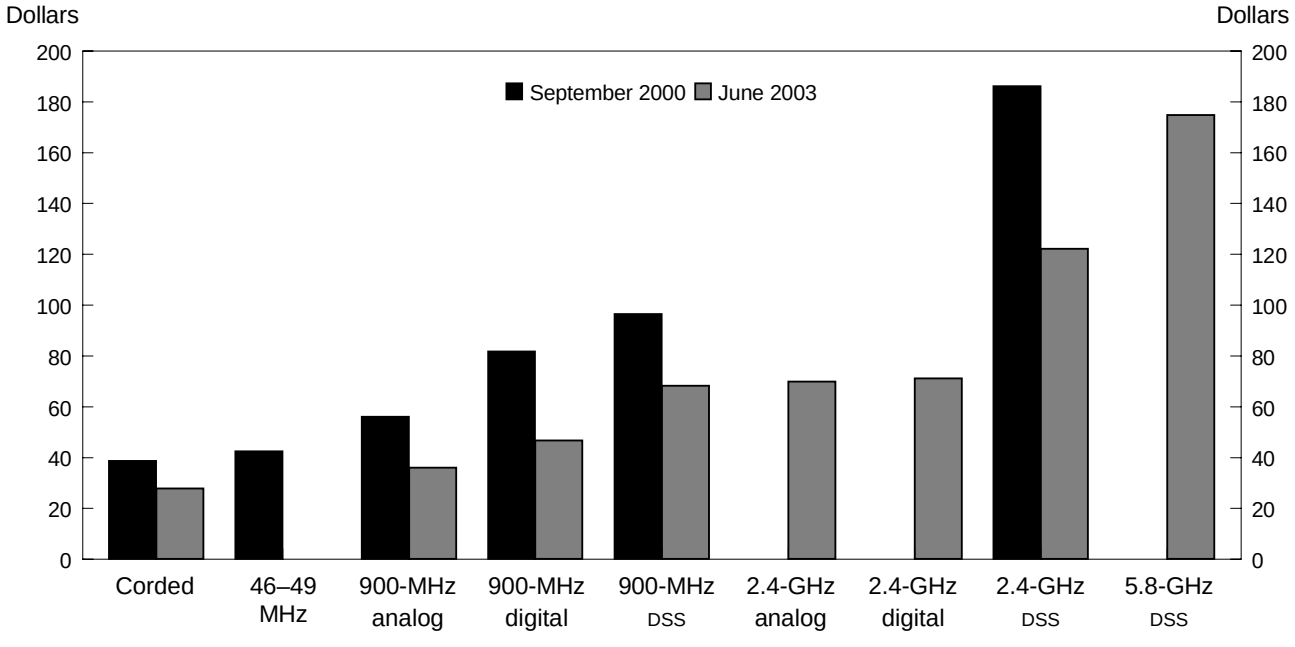


Chart 5. **Average price of CPI sample by type of telephone, September 2000 to June 2003[1]**



[1] The June 2003 CPI sample included one 2.4-GHz analog telephone; hence, the average price is the price of that model.

Notes

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[1] Most notably, the hedonic models for items of apparel and their continual upkeep. (For more information on early work with hedonic models for apparel items in the CPI, see P. Liegey, "Adjusting Apparel Indexes in the Consumer Price Index for Quality Differences," in *Price Measurements and Their Uses*, National Bureau of Economic Research Studies in Income and Wealth, 57 (Chicago, University of Chicago Press, 1993), pp. 209–26, and "Apparel price indexes: effects of hedonic adjustment," *Monthly Labor Review*, May 1994, pp. 38–45; and N. Shepler "Analysis of Hedonic Regression: Applied to Women's Apparel in the Consumer Price Index," manuscript (Bureau of Labor Statistics, 1994).

[2] Between April and September in each of 1999 and 2000, supplemental research samples were collected for motor vehicle painting, film processing, refrigerators, microwave ovens, videocassette recorders (VCR's), digital video disk (DVD) players, camcorders, telephones, and dental restorations.

[3] See M. Kokoski, K. Waehrer, and P. Rozaklis, "Using Hedonic Methods for Quality Adjustment in the CPI: The Consumer Audio Products Component," BLS working paper (Bureau of Labor Statistics, 2000), for an example of research conducted with this type of data.

[4] A detailed explanation of NPD's aggregation procedure can be found in Kokoski, Waehrer, and Rozaklis, "Using Hedonic Methods," or on NPD's Web site at **www.npd.com**.

[5] The seven model numbers were either conference call stations or extra handsets that are used with expandable telephone systems.

[6] A complete history of cordless telephones is available on the Internet at **www.affordablephones.net/HistoryCordless.htm**. Since the time of this report, the Commission has opened up the 5.8-GHz frequency to cordless telephones as well.

[7] More information on DSS and other cordless telephone technologies can be found on the Internet at **www.howstuffworks.com/question326.htm**.

[8] The next section discusses the weighting methods of the NPD data in further detail.

[9] E. Diewert, "Hedonic Regressions: A Review of Some Unresolved Issues," presentation given at the Seventh Ottawa Group Meeting on Price Indices, Paris, May 2003.

[10] The NPD sample is designed so that each observation represents the average price of a unique model number, as calculated from 1 month's total expenditure and sales volume for that model number.

[11] Kokoski, Waehrer, and Rozaklis, "Using Hedonic Methods."

[12] The CPI rotates approximately 25 percent of its sample each year. It is during this process that the sample is most likely to incorporate the newest and most popular products in the market.

[13] For a more detailed discussion of this survey, see *BLS Handbook of Methods*, Bulletin 2490 (Bureau of Labor Statistics, April 1997), chapter 16.

[14] Guides to the characteristic data in each sample are available from the author.

[15] Recommendations on functional forms in the hedonic model literature can be found in Z. Griliches, "Introduction: Hedonic Price Indexes Revisited," in Z. Griliches, ed., *Price Indexes and Quality Change* (Cambridge, MA, Harvard University Press, 1971); and J. Triplett, "The Theory of Hedonic Quality Measurement and Its Use in Price Indexes," BLS staff paper 6, 1971.

[16] See E. V. Georges and P. Liegey, "An Examination Using Hedonic Regression Techniques to Measure the Effects of Quality Adjustment on Apparel Indexes," internal report (Bureau of Labor Statistics, 1988).

[17] Diewert, "Hedonic Regressions."

[18] The experimental models are intended to highlight the variation found in the datasets and are not suggested to be superior to the final models. Part of the reason for the latter claim is that the experimental models do not utilize the available data to their fullest extent.

[19] One of the 13 common brand names did not appear in the 67 common model numbers.

[20] The imputation or "link" methodology is explained in greater detail in the *BLS Handbook of Methods*, chapter 17, p. 186.

[21] An additional benefit of employing hedonic models in evaluating substitutions is that the analyst is able to rely on statistical tools, rather than expert judgment alone, when making comparability decisions. Because of this approach, the percentage of directly compared substitutions increased under the reevaluation.

[22] This type of analysis was not possible with NPD data, because the Bureau does not have access to a current NPD sample. Also, the September 2000 CPI sample is from the official CPI sample used in calculating indexes. The supplemental observations added to increase the sample size for modeling were excluded from the analysis in order to compare official CPI samples.

[23] This information was reported to the Bureau by employees of NPD at a meeting on March 24, 2003. The meeting was scheduled to discuss the future relationship between the two organizations.

[24] Specifically, the Bureau has the ability to find and correct errors in the data in a timely manner by communicating directly with the data collectors. It also has the capability of tailoring its data collection forms to fit the marketplace and its research needs.

[25] Research projects using NPD data for televisions and stereo receivers are currently underway. Ariel Pakes's new method of model estimation and application also is being studied. (See Ariel Pakes, "A Reconsideration of Hedonic Price Indexes with an Application to PC's," *American Economic Review*, December 2003, pp. 1578–96.)