Hedonic Quality Adjustments in the U.S. CPI:
A Statistical Agency Perspective

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Abstract

The term "hedonics" derives from the Greek root for satisfaction. The term is used because it describes an approach that separates a good or service into its elementary components or parts, which individually (and collectively) provide satisfaction to users. Since for certain goods and services this bundle of characteristics changes continually, having a way to estimate the relative value of each component helps to isolate the value of quality change from pure price change when retailers change the product mix available for sale in the market place.

This paper is a compilation of Bureau of Labor Statistics (BLS) studies conducted over the last few years and summarizes an application of hedonic regression techniques on Consumer Price Index (CPI) price data. Beginning in fiscal year 1999, the BLS received funding for special data collection to support the expansion of hedonic quality adjustment. Though BLS has been applying hedonic quality adjustments in its housing and apparel components of the CPI for more than a decade, the focus of the current paper is on recent experiences with consumer electronic and appliance goods.

Introduction

The recent expansion of hedonic methods, in the United States and elsewhere, has called attention to the different ways in which hedonic regression coefficients can be used in the construction of price indexes. In the U.S., hedonic coefficients are used only when an item included in the CPI market basket becomes unavailable or obsolete and a "new" or substitute item is selected to replace it for price index calculations.

One of the fundamental problems that producers of CPIs face is that the characteristics of goods and services, not just their prices, change over time. The non-price aspects of consumer goods and services, often referred to as "quality characteristics," can change in various ways to create "new goods." Examples include the following:

- New goods generated by re-bundling existing product characteristics. In the clothing industry, for example, fashion changes make apparel an example of "new" goods that perform the same function as old ones but in a novel way.

- New goods produced by "upgrading" existing product characteristics. In the computer and consumer electronics industries, for example, a steady stream of new models entering the market typically incorporate technological upgrades which improve product performance. Computers with increased memory or faster processing speed and televisions with enhanced picture resolution or clarity serve as examples.

- New goods created by never-seen-before product characteristics. These types of characteristics may occur for goods and services with previous generation models or for *bona fide* new goods or services.
  - Examples of never-seen-before product characteristics for goods and services with previous generation models may include computers with DVD drives or processing film in an electronic format--floppy disk, CD-ROM or as an electronic attachment sent by electronic mail--as opposed to paper prints.
  - Examples of never-seen-before product characteristics for *bona fide* new goods or services may include the following: the type of handset for cellular telephones; download (upload) speed (in kilobits or megabits) for internet access service; dual laser read capability for DVD players; strength (in milligrams) of the prescription drug Viagra; or type of operating system for a personal digital assistant (PDA).

These examples of new goods may, fairly soon after their arrival, drive old ones from the marketplace, or the old and new items may coexist. That is, the problem of changing product characteristics, or the quality change problem, is closely related to the new goods problem. When possible, a direct quality comparison and price adjustment is made between the two items when an item substitution occurs in the CPI sample. This is the hedonic version of the standard "matched model" approach to CPI pricing.

Beginning in fiscal year 1999, as part of a broad CPI Improvement Initiative, the BLS received funding for special data collection to support the expansion of hedonic quality

adjustment. The initiative provided money to collect two pricings of approximately 2500 observations in current CPI outlets.

The particular CPI strata selected for the study were chosen with a few simple criteria in mind: A perception that there may be some current inadequate accounting of quality change in the items; and, a belief that useful hedonic models could be developed for at least some subset of the items in the stratum.

The products selected for hedonic modeling are at varying points in their development stream, some being fairly new and undergoing very rapid technological improvements (DVD players), others having been on the market for some time (refrigerators and microwave ovens). Televisions are somewhere in between, obviously having been around for a long time, but currently marked by important changes (the digital revolution). We have learned a great deal not only about the particular products selected for hedonic modeling in the last few years but also about the success we might expect in the future for other product groups.

Experiences with Consumer Electronics and Appliances

This section will proceed as follows:

- For each new item using hedonics (not counting housing and apparel), briefly

  - Review background and initial research on item
  - Review data sources
  - Review regression results
  - Review results of simulations

Personal Computers (Item Stratum EE01)

Effective with the release of the CPI for January 1998, the BLS began using hedonic-based quality adjustments for its Personal Computers and Peripheral Equipment item stratum index of the CPI. The work on computer hedonic regressions was initially reported in a 1990 *Monthly Labor Review* article by Jim Sinclair and Brian Catron. Since that time the BLS has posted a paper by Michael Holdway about quality adjusting computer prices on the Producer Price Index (PPI) internet website that was last modified in June 2001.

The Producer Price Index (PPI) is a sibling program of the Consumer Price Index in the United States. The CPI and PPI share data and research results when appropriate. For example, the PPI works with motor vehicle manufacturers to determine the value of new or improved features. The CPI uses these values, modified to include the retail markup, to determine the quality adjustments for automobiles and other consumer vehicles.

The PPI program has developed hedonic regressions for various types of computers, including both large-scale computers and desktop personal computers; since December

1990 the PPI has used the values from these regressions to quality-adjust price changes for computers in situations of item substitution. The CPI began using the computer results for desktop computers starting with the index for January 1998. The third BLS price program, the International Price Program (IPP), also uses the PPI's computer regression results.

The regressions for desktop computers include variables reflecting chip type and chip speed, amount of system memory, video memory and hard drive capacity, sound system, modem, monitor type and size, type of operating system software, type of office suite software, business system (LAN ready) and manufacturer group.

The fact that computers change so rapidly has forced BLS to go beyond some of the traditional practices for hedonic regressions in order to get results that can be used in our indexes. First, they must find data on new computers, their attributes and their prices very quickly. This precludes use of BLS-collected data. The PPI has adopted a procedure of reviewing advertising in magazines and on the Internet and assembling observations from these sources. Second, the hedonic regressions must be rerun very often. The market for computers is so dynamic that product features and their contributions to the total value of the computer change very frequently, and accurately measuring their current value requires very frequent regression runs with newly assembled data.

Less often than every three months, but still at least annually, the team must reassess the model they are using, in order to account for additional features. They have found when major changes occur—these are usually associated with the introduction of a new master chip such as the Pentium IV—they must undertake a special modeling process to enable them to value the change. They refer to these as "bridge regressions." The analysts pool the data for computers with both the new and old chips and eliminate many of the variables for the other important features to focus the result on the chip difference alone.

Perhaps the most salient point to make is that using hedonic regressions for the computer index has had a dramatic impact on index movement. As reported in Stewart and Reed (1999), the BLS estimates that the annual rate of growth of the CPI index for personal computers and peripheral equipment was reduced by an annual rate of 6.5 percent during the period in 1998 studied. Another important point is that these regressions are a significant burden or resource intensive task on the BLS staff. The data must be painstakingly assembled (there are more than 600 observations in a recent regression) and the work must be repeated at frequent intervals to be useful.

Televisions (Item Stratum RA01)

Effective with the release of the Consumer Price Index (CPI) for January 1999, the BLS began using hedonic-based quality adjustments for the Television item stratum index of the CPI. The work on the television regressions was initially reported in a paper by Brent Moulton, Tim LaFleur and Karin Moses (MLM) presented at the 1998 Ottawa Group conference.

Like computers, televisions have properties that make them a likely candidate for hedonic analysis. They are a high-tech item that is subject to frequent quality improvement as new television models with new, never-seen-before features enter the market place and render older models obsolete. The data used for the hedonic model for TVs are drawn from the CPI television sample of more than 400 observations that is adequate for hedonic analysis. Initial characteristic data are drawn from specifications on the CPI data collection document known as a CPI checklist. Virtually all of the specifications or characteristic data are verified and, when necessary, overwritten with TV characteristic data from manufacturer and retail outlet web pages. Due to the complexity of television characteristic data, there are frequent errors or omissions in the data collected by the economic assistants for the CPI.

MLM used a semi-log model with the dependent variable as the logarithm of price and obtained quality adjustment values for screen size, wide screen, liquid crystal display, projection, surround sound, console, picture-in-picture (one tuner), picture-in-picture (two tuners), number of video inputs, brand group, learning/universal remote, and free delivery. Although a theoretical case can be made for using a linear functional form for some of the characteristics (for example, inclusion of a universal remote), the semi-log form provided better fit and more plausible coefficient estimates for most variables. The large and significant coefficient on the brand group variables indicated that brand is important. As MLM note, brand may proxy for unmeasured quality characteristics, such as the quality of the manufacturing, and also may reflect the value some consumers place on brand prestige.

The hedonic model for televisions is updated annually and most recently done so in 2000 using CPI collected data. In order to continue to use hedonic regression quality adjustments for televisions, BLS has to re-specify the model to accommodate new variables as well as new data. This may be less effort than the original MLM work required, but it is not insignificant. In addition to brands, other variables used as explanatory variables in the most recent regression model are: wide screen, liquid-crystal display, projection, console, picture-in-picture (1 tuner), picture-in-picture (2 tuners), number of video inputs, universal/learning remote, comb filter, 3-D comb filter, component video input, super flat screen, Guide + programming, high definition compatible, and free delivery. All of these are indicator or dummy variables except screen size, its square, and the number of video inputs.

Television models leave the market place fairly regularly. MLM noted that each month in the CPI television sample about 15 percent of the models become permanently unavailable and must be replaced, meaning that a typical television remains in the CPI sample for less than a year. Consequently, allowing the natural substitution process to occur provides a number of opportunities to apply quality adjustments. In the future, it may prove desirable to direct additional substitutions in some cases, in order to keep the television sample as current as possible.

 Based on BLS research, the television index would have been approximately 0.1 percent lower per year with the quality adjustments applied from August 1993 to August 1997.

See Brent R. Moulton, Timothy J. LaFleur, and Karin E. Moses, *Research on Improved Quality Adjustment in the CPI: The Case of Televisions*, paper presented at the Fourth Meeting of the International Working Group on Price Indices, Washington, DC, Apr. 22-24, 1999.

Audio Products (Item Stratum RA05)

Effective with the release of the Consumer Price Index (CPI) for January 2000, the BLS began using hedonic-based quality adjustments for the Audio Products item stratum index of the CPI. The work on the audio products regressions was initially reported in a paper by Mary Kokoski, Keith Waehrer, and Patricia Rozaklis (KWR) and presented at the 1999 "The Measurement of Inflation Conference," funded by the Statistical Commission of the European Commission (Eurostat) and jointly hosted by Cardiff Business School, Cardiff University and the UK Office for National Statistics.

The data used in the hedonic regressions for audio products are purchased by the Bureau of Labor Statistics from NPD, a private firm which specializes in the collection and packaging of such market data for sale. These data were generated from point-of-sale observations in various retail chain outlets and each observation represents the average price for a specific product model over a monthly period for each of several classifications of retail outlet types called "channels." The channels represented in the data include department stores, mass merchandisers, electronics specialty stores, and catalogue showrooms. Characteristic data collected by the BLS are somewhat limited in scope and do not capture important product characteristics such as product introduction date, buffer memory, and recent technological advancements such as surround sound capabilities. Several variables that appear on the CPI data collection document or CPI checklist for audio products are difficult to use in the context of hedonic regression analysis. These factors, as well as small sample size, prevented the use of CPI data in hedonic regressions.

The NPD data consist of thirteen categories of products: CD players, portable radios, solid state recorders, portable tape recorders, portable radio cassette players, stereo headset, stereo headphones, receivers/amplifiers/tuners, cassette decks, home speakers, one brand rack systems, and shelf systems. Each observation consists not only of an average or unit value price, but also includes information on the physical attributes of each model and number of units sold.

Hedonic models are estimated separately for the thirteen categories of audio commodities defined by the NPD data, with the vector of attributes specific to each category. Models are of the log-linear form and continuous or near continuous variables as well as categorical or dummy variables are used for specification. While the characteristic variables include many of the important attributes of a given product, there are additional attributes that are unobserved but may also affect a consumer's valuation of the product. Aside from the product characteristics, the regressions also include dummy variables for manufacturer. The coefficient estimates from the NPD regressions are applied to make quantitative quality adjustments to those cases in the CPI sample where one product is substituted for another.

The KWR study estimated that the audio equipment index would have been approximately 1.4 percent higher in calendar year 1998 with the quality adjustments. The authors note that the quality adjusted audio product indexes do not decrease as rapidly as the unadjusted ones. They also reiterate that audio products are a small sample item stratum with relatively few substitutions occurring. In addition, there is no model-year turnover pattern to audio products marketing. Innovations do not rapidly supplant existing models, and obsolescence is seldom a factor (at least for the time period of their study). Also, the products chosen as CPI substitutes are of similar vintage to the disappearing ones, not the newest models on the market, so that the average vintage of the CPI sample is probably older than that of the current market as represented by the NPD data. Thus, quality adjusting the audio products component of the CPI would not be expected to result in a more rapidly decreasing index.

Other Video Equipment (Item Stratum RA03)

Camcorders

Effective with the release of the Consumer Price Index (CPI) for January 2000, the BLS began using hedonic-based quality adjustments for video cameras, also known as camcorders, in the *Other Video Equipment* item stratum index of the CPI. The work on the camcorder hedonic regressions was initially reported in a paper by Nicole Shepler and has been posted on the CPI internet website since February 2000.

The CPI camcorder sample size was insufficient for regression modeling purposes. Based on current CPI sampling procedures, CPI statisticians designed a supplemental sample for hedonic modeling purposes only. The new sample added 190 outlets with 2 observations assigned in each outlet. The final sample data set used for estimating the regression model included 453 observations including specially collected observations and observations from the CPI sample. The camcorder hedonic regression model has been recently updated in 2001.

For the purpose of formulating the camcorder hedonic regression model, data was taken from various sources. CPI field economists collected the primary data. The manufacturer model numbers obtained by the CPI data collectors were matched with specifications provided by manufacturer internet sites and used to verify and, when necessary, overwrite CPI data. Those model numbers that did not match any manufacturer model numbers were dropped from the data set. Further research helped to develop an a priori model -- comparing retailer advertisements, determining which attributes are consistently reported by manufacturers, reviewing consumer magazines and websites, and reading the feedback provided by the data collectors.

The natural log of the collected price was specified as the dependent variable. The main price determinants are the format of the camcorder along with a premium brand versus other brands. There are currently five analog camcorder formats available: full-size VHS, 8 millimeter (8mm), Hi-8, VHS-C (compact VHS), and super VHS-C (S-VHS-C);

and two digital formats available: mini digital (miniDV), and digital 8 millimeter (digital 8mm).   Based on a priori expectations several other variables were included in the model: monitor size in inches, color viewfinder, image stability, and weight without battery is less than or equal to one pound. Those features that were included in the final model appear to be the non-gimmick and non-technical features. Several of the features that manufacturers and retailers tout as the "must haves" were not found to be price determinants.

Several variables were included in the model that control for type of business and area of the country where the data are collected. Most of these variables behaved as expected. Discount department stores and warehouse outlets usually have the lowest prices and thus a negative parameter estimate. The positive parameter estimate for furniture/appliance outlets is not unexpected since these are typically the smaller, more specialized and usually local outlets that are known for their customer service. Catalog outlets selling electronic items usually sell mostly high-end electronic items and also charge a steep shipping fee. This is accounted for in the large parameter estimate for catalog outlets.

The final camcorder regression model may appear to be much simpler than one might expect for a complicated high tech good. The parameter estimates in the final model conform with a priori expectations and the R-squared value indicates that almost 93 percent of the variation in the dependent variable is explained by the independent variables. This is quite high for a hedonic regression model calculated using CPI data. The final model was examined for multicollinearity using the tolerance statistic and pairwise correlations.

The Shepler study estimated that the other video equipment index would have been approximately 0.2 percent lower from May 1999 to November 1999 with quality adjustments for changes in camcorder substitute price quotes. Shepler notes that the impact of applying the quality adjustments to the *Other Video Equipment* index was minimal since camcorders are only a part of the index and camcorder substitutions an even smaller part. The application of the camcorder hedonic model does noticeably decrease the number of noncomparable (imputed) substitutions. This alone makes hedonics a worthwhile endeavor.

Video Cassette Recorders (VCRs)

Effective with the release of the Consumer Price Index (CPI) for April 2000, the BLS began using hedonic-based quality adjustments for video cassette recorders (VCRs) in the Other Video Equipment item stratum index of the CPI. The hedonic analysis on VCRs was initially reported in a 1999 *Monthly Labor Review* article by Paul Liegey and Nicole Shepler. Subsequent work about quality adjusting VCR prices is reported in a paper by William Thompson and has been posted on the CPI internet website since May 2000.

The sample of VCR prices used in monthly CPI estimation was insufficient for regression modeling purposes. Based on current CPI sampling procedures, CPI statisticians designed a supplemental sample for hedonic modeling purposes only. The new sample

added 296 observations in addition to the 243 observations from the CPI sample. The final sample included 460 observations. Observations with inconsistent or incomplete data and for which no manufacturer model number could be found were dropped from the data set. Collecting data for electronic goods is not a simple task. Manufacturers and retailers use confusing terminology and often use different names for the same feature. The manufacturer model numbers obtained by CPI data collectors were matched to specifications provided by the manufacturer Internet sites and used to verify and, when necessary, overwrite CPI data.

The VCR hedonic model developed is based on consumer retail offer prices and characteristics collected by CPI representatives. The natural log of the collected price was specified as the dependent variable. Almost 76 percent of the variation in the dependent variable, the natural log of price, is explained by the independent variables: tape format, brands, number of video heads, hi-fi / mono-sound audio, and dual cassette players.

Tape format is dominated by the Video Home System (VHS), VHS High Quality (VHS-HQ) or Super VHS (S-VHS); the latter offers the best among analog formats, with 50 percent more picture sharpness than standard VHS. The beta system, which was the early competitor to VHS, is used primarily for commercial applications. The 8mm players are relegated to use by those with 8mm camcorders that do not have converter with which to watch their 8mm camcorder tapes on VHS. Finally, Digital VHS (D-VHS) first introduced in 1998 and designed to be a partner with DirecTVSatellite System or the Dish Network, has not yet achieved mainstream acceptance.

Other features that are included as variables in the VCR model are flying erase head which permits smoother editing of tapes, the capability to advance through commercials or omit commercials when recording, and "VCR plus " recording, which allows the consumer to program the VCR to record a particular show using a five digit code.

The Thompson study estimated that the other video equipment index would have been approximately 1.0 percent higher from May 1999 to December 1999 with quality adjustments for changes in VCR substitute price quotes. Thompson notes that the results of his study are not surprising given that Liegey and Shepler had a similar although smaller difference (0.1 percent difference over a 12 month study) between the published index and the quality adjusted index. Although there are differences in the source of the data the index simulation results can not be totally discounted.

Thompson concludes by noting that it is unclear what the future holds for the VCR. It is likely that the VCR will continue to be popular in the near term. While someday in the future the VCR or at least the VHS format will give way to some type of digital format, recent VCR sales have hit record numbers. If DVD players develop and market the technology to record as well as play then it is foreseeable that DVD players will make the VCR obsolete at some point in the future.

Digital Versatile Disk (DVD) Players

Effective with the release of the Consumer Price Index (CPI) for April 2000, the BLS began using hedonic-based quality adjustments for digital versatile disk (DVD) players in the Other Video Equipment item stratum index of the CPI. The work on the DVD player hedonic regressions was initially reported in a paper by Paul Liegey and has been posted on the CPI internet website since May 2000.

DVD (Digital Versatile Disk) players were introduced into the US market in the spring of 1997. The CPI began reflecting price change for DVD players with the January 1998 revision. Approximately 15 CPI quotes were being priced for DVD players by the end of 1999, representing about seven percent of the average monthly sample (n ~ 227) for the item stratum.

Since the official CPI sample for DVD players was too small for regression estimation, an additional sample was selected for regression use only. This additional sample for DVD players was selected using a process that mimics the process used to select the official CPI samples. More than 500 DVD player price quotes were sent to the field for selection and collection in CPI pricing outlets. Unfortunately, many of the DVD player price quotes could not be collected because the outlets were not yet carrying the new product. The final sample size used for the DVD player model was 259 observations.

The 259 observations in the sample represent 45 unique DVD players with a specific brand and model number. Review of the data collected for this product revealed some inconsistent, inaccurate, or incomplete specification descriptions. The CPI specification elements collected in the sample were reviewed, and when necessary overwritten, using information primarily from manufacturers' websites for each of the 45 unique DVD players when such information was available. Other secondary source information was used to cross check or supplement the information on the manufacturers' websites. These other sources included *Consumer Digests' 1999 Annual Buying Guide* (December 1998) and *Consumer Reviews' Video Buyers' Guide* (Summer 1999).

As a *bona fide* new good, the superior audio and video performance of DVD players in terms of "total viewing experience" is usually bench-marked or (implicitly) compared to the current standard for video play back machines, VCRs. All DVD players provide enhanced features such as:

- All-digital playback that provides better video and audio detail than either VCRs or laserdiscs
- Choice of aspect ratios supporting both standard (4:3) or widescreen (16:9) TVs
- Choice of up to 8 tracks of digital audio for multilingual playback
- Choice of up to 9 camera angles for different vantage points during playback
- Menus and simple interactive features including "instant" rewind and fast forward, search by title, chapter, track, and timecode
- Automatic "seamless" branching of video for multiple movie versions (theatrical vs. director's cut) or rating choice (G, PG, or PG-13 version of an R-rated film)
- Choice of up to 32 multilingual subtitle tracks

These enhanced benefits are realized on all DVD players as long as the DVD discs provide the information (that is, for example, not all DVD discs are coded to playback 8 different languages). While these features undoubtedly represent a greater array of consumer choice and presumably increase the viewing experience utility for the average consumer, they are common to all DVD players and thus exhibit no variation as potential variables. More variation in characteristics data is better than less when developing a hedonic model.

Nevertheless, both group and individual dummy variables were created for each of the 14 DVD player *brands* represented in the sample. *A priori* expectations about how these brands should influence price were based on retail and industry information. Some brands (and models) are targeted toward more sophisticated users of consumer electronics while most other brands (and models) are advertised simply by comparing the enhanced performance of DVD players to VCRs. Many manufacturers are racing to put their DVD player products on the market now to establish a reputation for future sales.

The only (physical) characteristic that was available in the sample believed to distinguish video performance among DVD players was *component video output*. Industry and retail information indicates that this characteristic contributes to the overall capability of a DVD player when connected to a TV that possesses a component video input. While *component video outputs* are often touted as a distinguishing quality feature, they were more commonplace in 1999 than when DVD players were introduced to the market in early 1997.

Similarly, the only (physical) characteristic that was available in the sample and that is believed to distinguish audio performance among DVD players was a *built-in Dolby digital decoder*. All DVD players output a digital audio stream that can produce surround-sound-like audio capabilities; however, a decoder (either external or built-in) is needed to process this digital audio stream. This feature contributes to price positively, however consumers may not be interested in this feature if they have already purchased an external Dolby digital decoder.

Other characteristics data that were collected on the DVD checklist and were tested for price influence included: remote control type—standard versus universal, and warranty coverage--1 year parts and labor warranty versus 1 year parts and 3 months labor. In addition, control variables were created for *city size*, *region,* and *type of business* as collected by the CPI. The use of these control variables is to minimize any of the unexplained variation that might remain after the model has been fitted with price determining characteristics.

Iterative regressions were performed until the remaining parameter estimates in the final model exhibited relative robustness to the inclusion and deletion of other variables not included. The direction and magnitude of the parameter estimates seemed reasonable, and the statistics pertaining to fit, significance, and collinearity are within generally accepted limits.

Researchers have acknowledged that in "the (consumer) electronics market, *brand* plays an important role as a price factor" when developing a hedonic model for a consumer electronic good. Given the data limitations in terms of variation of collected characteristics and the difficulty associated with collecting (technical) supplemental characteristics consistently across brands, the final model represents a snapshot of how the average consumer valued quality of DVD players in the embryonic market.

Ideally, the final regression would have contained more variables representing the product characteristics that consumer's value instead of brand (dummy) variables. The CPI checklist for this product was revised in 2000 prior to the planned collection of the FY 2000 hedonic DVD sample as a means of capturing some additional quality characteristics that have been define for this product.

On average, 11 price quotes represented DVD players each month in the CPI in the second half of 1999. Of these 11 DVD player price quotes, less than one price quote per month, on average, represented a substitution price change. Since the *Other Video Equipment* item stratum index averaged about 227 price quotes per month in the second half of 1999, little reason existed to believe that a quality adjusted index would differ from the published index for this item stratum index. Therefore, the impact of applying hedonic quality adjustments for DVD player substitutes to the *Other Video Equipment* index was not calculated.

Major Appliances (Item Stratum HK01)

Refrigerators

Effective with the release of the Consumer Price Index (CPI) for July 2000, the BLS began using hedonic-based quality adjustments for refrigerators in the Major Appliances item stratum index of the CPI. The work on the refrigerators hedonic regression model was initially reported in a paper by Nicole Shepler and has been posted on the CPI internet website since August 2000.

The existing CPI refrigerator sample was not sufficient for regression modeling purposes. A supplemental sample of 390 observations was drawn by CPI statisticians for hedonic modeling purposes only. The sample design for the additional observations was based on current CPI sampling procedures. The final sample included 124 observations from the CPI sample and 214 specially collected observations for a total sample of 338 observations. The CPI data collectors were unable to collect data for 45 percent of the supplemental sample due to lack of respondent cooperation. There was some confusion over collecting some of the feature specifications. The information for many of these specifications was obtained through secondary sources.

Refrigerators are a fairly homogeneous item. Virtually all of the refrigerators available in today's market are frost free, have separate temperature controls for the refrigerator and freezer, shelves built into the door, and so on. The most important characteristics in a consumer's mind are size (capacity) and type. There are four different types of

refrigerators: one door (includes compact refrigerators); two door, freezer on top; two door, side-by-side refrigerator/freezer; and two door, freezer on bottom.

Initial models were specified with refrigerator types as independent variables and the natural log of collected price as the dependent variable. Since total refrigerator capacity was also believed to be an important price factor, a subsequent regression model was run including this variable. Low tolerance values in the total capacity model indicate that multicollinearity was present. Total refrigerator capacity was correlated with virtually all the refrigerator type variables.

The existence of multicollinearity was confirmed after comparing the initial and subsequent models. Including the total capacity term caused the standard errors for the refrigerator type parameter estimates to increase. Since the purpose of the hedonic model is to use the actual parameter estimates for quality adjustments, the parameter estimates should be as precise as possible. In this case, multicollinearity caused the parameter estimates for the total capacity and refrigerator type variables to be imprecise. Therefore, a total capacity variable and dummy variables for refrigerator type were not included together in the regression model.

An analysis of the natural log of price versus total capacity revealed that there was a strong linear relationship between the two. The analysis also shows that the total capacity variable could serve as a proxy for refrigerator type. The one-door, refrigerator-only type of refrigerators have the lowest total capacity, and at the other end of the spectrum the side-by-side refrigerator/freezer type refrigerators have the highest total capacity. Therefore, leaving refrigerator type out of the model should not bias the results of the regression model.

Dummy variables for manufacturer/brand, miscellaneous features, color, ice maker, type of outlet, and other control variables were added in addition to the sale price dummy variable and total capacity variable. The results of the model for the most part met *a priori* expectations. Determining expectations for the manufacturer/brand variables was difficult. There were 22 different refrigerator brands in the data set.

As for the other variables in the miscellaneous features category, the parameter estimates for sound insulation, water filtration, humidity controls, and third refrigerator drawer were all positive, while the energy saver switch had the only negative parameter estimate. The parameter estimates for these miscellaneous features variables are all consistent with assumptions:
- The sound insulation feature significantly reduces the noise the refrigerator makes while it is running. This feature is achieved by a more sophisticated engineering design process which pinpoints where more insulation is needed to reduce noise. These refrigerators are also more energy efficient due to the extra insulation.
- A water filtration system filters out contaminants and odors from the water used in the ice maker and water dispenser.
- Humidity controls regulate the humidity in the fruit and vegetable crispers. This allows the fruits and vegetables to stay fresh longer.

- Three refrigerator drawers offer increased storage for types of foods that are generally stored separately from the rest of the food.
- The energy saver switch was historically included on freezer-on-top refrigerators to keep moisture from forming on the outside. Side-by-side and newer top mount refrigerators have eliminated the need for this type of feature. Most refrigerators in today's market have been engineered to automatically prevent the formation of moisture on the outside. The negative estimate for this variable indicates that there are still some low priced refrigerators with this feature.

Refrigerator color is also an important price factor. White, almond, or cream colored refrigerators are the most common color in today's market. Some high-end refrigerators are now available in black, stainless steel, or even paneled with wood. Many consumers are looking to emulate professional kitchens where stainless steel is common. In a certain sense, refrigerator color serves as a proxy for perceived quality. Therefore, it is not surprising that the parameter estimates for black, stainless steel, and wood panel are all positive.

Ice maker options were also included in the hedonic model. The most common option in this data set was a combination of ice and water dispenser in the refrigerator door with an ice maker. This option was designated as the base variable since it was present in 49 percent of the sample. The remaining options were for an installed automatic ice maker, ice maker ready (the customer has the option to install an ice maker), or no ice maker. The resulting parameter estimates make intuitive sense.

Several variables were included in the model that control for type of business and area of the country where the data are collected. These variables behaved as expected. The negative parameter estimates for discount department, discount appliance, and warehouse outlets are not surprising since these types of outlets are known for their low prices. The parameter estimate for full price appliance outlets is positive. These outlets are more service oriented and usually have higher quality merchandise than the discounters.

The final model exhibits a high explanatory power with an R^2 of 95 percent. The largest correlations (as measured by the Pearson correlation coefficient) were between total capacity and water filtration (0.45) and total capacity and no ice maker (-0.55). These variables were kept in the final model since the correlations were felt to be at an acceptable level. A high correlation between kilowatt hours used and total capacity did preclude the inclusion of kilowatt hours into the final model. Kilowatt hours of electricity used per year was believed to be an important price factor; however, it is strongly related to total capacity since in general larger refrigerators require more electricity.

The Shepler study estimated that the major appliance index would have been unchanged from July 1999 to April 2000 with quality adjustments for changes in refrigerator substitute price quotes. Shepler notes that the lack of impact of applying the quality adjustments to the major appliances index was negligible due to the small proportion of refrigerator substitutions in the index. Refrigerators is just one of six items included in the major appliances index -- freezers, washers, dryers, stoves and ovens, and microwave

ovens are also included. On average, there were only five refrigerator substitutions each month. The low counts for substitutions combined with the low proportion of refrigerator substitutions in the overall index limits the potential impact of using hedonics for quality adjusting refrigerator substitutions.

Microwave Ovens

Effective with the release of the Consumer Price Index (CPI) for July 2000, the BLS began using hedonic-based quality adjustments for microwave ovens in the Major Appliances item stratum index of the CPI. The work on the microwave ovens hedonic regression model was initially reported in a paper by Paul Liegey and has been posted on the CPI internet website since August 2000.

The official CPI sample of microwave oven prices was too small for hedonic regression estimation. Using a process that mimics the official CPI sample selection process, an additional sample of 195 consumer businesses, or outlets, was chosen to augment the official CPI sample for microwave ovens. This additional outlet sample was used to select a sample of microwave oven prices. The supplementary sample was used only for estimating the hedonic regression model for microwave ovens. CPI field economists were instructed to collect a total of 390 microwave oven prices in the sample of 195 additional outlets. Individual microwave oven brand and models were selected by grouping all microwave ovens in a particular outlet into two groups--the "standard" microwave ovens and "better model" or higher quality microwave ovens. Once categorized into these two groups, the CPI field economist was instructed to select a "good selling" microwave oven from each of the "standard" and "better model" groups.

A total of 381 prices--and characteristic descriptions--were used to estimate the hedonic model for microwave ovens. This total sample consisted of 98 official CPI observations and 283 additional sample observations. All of the price and characteristic data used for the microwave oven hedonic model was captured on CPI data collection documents, or checklists, for this item.

The prices that were collected for the microwave oven sample represent "retail offer" prices. Retail offer prices represent what a consumer business is willing to sell an item for which may, or may not, differ from the transaction price--what a consumer actually paid for the item. Retail offer prices, like transaction prices, may change through time depending on whether the item being sold is offered at a "regular" price or a "sale" price.

Secondary source information such as manufacturer websites and consumer information magazines--including *Consumer Digest's* and *Consumer Reports*--were used to verify the accuracy of, and when necessary overwrite, the characteristic data collected on the CPI checklist for microwave ovens. Overall, the CPI field economists were able to provide complete, consistent, and accurate descriptions for most microwave oven observations included in the hedonic regression sample.

Microwave ovens were selected as a product that would benefit from hedonic regression modeling since manufacturers provide a vast range of sizes, configurations, and features.

Many include electronic sensors along with automatic controls for easy programming of cooking commands. *A priori* expectations about which microwave oven characteristics influence price were developed on industry information, manufacturer websites, and consumer information magazines.

The hedonic model that was specified for microwave ovens in this study resembles the categories of quality characteristics that are presented on the CPI checklist for this item. Variables for microwave oven types--countertop versus over-the-stove--were created for initial regression models. Both size (in cubic feet) and cooking power (in maximum watts) characteristics of microwave ovens were also assumed to have a significant impact on microwave oven prices.

A preliminary model was specified with the above stove variable, and two continuous variables--cavity cubic feet and maximum wattage. This model specification proved to explain a significant portion of the variation in (the natural log of) price with an R^2 of slightly more than 82 percent. While the magnitude, direction and significance of the parameter estimates in the preliminary model generally conformed with *a priori* expectations, somewhat low tolerance values for the cavity cubic feet and maximum wattage variables indicated that multicollinearity might be present in the model. Further investigation revealed that the Pearson correlation coefficient, or measure of collinearity, for these two variables was positive and strong at 0.61--they tend to move together and can serve as a proxy for each other. Subsequent variations of this preliminary model revealed that the variable for cavity cubic feet provided a better overall fit for the model and was included in the final model.

Brand was the next category of quality characteristics used to specify the hedonic model. In addition to the nine brands listed on the CPI checklist for this item, dummy or indicator variables were created for seven additional brands that were collected in the "Other brand" specification element. In the absence of strong *a priori* assumptions about brands, low tolerance values and statistically insignificant parameter estimates led to the exclusion of some of the brand name variables. Inclusion of the brand variables with the previous model specification yielded a slightly better fit with an R^2 of 87 percent.

While most of the microwave ovens in today's appliance market possess touch sensitive or electronic controls, some manufacturers still offer models with push button or rotary dial manual controls.   Almost 95 percent of the microwave oven sample contained microwave ovens with electronic controls, but a variable for manual controls was included in a preliminary model since *a priori* expectations were that only inferior quality models possessed this type of control. As expected, the parameter estimate for the manual controls variable was negative, remained robust in subsequent regressions, and was included in the final model.

Manufacturers and retailers of microwave ovens offer and advertise a variety of features on their products. Microwave oven features are represented in the "Cavity Features," "Cooking Features," and "Programming Features" specification categories on the CPI checklist for microwave ovens. Dummy or indicator variables were created for all

characteristics in these specification categories. Of the 19 dummy variables that were created for the three categories of feature specifications, only four of these variables--built-in sensor**,** auto sensor**,** convection cook**,** and convection broil--were used in the final regression model for microwave ovens. In addition, since these characteristics were not clearly delineated on the CPI checklist--or in the product descriptions at the retail outlets--the built-in sensor and auto sensor variables were combined into one variable called sensor and the convection cook and convection broil variables were combined into one variable called convection.

Iterative regressions were performed until the remaining parameter estimates in the final model exhibited relative robustness to the inclusion and deletion of other variables not included. The direction and magnitude of the parameter estimates seem reasonable, and the statistics pertaining to fit, significance, and collinearity are within generally accepted limits.

The Liegey study estimated that the major appliance index would have been approximately 0.2 percent lower from August 1999 to April 2000 with quality adjustments for changes in microwave oven substitute price quotes. Liegey notes that two factors may account for the empirical results reported in his study.

First, the small number of microwave oven substitution price quotes that were quality adjusted may have been too few to make a (representative) impact on the major appliances indexes in 1999-2000. Microwave oven substitution price quotes accounted for less than two percent--on average, four of 215 prices--of the monthly CPI sample for major appliances from August 1999 to April 2000 and only half of these microwave substitutions had their price changes adjusted using the hedonic technique.

Second, CPI data collection procedures direct BLS field economists to select substitution or replacement items that are the "same or similar" in quality as the old item they had been pricing. This procedure tends to yield substitution price quotes that have fewer *bona fide* characteristic changes (between substitute items) than might have occurred if the procedures had instructed field economists to collect (substitute item) data for the most technologically advanced or best selling microwave ovens.

This second factor is important in developing expectations as to the direction and magnitude of quality adjusted indexes when compared to indexes without quality adjustments for consumer appliance goods. If BLS field economists were instructed to substitute to the best selling or most technologically advanced microwave oven products, one might expect that the major appliances indexes with and without hedonic quality adjustments would diverge further (than in this study) from each other.

Clothes Washers

Effective with the release of the Consumer Price Index (CPI) for October 2000, the BLS began using hedonic-based quality adjustments for clothes washers in the Major Appliances item stratum index of the CPI. The work on the clothes washers hedonic regression model was initially reported in a paper by Nicole Shepler.

The existing CPI washers sample was not sufficient for regression modeling purposes. CPI statisticians drew a supplemental sample of 390 observations. The sample design for the additional observations was based on current CPI sampling procedures. The final sample included 80 observations from the CPI sample and 306 specially collected observations for a total sample of 386 observations. The CPI data collectors were unable to collect data for 22 percent of the supplemental sample due to lack of respondent cooperation. Also, the data collectors were only able to obtain store model numbers and prices for 17 percent of the hedonic sample. These observations could only be used in the regression model after characteristic data for each model number was obtained.

As with other CPI hedonic items (DVD players, VCRs, camcorders, refrigerators, and microwaves) the nationwide CPI data collectors were asked to report characteristics and current prices for their assigned washer sample. The data collection form requested information for 19 categories of washer features. Some categories were over-optimistic in terms of what information would be available to data collectors; for instance, the wash cycle category was difficult for the data collectors since manufacturers do not always list every single wash cycle and they also use different terminology for similar cycles.

After reviewing manufacturer literature, consumer-oriented articles, retailers' advertisements, data collector feedback, etc., only those categories where reliable information was available were further reviewed for consistency and accuracy. This review process also took into consideration what information would consistently be available to the average consumer. For instance, if the average consumer does not know (or care about) the difference between a "delicate wash cycle" and a "hand wash cycle" then it is unlikely that these "features" would be important price factors in a hedonic regression model. Despite not examining all the data for consistency, the data review and cleaning process was still quite time consuming and cumbersome.

Developing *a priori's* for the regression model was challenging since washers have traditionally been homogeneous. Only recently have shoppers been able to select from conventional top loaders versus the "European" style front loaders. The characteristics that tend to vary and impact price are brand, loading location, washer tub capacity, number of wash/rinse speeds, number of wash/rinse temperatures, control type, and energy efficiency.

The final model met *a priori* expectations. Total capacity was expected to be significant based on the other hedonic regression models for appliances (clothes dryers, refrigerators, and microwaves all found total capacity to be a positive, significant parameter estimate). The plot of total capacity against the natural log of price (in the study) shows that there is a positive relationship between the two variables.

Given that washers are rather homogeneous, several of the potential price determining characteristics were highly correlated with each other. For example since electronic controls are usually found on machines with more "bells and whistles," electronic controls were highly correlated with the more sophisticated features. Front loading

washers were highly correlated with kilowatt hours used per year, childproof features, and stainless steel tub material. The presence of highly correlated variables made model specification even more difficult.

Energy efficiency improvements are the much touted laundry appliance innovation. Washers have a range of features that help improve their efficiency. For instance, having a variable number of water level settings has the potential to conserve water if the user washes less than full loads. However, if the user always fills the washer to its capacity then this feature will not be beneficial. Also, having the ability to select from a number of temperature options allows the user to select one temperature for the "wash" cycle and another for the "rinse" cycle. The more sophisticated washers have automatic temperature controls. These controls adjust the flow so that the machine's "warm" water won't be too cool or the "cold" water too cold

Not many top loading washers in the data set were energy saver models -- just over 2 percent had this feature. Consumer Reports (July 1999) found that top loading washers could not match the front loading washers "for miserliness with both water and energy". However, since saving energy is a big selling point, retailers are able to charge more for top loading models that meet the energy star standards.

All the front loading (horizontal axis washer) observations in the data set were energy saver models and had the delay start option. Therefore, these features were combined to form one variable. The large, significant parameter estimate for this variable is not unexpected since these washers are much more expensive than the conventional top loaders. These washers "cost more to manufacture than top-loaders due to heftier suspension systems, motors, and door gaskets"--consumer review article on washers. Instead of using an agitator to clean clothes, front loading washers clean by tumbling the wash load through the water. They have a bigger cleaning capacity and are thought to be gentler on fabrics than top loading washers.

All of the variables in the features category were consistent with *a priori* expectations.

- Delay start for top loading washers is a convenient feature that allows the user to set the washer to start several hours in the future. In the data set used for model estimation, this feature was found in 5 percent of the observations. These observations were all rather high-priced compared to the others (a mean price of $950.07 compared to $560.31).

- Sound insulation was a common feature in the data set used for model estimation. Seventy-six percent of the data set listed some form of sound insulation in the manufacturers' specification description (for example, sound dampening package, sound reduction, etc.).

- The optional extra rinse cycle is useful for consumers who are sensitive to laundry detergent. The extra rinse also helps to cut down on the laundry detergent build up that often occurs with heavy terry cloth items such as bath towels.

- Number of temperature options and number of water level options are both continuous variables. Having more temperature options or water level options potentially allows the consumer to save money by setting the water level based on the laundry size and by setting the temperature option to the most optimal for the laundry type.

- The parameter estimate for no bleach and fabric softener dispensers is the only negative estimate in the features category. This variable serves as a proxy for the bare bones washer models.

The model also included variables for type of business and region to control for the effects of these conditions. The parameter estimates for these variables behaved as expected.

Washer manufacturer brands were not included in the regression model for several reasons. First, using *a priori* reasoning none of the brands in the data set stood out as having higher or lower perceived quality than the rest of the brands. Perceived brand quality is difficult to gauge and is made even more difficult for appliance brands since several manufacturers market the same appliance (only brand and model numbers vary) under different brands. Second, the data set was heavily dominated by a few brands -- three brands accounted for 74 percent of the data set. Lastly, those brands that did have higher or lower mean prices compared to the average mean price were more or less expensive because of the features (or lack of features) available and not due to brand. Brand is often used as a proxy variable for quality in hedonic models but in this case it was not needed to serve as a proxy variable. It was instead preferable to include the true quality characteristics in the model.

The Shepler study estimated that from September 1999 to June 2000 the experimental index using the direct hedonic quality adjustments decreased 0.6 percent more than the published index. Shepler notes that surprisingly, the impact of applying the washer quality adjustments to substitutions in the *Major Appliances* index was quite large compared to the impact from the other three items tested in the *Major Appliances* index (clothes dryers, refrigerators, and washers). Compared to the other three *Major Appliances* items, washers had the largest proportion of quality adjusted substitutions.

Washers are one of six items included in the *Major Appliances* index -- refrigerators, freezers, dryers, stoves and ovens, and microwave ovens are also included. Washer substitutions accounted for 22 percent of the substitutions in the *Major Appliances* index during the time period studied. On average, there were only four washer substitutions each month. The low counts for substitutions combined with the low proportion of washer substitutions in the overall index should limit the potential impact of using hedonics for quality adjusting washer substitutions.

Clothes Dryers

Effective with the release of the Consumer Price Index (CPI) for October 2000, the BLS began using hedonic-based quality adjustments for clothes dryers in the Major Appliances item stratum index of the CPI. The work on the clothes dryers hedonic regression model was initially reported in a paper by Paul Liegey and has been posted on the CPI internet website since March 2001.

The official CPI sample of clothes dryer prices used to calculate the *Major Appliances* CPI was too small for hedonic regression estimation. Using a process that mimics the official CPI sample selection process, an additional sample of 194 consumer businesses, or outlets, was chosen to augment the official CPI sample for clothes dryers. This additional outlet sample was used to select a sample of clothes dryer prices. The supplementary sample was used only for estimating the hedonic regression model for clothes dryers.

CPI field economists were instructed to collect a total of 400 clothes dryer prices in the sample of 194 additional outlets. Individual clothes dryer brand and models were selected by grouping all clothes dryers in a particular outlet into two groups--the "standard" clothes dryers and "better model" or higher quality clothes dryers. Once categorized into these two groups, the CPI field economist was instructed to select a "good selling" clothes dryer from each of the "standard" and "better model" groups.

About 69 percent of the additional sample price quotes that were collected for clothes dryers had price and characteristic data that could be used in the regression model. The most common reason that CPI field economists could not collect the additional sample price quotes for clothes dryers was respondent refusal. A total of 341 prices--and characteristic descriptions--were used to estimate the hedonic model for clothes dryers. This total sample consists of 64 official CPI observations and 277 additional sample observations

A priori expectations about which clothes dryer characteristics influence price were developed from industry information, manufacturer websites, and consumer information magazines and websites.

Two types of clothes dryers--electric and natural gas--are sold in today's market. Electric models are sold more frequently by retailers and account for approximately 65 percent of the clothes dryers in the sample. Typically, retail offer prices for electric dryers are less then gas dryers. Dummy or indicator variables are created for both types of clothes dryers. The gas variable included in preliminary hedonic models is expected to have a large, positive impact on price.

Manufacturers and retailers advertise drum capacity in terms of cubic feet. Drum capacity can assume a wide range of numeric values. To accommodate this potential wide range of values, a continuous variable is created for capacity (in cubic feet). It is assumed that the price of clothes dryers increases with increasing values of this variable.

The dry cycle specification category on the clothes dryer checklist was just as problematic as the wash cycle category for clothes washers in terms of obtaining a complete and consistent description across specific brands and model numbers. Manufacturers and retailers tend to do a better job at reporting the number of dry cycles rather than listing each cycle. Secondary source information was used to verify, and when necessary overwrite, the information in the sample data set for the variable for number of dry cycles. It is assumed that dryers with a greater number of dry cycles provide consumers with greater drying functionality and have a positive impact on price.

Preliminary models were specified with two dummy variables, sale price and gas dryer, and two continuous variables, capacity (in cubic feet) and number of dry cycles. The first model specification with sale price, gas dryer and capacity (in cubic feet) proved to explain a significant portion of the variation in (the natural log of) price with an R^2 of slightly less than 54 percent.

Inclusion of the number of dry cycles variable resulted in somewhat lower tolerance values for the capacity (in cubic feet) and number of dry cycles parameter estimates and indicates that multicollinearity might be present in the model. Further investigation revealed that the Pearson correlation coefficient, or measure of collinearity, for these two variables is positive and strong at 0.74--they tend to move together and can serve as a proxy for each other. Subsequent variations of these preliminary models revealed that the variable for capacity (in cubic feet) provides a better overall fit for the model; therefore, this variable was included in the final model.

Other 'technical' clothes dryer characteristics are included in the "Drying Mechanisms," "Number of Temperature Settings," and "Control Types" specification categories on the CPI checklist.

The moisture sensor characteristic is found in 54 percent of the clothes dryer sample while the temperature sensor and timed drying characteristics occur throughout the entire sample. It is assumed that the presence of a moisture sensor would have a positive impact on price.

While most of the clothes dryers in today's appliance market possess push button or rotary dial manual controls, some manufacturers are offering models with touch sensitive or electronic controls on their top of the line dryers. Electronic controls offer conveniences such as stored, customized temperature / cycle settings and easy to read displays. More than 90 percent of the clothes dryer price sample contained models with push button or rotary dial manual controls while the remaining 10 percent reflected electronic controls. It is expected that the electronic controls variable has a positive impact on price.

Including variables from the "Drying Mechanisms," "Number of Temperature Settings," and "Control Types" specification categories, increases the overall explanatory power of the preliminary hedonic models from an R^2 of slightly less than 54 percent to an R^2 of slightly more than 74 percent.

Of the 11 brands that are collected in the clothes dryer hedonic sample, 10 are included in iterative regression 6 excluding the most frequently occurring brand which accounted for a little more than 44 percent of the sample. In addition, three of the 10 brands included in preliminary models are excluded since they exhibited statistically insignificant parameter estimates.

Inclusion of brand variables in preliminary model specifications yields a better explanatory fit with an R^2 of slightly more than 84 percent from an R^2 of slightly more than 74 percent. The seven brands that remained in preliminary regression models emerged as two distinct groups--the "medium" and "low" quality groups. The "medium" and "low" quality groups are compared to the "base" group--the "high" quality brands that are the most frequently occurring and not included in the preliminary models.

An F test for brand equivalence is conducted for the individual brands in both the "medium" and "low" quality groups. For both groups, the F tests fail to reject the null hypothesis that the brands are equivalent. The parameter estimates for both the "medium" and "low" quality groups are (highly) statistically significant. Both the "medium quality" and "low quality" brand groups were included in the final model specification.

Manufacturers and retailers of clothes dryers offer and advertise a variety of features on their products. Of the seven dummy variables that are created for the "Features" specification category on the CPI checklist, all are excluded from the final regression model because of their poor performance in preliminary and subsequent regression models. In particular, the lint filter indicator and sound insulation variables are excluded from the final model because of statistical insignificance. Sound insulation is another example of a characteristic that is difficult to collect due to varying terminology and limited product descriptions in retail outlets. Secondary source information was used to verify, and when necessary overwrite, the sound insulation information collected for the sample data set but the parameter estimate for sound insulation remain insignificant.

The efficiency of a clothes dryer is measured by a term called the energy factor. It is somewhat similar to the miles per gallon for a car, but in this case the measure is pounds of clothing per kilowatt-hour of electricity. Unlike most other types of appliances, energy consumption does not vary significantly among comparable models of clothes dryers. Clothes dryers are not required to display EnergyGuide labels. Proxy measures for clothes dryer efficiency include clothes dryer type--electric or gas--and clothes dryer drying mechanisms--moisture sensors versus temperature sensors and timed drying.

The Liegey study estimated that the major appliances index would have remained unchanged instead of the official index decline of 0.1 percent if hedonic quality adjustment methods had been applied to clothes dryer substitution price changes from October 1999 through June 2000. During the study period, clothes dryer prices accounted for approximately 15 percent of the monthly major appliances sample, and averaged only two (substitution) price changes per month. Liegey notes that the small number of clothes dryer substitution price quotes that were quality adjusted were too few to make an

impact on the major appliances indexes. Clothes dryer substitution price quotes accounted for less than one percent--on average, two of 218 prices--of the monthly CPI sample for major appliances from October 1999 to June 2000.

Overall Impact on the CPI

The Bureau of Labor Statistics (BLS) employs the "matched model" method in its official indexes. This method controls for quality changes based on the difference in product specifications or characteristics between two items when a substitute observation, or quote, occurs in the price index sample. It is important to note that under the matched model approach *only substitution price changes are eligible for hedonic quality adjustments*.

Diewert (2001) succinctly describes the statistical agency's problem in reflecting price change for goods and services that are undergoing quality change in the market place:

> At some point in time, the statistical agency initiates a sample of models whose prices are to be collected until the next sample initiation period--typically some four years in the U.S. Unless some of these models disappear from the market, no other models will be added to the sample. Thus what may be happening is that the market throws up new models over the period of time between sample initiations. These new models benefit from technical progress and tend to have lower prices (quality adjusted) than the models that the statistical agency is following. In theory, the producers of these outmoded models should drop their prices to match the new competition but perhaps instead they simply stop producing these outmoded models, leaving their prices unchanged (or not dropping them enough). However, until every last model of these outmoded models is sold, the statistical agency continues to follow their price movements, which are no longer representative of the market. If a model disappears, there is the possibility that the replacement model chosen by the statistical agency is not linked in at a low enough quality adjusted price.

CPI data collection procedures direct BLS field economists to select substitution or replacement items that are the "same or similar" in quality as the old item they had been pricing. This procedure tends to yield substitution price quotes that have fewer *bona fide* characteristic changes (between substitute items) than might have occurred if the procedures had instructed field economists to collect (substitute item) data for the most technologically advanced or best selling item.

This factor is important in developing expectations as to the direction and magnitude of quality adjusted indexes when compared to indexes without quality adjustments for consumer goods and services. If BLS field economists were instructed to substitute to the best selling or most technologically advanced goods and services, one might expect that the indexes with and without hedonic quality adjustments would diverge further than our experiences thus far in the U.S.

The table below summarizes the index difference between the published index and the experimental quality adjusted index for recent hedonic items in the CPI Improvement Initiative.

U.S. CPI Item Stratum Index	Product	Simulation Time Period (year/month)	Hedonic Index Impact	Relative Importance December 2000
EE01	Computers	98/06 – 98/12	6.5% lower (annualized)	**0.079**
RA01	Televisions	93/08 – 97/08	0.1% lower (average annual)	**0.157**
RA05	Audio Products	98/01 – 98/12	1.4% higher	**0.139**
RA03	Camcorders	99/05 – 99/11	0.2% lower	**0.049**
RA03	VCR	99/05 – 99/12	1.0% higher	
RA03	DVD Player		NA	
HK01	Refrigerators	99/07 – 00/04	Unchanged	**0.194**
HK01	Microwaves	99/08 – 00/04	0.2% lower	
HK01	Washers	99/09 – 00/06	0.6% lower	
HK01	Dryers	99/10 – 00/06	Unchanged	
SA0	All Items		NA	**100.00**

The sum of the December 2000 relative importance, or share of weight, for the five item strata included in this paper rounds to approximately six-tenths of one percent. Given the relatively small index impacts--computers being the exception--that hedonic quality adjustments have produced, combined with the small item weights, the overall impact on the (all items) CPI is negligible.

Increased Use of Directed Replacements

BLS is considering additional ways to more quickly bring a greater number of quotes for new goods into the CPI rather than just relying on the current Telephone Point of Purchase Survey (TPOPS) rotations. Lane (2000) provides a summary of additional methods for bringing new goods into CPI samples more quickly. In particular, the directed item replacement method of updating price index samples instructs field economists to "select a new set of (sample) items representing a more recent period's purchases" for target groups of goods or services that are constantly changing in quality with successive generations of product introductions.

The directed item replacement method or "directed substitution" approach is currently applied to the *Personal Computers and Peripheral Equipment* (CPI item stratum EE01) index. There were a few reasons for selecting this stratum for this method:

First, BLS recognized that the quality of models that people buy in this item stratum index changes so fast that the computer sample became out of date quickly. This is despite the fact that BLS obtained a representative sample at the time of initiation. BLS was finding that at the end of a six to twelve month period, it had virtually no "high-end"

computers or the new budget computers; instead it had mostly items that were near the end of their product life. When the field substitutes to a new item because the outlet has discontinued selling it, our standard substitution procedures directed the field, in effect, to select the next most obsolete item in the outlet.

Second, as noted above, in January 1998 the CPI began using hedonic quality adjustments for computers. Hedonic quality adjustment makes it possible to compare the prices of older and newer models directly in index calculation. Put another way, once we have these regression-based quality adjustment values, we need replacements to take advantage of them. Traditional CPI procedures discourage replacements to minimize use of the linking method. The direct replacement procedure will assure that we get these replacements in a timely manner.

For this project, a new "modified tiered" checklist that has two tiers was designed and tested. In the first tier is a specification for "Computer configuration classifications"; the elements of this spec are "high end", "mainstream", "economy", "entry-level", and "other". Every six months (January/February and June/July) we send a directed replacement instruction for Personal Computers to the field stating what computer configurations are in what classifications. We expect that a given configuration will drop to a lower classification over time.

The directed replacement approach now used for personal computers will soon be extended to a broader range of products. The BLS recently received funding for an enhanced program of item sample updating in addition to the outlet and item sample rotation process that now occurs on a four-year cycle using probability proportionate to sales (PPS) sampling methods. Beginning in 2003, in many item categories, item samples will be reselected within sample outlets midway between the outlet sample rotations; that is, item samples in these categories will be replaced every two years. As part of this program of "within-outlet rotation," directed replacement will be employed instead of PPS re-sampling in certain item categories where hedonic models are available.

The CPI program has also discussed a more general modification of the instructions given to field economists for selecting substitute items. There are no changes currently planned in this area, however.

Alternative Data Sources for Hedonic Regressions

The hedonics projects described above, which is part of the CPI Improvement Initiative, use, for the most part, price and characteristics data collected directly by the CPI field staff. The advantage of using such data is that we can control what is collected and then combine the collected data with the regular CPI data used in the monthly index. The disadvantage is that the regression results are useful only for a limited period. Further changes in the items under study that occur after the special data collection cannot be modeled; this is especially true for new items with never-seen-before characteristics.

After a period of a few years, at most, we will need new data and new regression results if we are to continue to be able to quality adjust for future new goods.

The success of the PPI's computer hedonic model relies in large part on the use of secondary source data. This suggests that we should pursue efforts to build hedonic regression models on such data. As described above, we have purchased and employed point-of-sale data for audio products. This provides a useful comparison with the CPI hedonics for video products. Compared to the four main items in the video stratum, there are thirteen items in the audio stratum; consequently, it would require a great deal of special data collection to amass enough data to produce the hedonics for audio products.

Comparison of the results reported in this paper from the audio product hedonics to those of the video products, highlights the tradeoffs between specially collected data and secondary data. The audio product data provide observations by retail channel, (a channel is a category of outlet: department store, mass merchandiser, electronics store, etc.) for each manufacturer and model number. The data have the price (the unit value) and the number of units sold in each one-week period, but provide very limited information about the product attributes. This forces us to seek much of the information about the products from other sources, usually from the manufacturers internet sites. The vendor charges a fairly high price for this point-of-sale data, so it is more expensive than collecting BLS samples. On the other hand, the data come continuously with about a one-month lag; this would permit frequent reruns and re-specifications of the regressions. The BLS has now purchased point-of-sale data on video products, and we hope to be able to employ hedonic models estimated from these data in the CPI.

This leads to the general question, applicable to regressions using either primary or secondary data, of how often the hedonics must be updated. Ideally we would update them every month but a number of practical considerations will force a much more modest schedule. We should distinguish between simply rerunning the regressions with more current data and completely redoing the regression model, adding new variables and/or changing the functional form. If we have new data, simply re-running the regressions and getting more current estimates of the value for the old set of product characteristics may impart a specification bias on the model if the new product with previous generation models includes never-seen-before product characteristics and they are not accounted for in the new model. Completely redoing a hedonic model can be quite resource-intensive and so likely will have to be done less often. Of course, when *bona fide* new product characteristics appear is exactly when a CPI most needs hedonic quality adjustment values. So to make hedonic regression truly of value to CPIs and "hold the gain" in index quality once one has decided to use this technique for a particular CPI item, one must be ready to recalculate the regression models fairly regularly and fairly quickly.

Future Plans

The use of the hedonic regression technique continues to grow. It offers potentially significant gains in the accuracy of quality adjustment, particularly for consumer durable

goods. A major obstacle to its use has been a lack of data sets extensive and timely enough to support regression estimation of the necessary parameters. The increasing availability of electronic scanner data may help overcome this problem. Scanner data sets are large and if they can be acquired in a timely fashion they may enable agencies to estimate coefficients for product attributes soon after those attributes reach the market. Mick Silver and Saeed Heravi (2002) have written persuasively on this subject and have presented considerable evidence in support of the use of scanner data.

An important question is how to expand the use of hedonic modeling beyond the current focus on consumer durables. The recent report by a panel of the National Research Council, chaired by Charles Schultze, has argued that the CPI program proceed with caution in further model deployment. At the same time, the panel recommends a broad "audit" of quality adjustment issues throughout the CPI to avoid an overemphasis on high-tech areas. The BLS is sympathetic to this recommendation.

Outside of the goods categories of the CPI, formidable obstacles remain. Hedonic methods are likely to be much less successful for modeling the price-quality relationship in services than in consumer durables. For several services categories, including legal services and medical care, it is difficult even to describe the data that one might attempt to collect as a basis for timely quality adjustment. In the same way, comments on the rate of quality change in services like airline fares sometimes have been based more on fragmentary or anecdotal information (on safety, on-time records, courtesy, or comfort) than on the type of systematic analysis that has been applied to consumer durable products. This is a field in which much more research is needed. The BLS has recently funded hedonic analyses on airline fares by Robin Sickles and Jessie Weiher (2000) and on college tuition by Amy Schwartz and Benjamin Scafidi (2000).

A final, although fundamental and major, issue is the use of what the Schultze panel termed the "direct characteristics" method for using hedonic models in price indexes. The CPI employs hedonic coefficients only to improve quality adjustments in situations of product replacement. Hedonic models can, of course, be used to estimate price indexes directly. Many analysts have suggested that the direct approach could yield much greater impacts and benefits than have so far been achieved in the CPI. However, there are considerable operational obstacles to the direct characteristics approach—most crucially, the requirement that regressions be estimated and employed in "real time" rather than on a quarterly or annual basis. For discussions of the advantages of the direct characteristics approach see, for example, David Lebow and Jeremy Rudd (2001) and Ariel Pakes (2002).

Hedonic quality adjustments in the U.S. CPI since 1998

Hedonic quality adjustment of the prices for:	Description	Year implemented in U.S. CPI
Personal computers	Regression models used to adjust personal computer prices for changes in quality	1998
Televisions	Regression models used to adjust television prices for changes in quality	1999
Audio equipment	Regression models used to adjust audio equipment prices for changes in quality	2000
Other video equipment	Regression models used to adjust other video equipment prices for changes in quality: - video cameras - video cassette recorders - DVD players	2000 2000 2000
Refrigerators/freezers	Regression models used to adjust refrigerators/freezers for changes in quality	2000
Microwave ovens	Regression models used to adjust prices of microwave ovens for changes in quality	2000
Clothes washers	Regression models used to adjust prices of clothes washers for changes in quality	2000
Clothes dryers	Regression models used to adjust prices of clothes dryers for changes in quality	2000

References

Diewert, Erwin, 2001. "Hedonic Regressions: A Consumer Theory Approach," Forthcoming in <u>Scanner Data and Price Indexes</u>, Robert Feenstra and Matthew Shapiro, editors Forthcoming from The University of Chicago Press
http://www.nber.org/books/criw00/diewert11-13-01.pdf

Fixler, Dennis, Charles Fortuna, John Greenlees and Walter Lane, 1999. "The Use of Hedonic Regressions to Handle Quality Change: The Experience of the U.S. CPI," Washington, DC: Bureau of Labor Statistics, *Presented at the 5th meeting of the International Working Group on Price Indices*.
http://www4.statcan.ca/secure/english/ottawagroup/ottawa/bls.pdf

Greenlees, John S., "Consumer Price Indexes: Methods for Quality and Variety Change," *Statistical Journal of the United Nations ECE*, 17 (2000), pp. 59-74.
http://www.unece.org/stats/documents/ces/ac.49/1999/11.e.html

Holdway, Michael, "Quality-Adjusting Computer Prices in the Producer Price Index: An Overview," mimeo, Bureau of Labor Statistics, April 2000.
http://stats.bls.gov/ppi/ppicomqa.htm

Kokoski, Mary, Keith Waehrer, and Patricia Rozaklis, "Using Hedonic Methods for Quality Adjustment in the CPI: The Consumer Audio Products Component," mimeo, Bureau of Labor Statistics, April 2000.
http://stats.bls.gov/cpi/cpiaudio.htm

Lane, Walter, 2000 "Addressing the New Goods Problem in the Consumer Price Index," Washington, DC: Bureau of Labor Statistics, *Presented at the 6th meeting of the International Working Group on Price Indices*. June 2000.
http://www.abs.gov.au/websitedbs/D3110122.NSF/4ba1169b49f64724ca25694c0004f05c/78c90fc90ecd713fca256a1d0006d68a!OpenDocument

Lane, Walter F., William C. Randolph, and Stephen A. Berenson, 1988: "Adjusting the CPI shelter index to compensate for the effect of depreciation", Technical Note, *Monthly Labor Review,* October, 34-37.
http://www.bls.gov/opub/mlr/1988/10/rpt1full.pdf

Lebow, David E. and Jeremy B. Rudd, 2001. "Measurement Error in the Consumer Price Index: Where Do We Stand?" Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series; December 2001—61.
http://www.federalreserve.gov/pubs/feds/2001/200161/200161pap.pdf

Liegey, Paul, "Developing a Hedonic Regression Model for DVD Players in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000a.
http://stats.bls.gov/cpi/cpidvd.htm

Liegey, Paul, "Hedonic Quality Adjustment Methods for Microwave Ovens in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000b.
http://stats.bls.gov/cpi/cpimwo.htm

Liegey, Paul, "Hedonic Quality Adjustment Methods for Clothes Dryers in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000c.
http://stats.bls.gov/cpi/cpidryer.htm

Liegey, Paul, and Nicole Shepler, "Adjusting VCR Prices for Quality Change: A Study Using Hedonic Methods," *Monthly Labor Review*, September 1999, pp.22-37.
http://stats.bls.gov/opub/mlr/1999/09/art3full.pdf

Liegey, Paul R. Jr. 1994. "Apparel Prices Indexes: Effects of Hedonic Adjustment," *Monthly Labor Review*, May 1994 117 (5): pp.38-45.
http://stats.bls.gov/opub/mlr/1994/05/art6full.pdf

Moulton, Brent R. Timothy J. LaFleur, and Karin E. Moses, "Research on Improved Quality Adjustment in the CPI: The Case of Televisions," in Walter Lane, ed., *Proceedings of the Fourth Meeting of the International Working Group on Price Indices,* Bureau of Labor Statistics, Washington, DC, January 1999, pp. 77-99.
http://www.statcan.ca/secure/english/ottawagroup/pdf/18moul98.pdf

National Research Council, 2002. At What Price?: Conceptualizing and Measuring Cost-of-Living and Price Indexes " Committee on National Statistics, Division of Behavioral and Social Sciences and Education. National Academy Press, Charles L. Schultze and Christopher Mackie, Editors, Washington D.C.
http://www.nap.edu/books/0309074428/html/

Pakes. Ariel, 2002. "A Reconsideration of Hedonic Price Indices with an Application to PC's ,". The National Bureau of Economic Research, Inc.; Washington, DC: NBER Working Paper No.w8715.
http://papers.nber.org/papers/W8715

Randolph, William C., 1988: "Housing Depreciation and Age Bias in the Consumer Price Index," *Journal of Business and Economic Statistics,* July, 359-71.

Reinsdorf, Marshall B. Paul Liegey and Kenneth J. Stewart. 1996. ."New Ways of Handling Quality Change in the U.S. Consumer Price Index,". Washington, DC: Bureau of Labor Statistics Working Paper 276.

Schwartz, Amy E., and Benjamin P. Scafidi., 2000. "What's Happened to the Price of College? Quality Adjusted Price Indexes for Four-Year Colleges," Presented at the National Bureau of Economic Research, Inc Conference on "Higher Education Meeting," Cambridge, Massachusetts, November 10, 2000. Also presented at the Bureau of Labor Statistics Conference on "Issues in Measuring Price Changes and Consumption," Washington, DC June 5-8, 2000

http://www.nber.org/~confer/2000/highedf00/schwartz.pdf

Shepler, Nicole, "Developing a Hedonic Regression Model for Camcorders in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000a.
http://stats.bls.gov/cpi/cpicamco.htm

Shepler, Nicole, "Developing a Hedonic Regression Model for Refrigerators in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000b.
http://stats.bls.gov/cpi/cpirfr.htm

Shepler, Nicole, "Developing a Hedonic Regression Model for Washing Machines in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000b.

Sickles, Robin C. and Jesse C. Weiher, 2000. "Are Airline Fares Fair?: A Hedonic Price Index for Airline Travel," Presented at the Bureau of Labor Statistics Conference on "Issues in Measuring Price Changes and Consumption," Washington, DC June 5-8, 2000
http://www.owlnet.rice.edu/~jessew/bls13.pdf

Silver, Mick, and Saeed Heravi, 2002. "Why the CPI matched models method may fail Us: Results from an hedonic and matched experiment using scanner data," Presented at the Brookings Institute Productivity Workshop conference entitled, "Hedonic Price Indexes: Too Fast, Too Slow, or Just Right?, Washington, DC, February 1, 2002
http://www.brookings.edu/dybdocroot/es/research/projects/productivity/workshops/20020201_silver.pdf

Sinclair, James, and Brian Catron, "New price index for the computer industry," *Monthly Labor Review*, October 1990, pp. 16-24.
http://stats.bls.gov/opub/mlr/1990/10/art2full.pdf

Thompson, William, "Developing a Hedonic Regression Model for VCRs in the U.S. CPI," mimeo, Bureau of Labor Statistics, 2000.
http://stats.bls.gov/cpi/cpivcrp.htm