Research Spotlight

Hedonic Price Indexes for Digital Cameras

By Kari Manninen

ECONOMISTS generally agree that changes in the quality of products should be considered when price indexes are compiled. However, economists tend to disagree on which method or combination of methods can best account for quality changes, especially of rapidly changing, high-technology products.

Hedonic methods basically attempt to derive or to adjust price indexes with regression-driven methods that relate a product's price to its features. Applying hedonic approaches to digital cameras, for example, entails calculating price estimates based on the number of pixels, storage capacity, manufacturer, resolution options, size of camera and other quality characteristics. (See the box "What Does 'Hedonic' mean?")

Since hedonic approaches were introduced in the early 1960s, they have generated a large body of scholarly literature and, over the past decade, have become an accepted and even integral tool for U.S. statistical agencies.[1] The Bureau of Economic Analysis (BEA) uses hedonically adjusted price indexes to deflate 22 percent of the final expenditures captured by gross domestic product. The Bureau of Labor Statistics (BLS) uses hedonic adjustments for high-tech items and appliances, which account for about 1 percent of the Consumer Price index. BLS also uses hedonic adjustments to reduce the effects of aging in housing units and to make price comparisons among apparel items easier.

While other economists have explored hedonically adjusted price indexes for a host of high-technology products, such as computers and camcorders, this appears to be the first case study of digital cameras.

Specifically, six well-known techniques—conventional and hedonic—were used to calculate price indexes for digital cameras for 1998–2002. By comparing these methods, two main conclusions emerged:

- The quality adjustment techniques explored in the study, including three hedonic techniques and the conventional matched model-method, deliver similar results.
- Hedonic methods offer a practical and accurate tool for statistical agencies that aim to produce price

1. See Jack E. Triplett, *Handbook on Hedonic Indexes and Quality Adjustments in Price Indexes: Special Application to Information Technology Products* (Washington, DC: Brookings Institution, July 2004).

Kari Manninen, Senior Statistician at Statistics Finland, visited the Bureau of Economic Analysis in 2002–2003. *During his visit, he conducted a study of the quality adjustment of a price index for digital cameras. His working paper "The Effects of Quality Adjustment Methods on Price Indices for Digital Cameras" is available on BEA's Web site at <www.bea.gov/bea/working_papers.htm>. This research spotlight summarizes that working paper.*

What Does "Hedonic" Mean?

The term "hedonic" refers to a relation between the prices of different varieties of a product and their quality characteristics. The relation is typically estimated by regression analysis.

In the case of digital cameras, hedonic-based adjustments would require a function that estimates the prices of camera based on various "quality" measures:

Price=f(pixels, storage size, manufacturer, size, etc.)

Hedonic formulas can be used in several ways to create quality-adjusted price indexes. The most common method is a composite method that combines conventional price indexes, notably the matched model, with hedonic techniques that are used to fill gaps in price data coverage.

Some government indexes are calculated solely from hedonic functions. Examples include the Census Bureau's single-family house price index and BEA's multifamily house price indexes. The Federal Reserve Board's indexes for LAN routers and switches are calculated based on the coefficients of dummy variables.[1] The BLS CPIs for rent and owners' equivalent rent use hedonically derived coefficients to adjust price changes for the increased age of the units.

1. Brent R. Moulton, "The Expanding Role of Hedonic Methods in the Official Statistics of the United States (presented at the meeting of the BEA Advisory Committee, November 30, 2001); <www.bea.gov/bea/papers.htm.>

indexes for rapidly changing, high-technology goods. In some cases, hedonic measures may be preferable to other methods.

The rest of this article is divided into two sections. The first describes each of six digital camera price index calculations explored in the study and the results when calculating digital camera price indexes. The second section discusses the author's conclusions in more detail.

Quality Adjustment Methods

To develop an accurate quality-adjusted price index, the author first had to document the improvements that were taking place in the quality of digital cameras. The study could not account for every characteristic of digital cameras, only the basics, such as manufacturer, number of megapixels, amount of memory, scale of optical and magnification.[2] (For a more detailed look at how data for this study were developed, see the box "Source of Data.")

In 1998–2001, the average values of select quality measures generally rose. Over the same period, average digital camera prices without adjustments for quality held steady for about 3 years and then substantially dropped (chart 1).

To analyze the phenomena of flat or declining digital camera prices in concert with rising quality indexes, six methods were explored:

- Grand unit value method
- Class unit value method
- Matched-model method
- Time dummy pooled regression method
- Time dummy two-period regression method
- Full hedonic regression method

Of these six methods, the first method does not explicitly account for quality changes, the second and third are considered conventional methods of accounting for quality changes, and the last three are hedonic methods.

Grand unit value method

This method provides a basic price index calculation that is useful for comparisons with price indexes derived by other methods. The index is created by simply dividing the average (geometric) price of all products in the sample by the average price in the preceding period.

The only way that this method could account for quality would be if all the products in the sample offered an identical set of features. If the features were exactly the same for all the products in the sample, this method would be identical to the so-called matched model, which remains the most widely used method of accounting for quality (see also the section on matched models).

The price index calculated with the grand unit value method shows that the average price of digital cameras remained steady until roughly the middle of 2001 and then fell steadily (chart 2).

2. Ideally, statistically valuable explanatory "characteristics" for hedonic regression would offer great variability both over time and within each time period. Ideally, they would be correlated with the price but not closely with each other to avoid colinearity issues. The author collected data on the following: Megapixels, megabytes, movie feature, remote control, external flash, manual focus, optical zoom, digital zoom, USB connection, serial connection, battery charger, type of camera, various resolution options, ISO, manufacturer.

Chart 1. Price and Quality Indexes

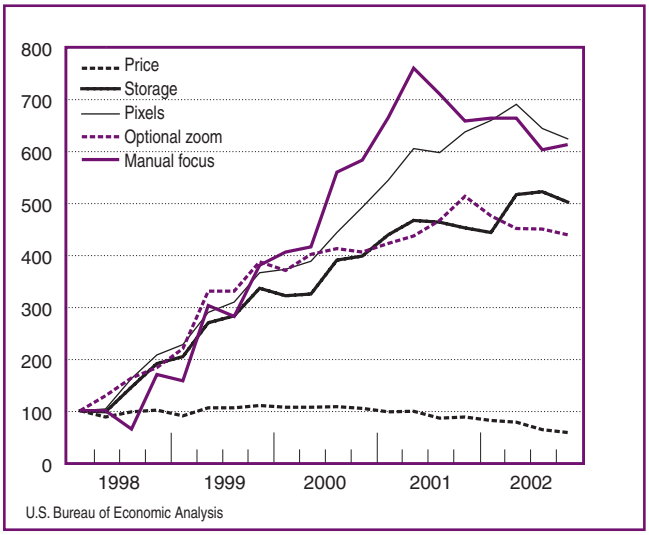
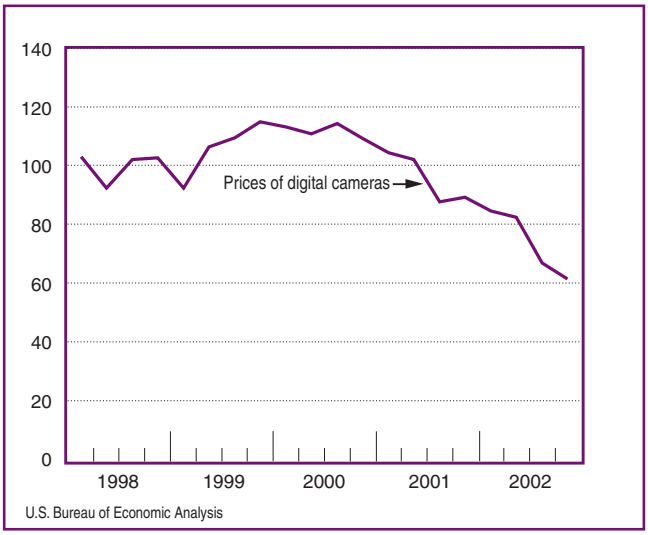


Chart 2. Grand Unit Value Index

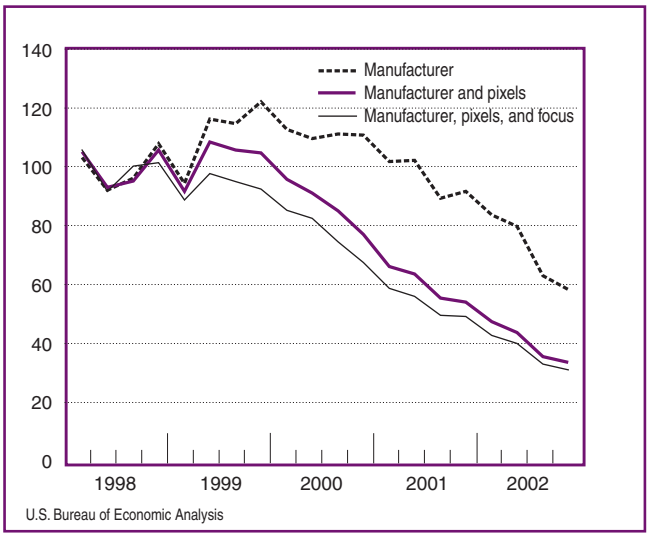


Class unit value method

This method accounts for quality differences by grouping cameras into separate classes based on their features and then by calculating separate price indexes for each class. Three classes were created: The first class was based on manufacturer; the second was based on manufacturer and the number of pixels; and the third was based on manufacturer, the number of pixels, and whether the camera had a manual focus feature.

All three price indexes showed declines. The price index for the first class declined more slowly than the other two, while the price index for the third class showed the least volatile changes (chart 3).

Chart 3. Class Unit Value Index



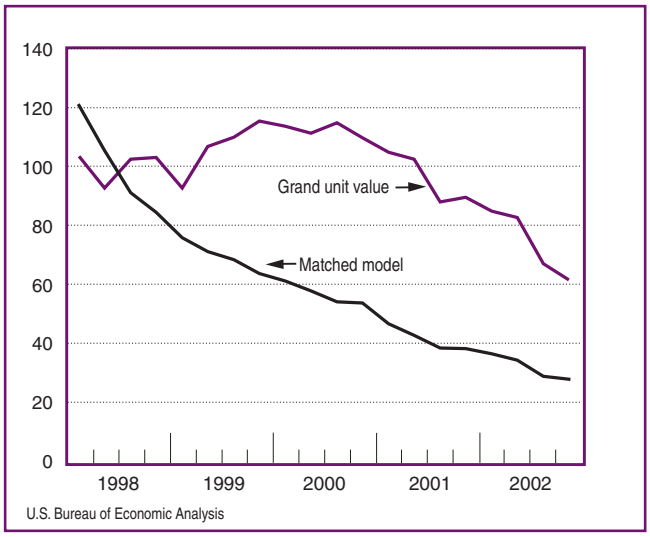
Matched-model method

This method, perhaps the most common method of accounting for quality, has long been used by various statistical agencies. The matched-model method controls for quality by evaluating prices of products that offer identical features. For digital cameras, this method requires creating a class of products with the same amount of memory, the same manufacturer, the same amount of pixels, and so on.

This method is difficult to use in practice, especially for products that have rapidly changing features, such as high-technology products.[3] The difficulty was evident in the data collected for the study. For nearly all of the 288 models in the data set, there were observations for at least two quarters, but there were only 167 models that had price observations for more than four quarters, and only 52 models had prices observations for more than six quarters.

For statisticians, high rates of products leaving or entering the sample raise questions about how well the sample reflects the population. Despite this limitation, a matched-model price index was calculated. It confirmed the downward trend of prices shown by the other indexes, but it declined more than the grand unit value index (chart 4).

Chart 4. Matched-Model and Grand Unit Value Indexes



Time dummy pooled hedonic regression method

Time dummy methods, which are explored in the next two sections, are among the most widely used hedonic methods. Typically, they require regressing a product's price on various measures of quality, often the natural logarithms of quantitative variables and some dummy variables.[4]

To explore time dummy methods, the author constructed price indexes for cameras based on four classes of quality measures. The four classes can be described as follows:

- Class 1 consists of manual focus (whether the camera offered this feature) and the number of megapixels.
- Class 2 consists of manual focus, the number of megapixels, and the number of megabytes.
- Class 3 consists of manual focus, the number of megapixels, and optical zoom (whether it was offered).

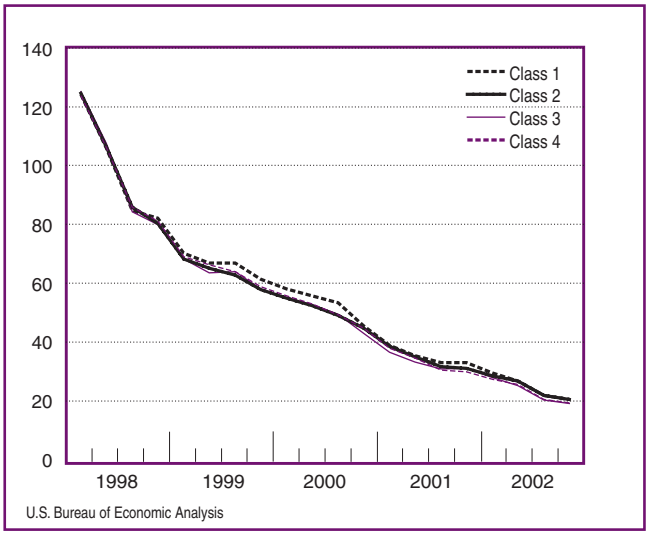
3. In practice, statistical agencies often use the matched-model method to calculate an index when a full set of data is available. Hedonic methods are used as a supplement to estimate prices when many values are missing because of new or retiring models.

4. Dummy variables typically are zero or one depending on the absence or presence of a specific feature.

- Class 4 consists of manual focus, the number of megapixels, and optical zoom, the number of megabytes and external flash (whether it was offered).

For the time dummy pooled regression method, prices were calculated based on changes in the quality indexes over 5 years. All four regressions show similar price trends (chart 5). They also show that adding more quality features as explanatory variables only modestly improved the fit of the model. In classes 2 and 4, including the number of megabytes as an explanatory variable resulted in slightly lower estimates in the last few quarters.

Chart 5. Pooled Regression Indexes



This method has several benefits. For one thing, the computation is relatively simple. For another thing, unmatched observations do not have to be discarded. In general, this method would likely be particularly useful when the coefficients of the quality measures are relatively stable.

However, over long periods, the linear nature of these regressions could present drawbacks. A long time series approach basically assumes that the effect of each variable remains constant over time—which may not be realistic. Sudden changes in coefficients may go unnoticed if a large number of periods were used.

In addition, the quality correction factor is the same for all observations at the magnitude given by the time indicator coefficient, something that may make this method unsuitable as a supplement to a matched-model index.

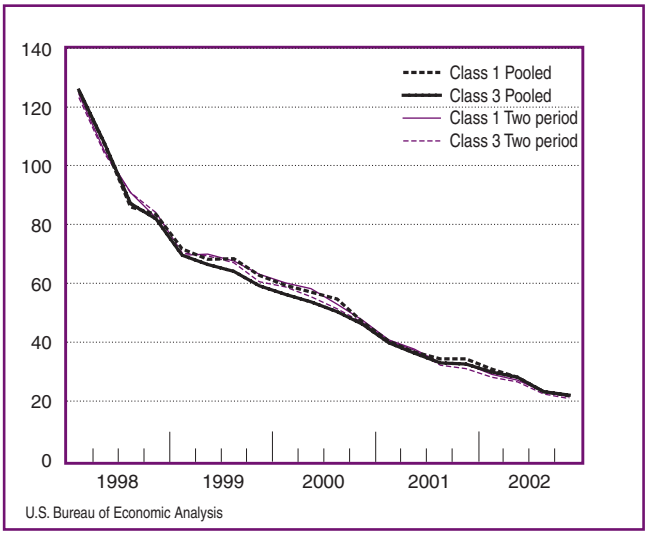
Time dummy two-period hedonic regression method

For this method, regressions are performed only for consecutive periods. The two-period results are then linked to form a price index. This approach requires much more computation. The author's data set included 20 periods, requiring 19 regressions (one for each set of consecutive periods) instead of just 1.

The benefit of this method is that it allows for more flexibility; the coefficients of each quality indicator can vary over time, which may be more realistic than assuming that they remain constant.

The author applied this approach to classes 1 and 3 from the previous section. A comparison of the classes calculated in the previous section and this section shows again that the differences are small (chart 6).

Chart 6. Pooled and Two-Period Regression Indexes



Full hedonic method

Another way to capture quality changes would be to use hedonic measures to help create a full set of price data that can be used to create standard price indexes. For classes 1 and 3, the author performed separate regressions for each of the 20 quarters. Based on those regressions, estimates for all missing price observations were calculated and added to the data set. This complete set of data was then used to derive price indexes for consecutive periods using Laspeyres, Paasche,

Fisher, and Törnqvist index formulas.[5]

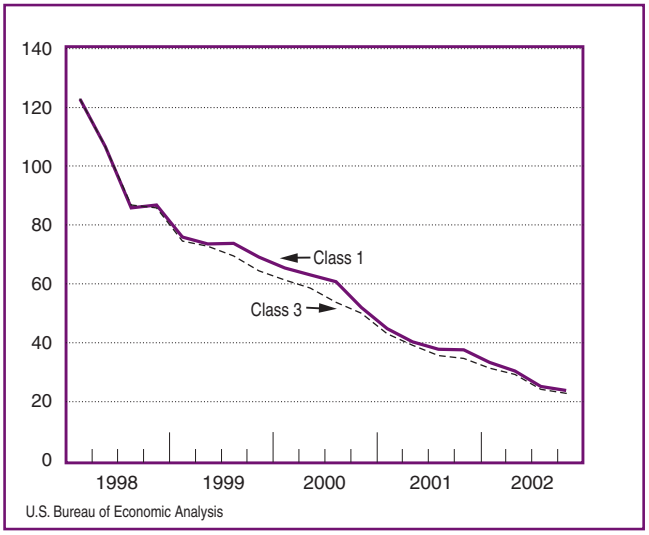
The Törnqvist results show that the differences in the quality-adjusted price indexes are minor (chart 7). Moreover, the quality correction factors between the two models differed at most by about 8 percent.[6]

In addition, when the matched-model index (chart 4) is compared with the hedonically derived class 1 and 3 indexes, the differences are small. However, some of the hedonic indexes declined slightly faster.

5. The Törnqvist index formulas is calculated as a geometric mean with average expenditure shares as weights, and it behaves very similarly to the Fisher index formula used by BEA.

6. Total quality correction factors are defined as the difference between quality adjusted index and the grand unit value index.

Chart 7. Full Hedonic Indexes

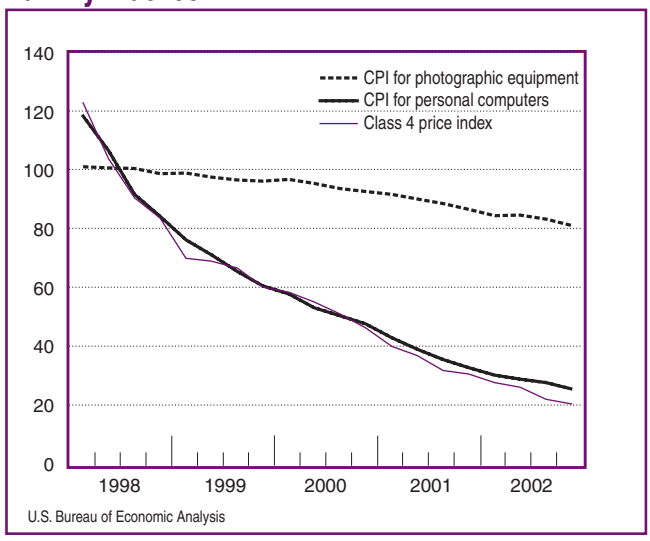


Comparisons with BLS indexes

The results of the two-period index for class 4 (rescaled to 1998=100) was compared with the BLS index for personal computers and photographic equipment. The author chose the computer index mainly because it incorporates hedonic methods, though not the methods investigated in this article. The photographic equipment index was chosen because it was generally comparable with the digital camera indexes constructed in the study.

Neither BLS index corresponds perfectly to the digital camera price indexes, but the results were similar. The personal computer price index and the class 4 index tracked especially closely (chart 8).

Chart 8. BLS CPIs and Two-Period Regression Dummy Indexes



Conclusions

All five broad quality-adjustment methods provided similar results: All five did a reasonably good job of accounting for changes in quality. Specifically, the price estimates delivered by regression models with only a few quality variables were not meaningfully improved when additional variables were added.

For statistical agencies, these conclusions have practical implications. For one thing, relatively simple hedonic methods may be sufficient to accurately control for the quality of products, even high-tech products with rapidly changing features, and additional, large-scale data collection may not be necessary for sound hedonic adjustment. As Pakes noted, the matched-model approach requires much of the same data about quality characteristics as simple regression models.[7] In practice, agencies relying on the matched-model method will likely have already collected a sufficient amount of data on characteristics. These data could be used for simple regression models similar to ones used by the author. Statistical agencies thus could soundly adjust for quality without significantly raising sampling requirements and costs.

The study also suggests that simple hedonic measures can be used to supplement the conventional matched model. Even when constructing indexes for high-technology goods, which tend to change rapidly, hedonic techniques can be used to determine reasonable prices estimates that can be used to complete data sets, providing a way to overcome missing observations.

7. Ariel, Pakes, "A Reconsideration of Hedonic Price Indexes with an Application to PC's," *American Economic Review* (December 2003): 1578–1596.

Source of Data

To test different quality adjustment methods, the author compiled a quarterly digital camera database that included roughly 1,200 prices from over 250 different digital camera models for 1998–2002.

The price data were gleaned from various sources. Before the third quarter of 2002, all prices quoted for the models advertised in the *Journal of Popular Photography* were recorded. For some advertised models, no price was available, as readers were told to call for the price. Prices for the third quarter and fourth quarter of 2002 were gathered from <www.pricescan.com>.

Gathering prices from <www.pricescan.com> may have introduced a downward bias into the data. The prices reported are usually the "best price" advertised by several online retailers and do not include shipping charges.

The quality characteristics were compiled from <www.dpreviw.com>. Most of the makes and models were included in the sample; models were included when they were first advertised. Overall, no attempt was made to track a fixed sample of models.