Quality Adjustment in Price Indices: Methods for Imputing Price and Quality Change

Paul A. Armknecht and Brent R. Moulton*

October, 1995

ABSTRACT

In many countries the issue of quality change in price indices is ignored. In others, the primary method of quality adjustment is linking (splicing) of one price observation with another to show no price change between observations. In this manner, the difference between the two observations is assumed to be the value of the quality difference. To the extent that some of the difference in price between observations is actual price change, linking will result in a downward drift in the price index. This paper discusses several methods of quality adjustment and offers alternative imputation solutions that are useful when linking is the tool of choice for making quality adjustments.

* Paul A. Armknecht is a consultant to the International Monetary Fund (IMF) and Brent Moulton is Chief of the Division of Price Index Number Research at the U.S. Bureau of Labor Statistics (BLS). The views expressed in this paper are the opinions of the authors and do not necessarily reflect those of the IMF or BLS.

Introduction

Quality change is one of the most difficult problems facing price index practitioners. The goal in producing price indices such as consumer and producer price indices is to measure pure price change and exclude changes due to improvements or deterioration in the quality of products. This measurement objective is difficult to achieve. Even in countries with more advanced measurement systems, adjustments for changes in quality are viewed by most users as a significant problem. Recent testimony before the U.S. Senate Finance Committee by a number of noted and respected economists provides evidence of the degree to which the problem has grown. Although there has never been a direct measurement of the precise amount of the quality effects on the CPI, some economists have suggested that the annual effects are between 1.0 percent and 1.7 percent.[1] In a period when the CPI is increasing at an annual rate of about 3 percent, effects of this order of magnitude are substantial.

This problem is not limited to the United States. Our colleagues in the United Kingdom, Australia and Canada tell us that criticism of the U.S. CPI soon ripple to criticism of their inflation measures which face similar problems in compilation. But these problems extend worldwide, not just in the industrialized countries. With the rapid globalization in the worldwide economy and ease with which technology and products are exported, the problem of quality change being counted as price change is a problem for measures of inflation in all countries. In fact, the problem is worse outside the sphere of the industrial economies. At least the industrial nations attempt to identify certain types of quality change and make adjustments for it in their inflation measures. This is not the case in the developing countries and the transitional economies of the world. Based on the experience from practitioners who have attended the BLS international training on price statistics, adjustments for quality changes in price measures are rarely, if ever, made. In fact, given the basic issues involved in developing price index measures, most of these countries have not given much thought to this problem.

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[1]In testimony prepared for the Senate Finance Committee Hearings Alan Greenspan, Chairman of the Federal Reserve Board suggested that the effect was 1.0 percent and Robert Gordon estimated the effect to be 1.7 percent. Other noted economists--Erwin Diewert, Dale Jorgenson, Michael Boskin to name a few--provided estimates between these two figures. See United States Senate, Committee on Finance (1995).

This raises the question of whether there are some basic, simple techniques that can be used by price practitioners to address the problem of adjusting for quality change in their price measurement programs.

When are Quality Adjustments Necessary

The need for quality adjustments in price index computation generally occurs when a priced variety is permanently missing. If a variety of an item is not available at the time of current price collection, the collector should determine whether this is a temporary or permanent condition. The previously selected variety is temporarily missing if it is not available due to seasonal shortages, low inventory or some other similar reason. The key point is that the shop expects to continue selling the variety when this temporary supply shortage is over. The variety is permanently unavailable when the shop has discontinued carrying the commodity or if it is no longer being produced. In this case, a product or service as similar as possible to the previous variety should be selected as a replacement.

When the replacement variety has been selected a decision must be made as to whether the new and old variety are of comparable quality. This decision can be made based on product or service characteristics between the varieties. Do they appear to be the same or does one have some feature that makes is better or worse than the other? If there is no distinguishable difference between the two, then they are comparable and the new variety's price can be used directly in the index with no further adjustment. To the extent that varieties can be chosen which are strictly comparable to the old variety, the substitution will not result in any special procedures for calculating the index.

If the replacement variety is not comparable, then some adjustment for quality will have to be made. An estimate is needed for the value of the quality difference.

Techniques Used for Making Quality Adjustments

Techniques for quality adjustment in price indices have been discussed recently in the economic literature (Turvey, et al., 1989; Armknecht and Weyback, 1989; Kokoski, 1993; Liegey, 1994; Reinsdorf, Liegey and Stewart, 1995). In general the techniques available fall into two classes--direct adjustment and imputation.

Direct Adjustment

Direct adjustment involves assigning a monetary value to the quality difference and then adjusting the price of the observation for the quality differential. Such adjustments, in practice, are handled in three ways. First is to have the data collector who is observing the products determine the value either through direct knowledge or in consultation with personnel in the outlet where the product or service is sold. Alternatively, analysts who are knowledgeable about the product could assign a value or, in the case of an improvement to an existing product, could contact the producer directly to obtain an estimate of the difference in production cost and normal mark up. With this information an estimate of the quality change can be made. The third way in which the value of the quality difference can be obtained is to estimate the value of the change in a product characteristic using hedonic regression models.

Each of these methods has its limitations. Reliance on individual's knowledge concerning the products is open to subjectivity. Estimates by producers of their marginal costs for changes provides better data but is often hard to come by because producers or unwillingly to provide such information since it takes considerable time to evaluate and often it is considered to be proprietary and highly confidential. Hedonic methods require large data bases with a wide range of product characteristics. Such data bases are just not readily available and require substantial design and maintenance costs. In addition, experience has shown that such models need to be re-estimated periodically.[2]

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[2]See Liegey (1994) for the U.S. experience with apparel commodities and Kokoski (1993) for other products.

Imputations

The other class of techniques for making quality adjustments is by imputation. In making imputations, the effects of quality change are estimated using observed price information when the price index is compiled. The imputations are made so that price changes are estimated only for comparable varieties of products. The assumption is that the two varieties differ in quality characteristics which is reflected in their prices, and we don't want to allow this price difference to enter the index. The actual adjustments that are made depend on the index formula that is used.[3]

One of the preferred imputation methods is referred to as overlap pricing. In this instance, the old and the new varieties are available and their prices are observed in the market place at the same time period. This period is known as the overlap period. The price change for the old variety is used in the price index in the overlap period and the price change for the new variety is used in the next period. The price differential between the two varieties never affects the index. This difference is the value of the quality adjustment that has been made and it is measured by the difference in the market prices. In this case, the market has determined the value of the quality adjustment.[4] This method is employed infrequently because the old and new varieties are not often available in the same time period.[5]

A more frequently used method is called "linking" or "splicing". With this method price change using current price information from other sample observations is employed to

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[3]Most countries use some form of a Laspeyres price index. If price movements are estimated using long-term relatives, then the base price is adjusted proportionately for the estimated quality difference. If price movements are estimated using short-term relatives, then the adjustment would be implicit by using the price change of the old variety this month and the new variety next month. Some examples of adjustments that are used with long-term relatives are presented in more detail in the next section.

[4]The market price of new features can also be used for making direct quality adjustments. For example, when radial tires became a standard feature on new automobiles the price of adding the optional radial tires was used as the value of the quality adjustment.

[5]Another important factor is whether the old variety is only available at closeout prices. This occurs when only a few are available and the shops in which they are sold have deep discount prices in an effort to sell quickly the remaining supply of the old variety. A careful evaluation must be made as to whether such discount prices adequately reflect the quality difference.

estimate the value of the quality adjustment. When a substitute variety is introduced to replace the old variety and there is a gap in the time between the observed prices (i.e., no overlapping price observations are available), the price of the old variety should be estimated for the current period to create an overlap price. This estimated price is obtained by using the price change of similar items for the current period to impute a price change for the old variety. The price difference between the imputed price for the old variety and the price of the new variety in the current period is the estimated quality difference that is to be excluded from the price index.

This procedure is used frequently because of its simplicity. Quality adjustments can be easily made with information obtained from the collection of current data and using fairly simple estimation techniques. The problem with this approach is that there may be an inherent bias built into the methodology. The bias is that the imputation for current price change using data for similar items may be incorrect. As discussed by Armknecht, Moulton and Stewart (1994) and by Reinsdorf, Leigey and Stewart (1995), major price changes frequently occur at the time new varieties or models of a product are introduced. In the U.S. this is quite common with new vehicles, electronic equipment and apparel commodities--to name a few. As the new varieties are introduced, a substantial supply of similar products are still available which show little price change or, in fact, may actually be declining in price. The use of the price change for these products to impute price change for new models would cause a downward bias in the price index due to an underestimation of the true price change for the new varieties.

An alternative methodology would be to use a better imputation procedure based on price changes for comparable new models. An imputation procedure recommended in the last cited papers uses only the price change in new varieties that are of comparable quality to estimate the price change for old varieties that are being replaced.[6] This is referred to as "class mean" imputation in which a substrata with different price change attributes has been identified within an existing strata. The standard procedure--"overall mean" imputation--in which all observations in the strata are used, is not applicable for all cases. This additional

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[6]Varieties of comparable quality are those items whose substitutes have been declared comparable after review by knowledgeable analysts or have already been quality adjusted through one of "direct" methods.

imputation procedure adds more complexity, but reduces two types of bias: (1) bias from ignoring quality change altogether and including all price movements as price change and (2) bias from over adjusting for quality change by including some pure price change as quality change.[7]

A cautionary note is presented here as a reminder. No matter how trivial we assume the effects of quality change may be or how sophisticated the models and procedures we derive to deal with it, adjustment for quality change is still an art for price index practitioners. Ignoring quality changes, which most users of price indices assume is the case, can result in substantial overstatement of price change as price increases due to quality improvements are included in our price indices. If one tries to correct for this problem through extensive use of linking observations when substitute varieties are introduced (which most users are not aware of), an over adjustment can occur with some pure price change being counted as quality change and excluded from the price indices.

The approach articulated and presented here provides a middle ground that has practicality for many countries. The following section provides some examples of how this procedure can be applied.

Examples of Quality Adjustments Using Imputation Procedures

Three examples are presented below. The first uses the overlap price imputation procedure, the second uses a linking procedure with overall mean imputation, while the third demonstrates the linking procedure with class mean imputation.

1. Overlap Price Imputation

As previously discussed, information for making direct quality adjustments is often not available. More realistically, the price information for the two varieties will have to be used to estimate the quality difference. If the old and new variety were available at the same time

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[7]The case of apparel commodities usually requires additional procedures to control substitutions depending on the season of the year, e.g., fall/winter versus spring/summer clothing. See Liegey (1993) for a description of the special procedures used in the U.S. CPI.

(overlap pricing), then the price difference between the two can be used as an estimate of the quality difference.

Consider the case where a Laspeyres formula is being used, i.e., if the following estimator is used at the elementary aggregate level:

(1) $$I_t = \Sigma\, s_{i,o}\, (P_{i,t}/P_{i,o})$$

where I_t is the current elementary index, $s_{i,o}$ is the expenditure share of variety i within the item stratum during the base period, $P_{i,t}$ is the current price of variety i, and $P_{i,o}$ is the price of variety i in the base period. (If there are no expenditure weights within the stratum then $s_{i,o}$ might be replaced with 1/n, where n is the number of price observations.) The Laspeyres formula can also be used in the following form:

(2) $$I_t = I_{t-1} * [\Sigma\, s_{i,o}\, (P_{i,t}/P_{i,o})] / [\Sigma\, s_{i,o}\, (P_{i,t-1}/P_{i,o})]$$

There is some disagreement about whether an adjustment needs to be made to the base price so that it reflects the same level of quality as the new variety. The United States and some other countries make this adjustment, which can be made simply by computing a price ratio of the new variety's price to the old variety's price. This ratio is then multiplied by the old variety's base price to provide an estimate of what the new variety's price would have been in the base period. The new base price and the new variety's price for the current period are used to calculate the index. The following example illustrates this procedure.

Variety	Base Price	Month 1	Month 2	Month 2 Relative
Prod 1	100	150	160	1.600
Prod 2	200	225	250	1.250
Prod 3	100	140	-	
Sub 1	(*114.29*)	160	180	1.575
Index	100	134.2		147.5

Within an item index we have selected three varieties of products. When the data collector visits the shop in Month 2 to collect prices, Prod 3 is permanently unavailable. The shop manager and the data collector determine that Sub 1 with a price of 180 is the most similar product to Prod 3. Review of the differences between the products indicates that Sub 1

has a couple of added features and is not comparable in quality to Prod 3. The shop manager was able to determine that Sub 1 was available during the last price collection period and its price was 160. Sub 1 can be used in the index this month once its base price is estimated. The price ratio when the two items were sold in the store last month is computed as 160/140 and this ratio is multiplied by the base price for Prod 3 of 100 to estimate a base price for Sub 1 of 114.29. The price of Sub 1 is now used to calculate the index this month with its estimated base price. In this example we assumed the quotes are equally weighted in calculating the index.

There is an alternative point of view on treatment of the base prices and weights. When the base price is changed, but the weights, which represent base period expenditures, are held fixed, then implicitly one is reducing the quantities in the Laspeyres fixed "market basket". The alternative approach would hold base period quantities fixed by adjusting the base period expenditure weight upward by the same proportion as the adjustment in base period prices. This is done most easily using formula (2), which allows the weights to be adjusted from one time period to another and does not require that they sum to 1. (Another, mathematically equivalent way to accomplish this approach is to use (2), but set the base period price of the substitute version to the same value as the previous version.) The following shows the same example using the alternative approach.

Variety	Weight	Base Price	Month 1	Month 2
Prod 1	.3333	100	150	160
Prod 2	.3333	200	225	250
Prod 3	.3333	100	140	-
Sub 1	(.3810)	(*114.29*)	160	180
Index		100	134.2	147.7

2. Overall Mean Imputation

Frequently, the price of the substitute variety will not be known for the previous pricing period. An estimate of the base price of the substitute still must be made. The following example will illustrate how to make the quality adjustment to the base price.

Variety	Base Price	Month 1	Month 2	Month 2 Relative
Prod 1	100	150	160	1.600
Prod 2	200	225	250	1.250
Prod 3	100	140	(152)	
Sub 1	(*118.42*)	-	180	1.520
Index	100	134.2		145.7

To get the required price ratio one can estimate (impute) the price of the discontinued variety by multiplying the price of Prod 3 in the previous period by the average price change of the other varieties available this month. Using formula (2) for Prod 1 and Prod 2, we calculate a price change between Month 1 and Month 2 of 1.086. This is multiplied by the price of Prod 3 in the previous period (140) to get an estimated price in Month 2 of 152. This estimated price is used to calculate the price ratio between Sub 1 and Prod 3 (180/152) and then multiplied by the base price of Prod 3 to provide an estimated base price of 118.42. The current price and the estimated base price can be used to calculate the index for the Month 2.[8]

3. Class Mean Imputation

The last example assumed that there was no difference in pricing strategy among the product varieties within the stratum. Assume that Prod 1 represents a variety that was available in both periods and that Prod 2 represents a new model in month 2 that was deemed comparable in quality to the previous model priced in month 1. Since Sub 1 is not comparable in quality to Prod 3, we could impute its price change by using only the observed experience from Prod 2. In such a case the price relative would be 1.111, the imputed price would be 155.56 and the new base price would be 115.71.

[8]The estimated price of Prod 3 could also be used for the month 2 index. The base price still must be estimated for Sub 1, however, because it will be needed for next month's index calculation, unless the alternative approach of not resetting base prices is adopted, as described in the previous section.

Variety	Base Price	Month 1	Month 2	Month 2 Relative
Prod 1	100	150	160	1.600
Prod 2	200	225	250	1.250
Prod 3	100	140	(155.56)	
Sub 1	(*115.71*)	-	180	1.556
Index	100	134.2		146.9

For both the class mean and overall mean imputation an alternative approach would multiply the base-period expenditure weight by the same multiple as the base price and subsequently apply formula (2), thereby implicitly holding base-period quantities fixed, as was shown earlier in the example of the overlap price. The alternative method would not affect the index in Month 2, but would affect index calculations during subsequent periods. Countries that calculate elementary aggregate indexes using a ratio-of-averages formula would perform the overall mean or class mean imputation using the ratio-of-averages formula.

The results in these three examples are different because the information that is available is different. In the first example an actual observation of the prices for each variety during the same time period was available. In the second example there were no overlapping observations so one was estimated using all the information that was available. In the third example we partitioned the sample into substrata and used only the information that was most relevant to the case at hand to estimate the overlap price.

The following table summarizes what effect each of these procedures would have on the strata price index.[9] In month 1 the price index stays the same. In month 2 the strata index changes due to the type of imputation used.

[9]The methodology used is to compute a Laspeyres index for each observation and compute the strata index as the simple average of the Laspeyres indices. If expenditure weights were available, a weighted average would be computed.

Table 1. Effect of Quality Adjustment Imputation on Price Change

	Month 1	Month 2	% Change
No Quality Adj.	134.2	155.0	15.5
Overlap Price	134.2	147.5	9.9
Overall Mean	134.2	145.7	8.6
Class Mean	134.2	146.9	9.5

The first line of table 1 shows that if no quality adjustment were made in the above example the price change would be 15.5%. Using different sources of information, adjustments have been made that result in reductions of about 6 percentage points for quality change. In this example the overall mean imputation procedure and the class mean procedure yield different results because of the different assumptions about the best estimator for underlying price trends within the strata.[10]

Summary and Recommendations

A variety of methods are available for practitioners to use in making adjustments for quality change when compiling price indices. Methods for making direct adjustments require substantial knowledge of product differences by data collectors or analysts, or substantial efforts at gathering additional information to make statistical estimates of the effects of quality change. Alternative methods using imputation procedures are also available to practitioners that don't require as much additional data as direct methods. However, practitioners must be selective and use the most appropriate imputation procedures based on pricing practices prevalent within the detailed strata of commodities and services. Much more can be done in countries to estimate the separate effects of quality change and pure price change, and exclude quality change from price indices.

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[10]If average prices for the observations in the strata were used and compared to average base prices (a Dutot index), the general observation about the effects would be the same but the specific results would differ. The overall percent change with no quality adjustment would be 14.5%, overlap pricing would result in a change of 10.6%, overall mean imputation would show a change of 9.5%, and class mean imputation would show a change of 10.2%.

One area for future research is to document how large an effect efforts at quality adjustment have each year on price indices. Armknecht and Weyback (1989) provided an estimate for 1984 in the U.S. consumer price index (CPI) of 1.2 percent for a period when measured inflation was about 3.5 percent. Thus, if no adjustments had been made for quality change, the CPI would have shown a rise of almost 5 percent. These data also indicated that most of the quality adjustments were being made in the apparel and new vehicle components. Such estimates are useful in two respects: they demonstrate how much quality change has been allowed for in price index compilation, and they show which major components have been affected. It would be quite interesting to get more recent results for the U.S. and be able to compare them with those in other countries.

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