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Consumer Price Indexes: Methods for Quality and Variety Change

Invited paper submitted by the Bureau of Labor Statistics of United States*

Summary

This paper describes the major methods used by statistical agencies to adjust for differences in the quality of a good or service when one item replaces another in a sample used to construct a Consumer Price Index. The methods are categorized as either direct, including the production-cost and hedonic approaches, or indirect, such as linking or class-mean imputation. The paper also presents simplified example calculations showing how the methods are applied in practice.

I. Introduction

1. A Consumer Price Index (CPI) is usually constructed by selecting a sample of goods and services and then recording the prices of those items on a regular basis. On occasion, it becomes necessary to replace one sample

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2. item by another, either because the first item disappears or as a result of deliberate action by the statistical agency. In order to compare the prices of the old and new item, a decision must be made as to the relative consumer valuations of the items. This decision is commonly referred to as quality adjustment, and this paper describes the major quality adjustment methods used by statistical agencies.[1]

3. By any measure, quality adjustment is critically important to the accuracy of a CPI. First, the treatment of replacement items and the decomposition of observed price differences into quality and "pure price" components is likely to have a large impact on the rate of growth of the index. This has been demonstrated for the U.S. CPI in papers by Armknecht and Weyback (1989) and Moulton and Moses (1997). Although price observations involving replacement items accounted for less than four percent of all price observations studied,[2] they accounted for the great majority of aggregate annual index change. The authors also demonstrate that if all quality differences between old and replacement items were ignored and the prices directly compared, CPI growth rates would be markedly different.

4. As a second indication of the importance of quality adjustment, it is commonly cited as the leading contribution to bias in the CPI relative to a cost-of-living index. The most widely-cited bias estimates are those by the Advisory Commission to Study the Consumer Price Index (the "Boskin Commission"), again in the context of the U.S. CPI.[3] According to the Commission, out of a total 1.1 percentage point estimated upward bias, 0.6 percentage point was due to the inadequate handling of new products and quality change in existing products.[4]

5. Quality adjustment is also important because it is so difficult. Practitioners and outside experts agree that the process imposes severe information requirements, both on product characteristics and on consumer valuations of those attributes. Moreover, there are few common solutions to the problems that arise. As Shapiro and Wilcox (1996) have famously and accurately commented, "Quality change is the house-to-house combat of price measurement." Nordhaus (1998) has convincingly summarized the reasons why quality adjustment warrants further research:

> "Quality change poses severe problems for a statistical agency. It is non-mechanical in the sense that there is no way to determine quality change on a routine basis. It is heterogeneous in the sense that each quality change is *sui generis* and, like a child, requires individual attention. It is informationally demanding because it may require vast quantities of data that are expensive to obtain and often do not pass the test of a market transaction. Even though routine procedures are established to handle quality change, in the end quality decisions require the subjective judgment about the extent of quality change, and agencies are reluctant to make subjective judgments."

6. Quality adjustment could, in principle, be undertaken in a variety of situations, such as when samples are rotated. In practice, however, statistical agencies make quality judgments primarily in cases of item replacement (sometimes called item substitution). Agency procedures guide the decision of when to replace a sample item, and how to select the replacement item. Ordinarily, the replacement will be necessary because the item priced in period t is no longer available in the sales outlet in period t+1.

7. In turn, the replacement makes it necessary to decide whether the new item can be treated as equivalent, or essentially similar, to the old item, and their prices compared as though no substitution had taken place. This decision is what we typically refer to as a quality judgment. If the prices are directly compared, the items must have been determined to be of comparable quality to the consumer. If not, then some implicit or explicit adjustment has been made for differences in quality between the new and old item.

8. Discussions of "quality" in price indexes often place the term within quotation marks, and few authors have attempted to provide a rigorous definition of quality. A notable exception is Triplett (1971), who presents three concepts of "quality" and argues that the third concept is most relevant for economic measurement:

> "'Quality' is associated with a ranking of products (or services) according to grade, desirability, usefulness, or degree of excellence."

9. This definition goes beyond the simple differentiation of products according to their characteristics or attributes, to focus on the ranking of those characteristic bundles. In the context of consumer price measurement, the relevant ranking is that implied by consumer preferences. Differences in product attributes that are irrelevant to the consumer are correspondingly irrelevant to construction of a CPI.

10. Finally, before proceeding it should be noted that, just as "quality" is a term that is difficult to define, there has also been confusion or disagreement about what constitutes "quality adjustment." Among practitioners, a distinction commonly is made between "explicit" or "direct" quality adjustments, on the one hand, and "implicit" or "indirect" quality adjustments that rely only on market prices to infer relative consumer valuations of items.[5] This is the usage that will be followed in this paper. Some authors, however, are reluctant to apply the term "quality adjustment" to the implicit methods.[6] Also, a distinction is sometimes drawn between adjustments for true "quality" and adjustments for quantity or other product attributes.[7]

II. Direct Estimation

11. This section describes the several approaches to the direct estimation of quality differentials between the items priced in periods t and t-1. Pure price change is then implicitly estimated as the remaining difference in price.

Comparable substitution

12. The simplest case is that in which the two items are determined to be of equivalent value to the consumer; that is, the best estimate of quality difference is zero. No quality adjustment is made, and the prices of the two items are directly compared in index calculation. In the United States, this case is referred to as a "comparable substitution." Hoven (1999) describes this as a special case of "subjective quality adjustment," because the determination of product equivalence is based on the judgment of the commodity specialist.

Transformation to quantities

13. In some situations, there is a readily available quantity metric that can be used to compare the items. Examples might be the number of units in a package (e.g., paper plates or vitamin pills), or the size or weight of a container (e.g., liters of soda or milligrams in a candy bar). Quality adjustment can be accomplished by scaling the price of the old or new item by the ratio of quantities.[8]

14. The index production system, in fact, may do this scaling adjustment automatically, by converting all prices in the category to a price per unit of size, weight, or number. The issue then becomes one of identifying and dealing with situations where such scaling is inappropriate. For example, it may be reasonable to decide that a bottle of aspirin containing 500 tablets may not have 10 times the quality of a 50-tablet bottle.

Option cost

15. Other situations may arise in which the old and new items differ in quantifiable characteristics that can be valued in monetary terms by reference to market prices. An example is the addition of a feature to an automobile model. The feature may have been available as an option either in the prior period or currently for other models, providing an absolute or proportional consumer valuation. For example, Armknecht and Maitland-Smith (1999) note that when radial tires became a standard feature on new automobiles the price of adding optional radial tires was used to determine the quality adjustments in the U.S. CPI. Similar opportunities to utilize option prices may present themselves most often in the case of other consumer durables.

16. In other cases, the valuation of a quantifiable product feature may be readily available from the comparison of different product prices. Turvey (1989) gives the example of whiskeys of different percentage alcohol content. The quality adjustment for a change in the alcohol content of one product may be inferable from the market relationship between proof and price. This approach can be viewed as a single-dimensional application of the hedonic method, which is described below.

Production cost

17. When the replacement item has additional features related to improved quality, it may be possible to obtain information from producers on the resource cost of those features. Although the objective in the CPI is to adjust for the consumer valuation of quality differences, the most effective way of estimating that valuation will sometimes be to begin with the difference in production cost.[9] The cost estimate must then be "marked up" to retail value, and associated indirect taxes added.

18. This approach will be most practicable in markets with a relatively small numbers of producers and in which new models are introduced at relatively predictable points in time. These conditions will facilitate the necessary communication between the producers and statistical agency staff. This approach will always be subject to the criticism that the producers may have the incentive and opportunity to exaggerate the resource costs of any particular product improvement. Consequently, the agency analysts must take care to verify, as much as possible, the information that they are provided.[10]

19. The new vehicle component of the U.S. CPI presents an example of the producer cost approach.[11] Just prior to the annual model year introductions, BLS staff visit selected manufacturers to collect cost information. The data are used in the Producer Price Index (PPI) and International Price Index programs as well as in the CPI, and the information gathering activity is a joint operation of the three programs. Allowable product changes for the purpose of quality adjustments include occupant safety enhancements; mechanical and electrical improvements to overall vehicle operation or efficiency; changes that affect length of service or need for repair; and changes affecting comfort or convenience. No adjustments are made for style or appearance changes, or for design changes that affect the cost of production but not functionality or performance.[12] Figure 1 displays an example of the annual public announcement of the average quality adjustment for vehicles priced in the PPI. The average adjustment will be different in the CPI, in part because of the retail markup and the different sample and weighting of vehicles.

20. The producer orientation of the PPI (and export price index) implies that resource cost is the appropriate criterion for quality adjustment in that program.[13] One distinction, then, between the use of producer cost estimates in the CPI and PPI is that only the former program will add retail

markups and indirect taxes. Another important difference in handling may occur in situations where product improvements are mandated by government. Some of these mandated improvements provide no direct benefit to the purchaser; in those cases it is appropriate to make a quality adjustment for the associated resource cost in the PPI, but not in the CPI, where the appropriate criterion is user value. [14]

21. The primary examples of this issue are mandated changes in motor vehicles and motor fuel, designed to improve air quality. The purchaser of an automobile receives only a negligible direct benefit from any pollution control devices on that vehicle, and the market price for such devices, if not mandated, would be near zero. Although the consumer benefits from any improvement in air quality that may be attributed to widespread adoption of these devices, changes in the quality of the environment are generally outside the scope of the CPI, and no quality adjustment should be made in the CPI for this type of pollution-control mandate.[15]

Hedonics

22. The use of hedonic regression is probably the fastest-growing method of direct quality adjustment. It is outside the scope of this paper to review either the theoretical underpinnings or the empirical history of the approach, which relies on statistical estimation of the consumer valuations of product characteristics, using market price data for products with differing combinations and levels of those characteristics.[16] Product price is the dependent variable in a hedonic regression, and the characteristic values are the explanatory variables.

23. A hedonic-based estimate of price change for a particular item category can be obtained explicitly from such a regression, typically by combining data from two time periods and including a dummy explanatory variable to indicate observations from the later period. In this case the coefficient on the dummy variable is the estimate price change in absolute or proportional terms, depending on the functional form of the regression.

24. Statistical agencies, however, have usually followed a different approach. As in other methods for quality adjustment, the adjustments have been made in the context of item replacement. When the new and old item differ in one or more of the characteristics included in the hedonic regression model, the coefficients associated with those characteristic variables are used to adjust the price differential, yielding an improved estimate of pure price change.

25. The recent paper by Bascher and Lacroix (1999) presents a hedonic regression model for dishwashers, now being used in the French CPI. The coefficients of the model are shown in Figure 2. The form of the model is linear, and the dependent variable is the price. The independent variables fall into three groups: technical appliance characteristics, product brand

category, and outlet type. Thus, for example, dishwashers with “Low Noise” levels are found to command a 735-franc premium, on average, relative to units with average noise levels, and to average 1,019 francs higher in price than the very-noisy units. In general, the results are satisfactory and support the use of the regression for quality adjustment. The coefficients are significant and plausible, and the explanatory power of the regression is high. Simulations by the authors indicate some upward effect on the index from the use of the hedonic method in 1998, as compared to exclusive use of the linking or “dissimilar” method.

26. Bascher and Lacroix list the several requirements for successful design and use of hedonic quality adjustment in the CPI, noting that these require heavy investments over a long period:

- Intellectual competencies and sufficient time to develop and reestimate the model, and to employ it when products are replaced;

- Access to detailed, reliable information on product characteristics; and

- A suitable organization of the infrastructure for collecting, checking, and processing information.

27. It should be noted that hedonic methods can also improve quality adjustment in the CPI by indicating which product attributes do *not* appear to have material impacts on price. That is, if a replacement item differs from the old item only in characteristics that have been rejected as price-determining variables in a hedonic study, this would support a decision to treat the items as comparable or equivalent and include the entire price difference, if any, as pure price change. The enhanced confidence in comparability decisionmaking, and parallel reduction in reliance on “linking,” has been cited as one of the significant benefits of the hedonic research on apparel in the United States.[17]

III. Indirect estimation

28. The so-called indirect methods for quality adjustment proceed by first estimating the pure price change component of the price difference between the old and new item. The quality difference is then implicitly defined by the residual price differential. The indirect methods are generally viewed as less desirable than the direct methods described above, but are the only available options in the great majority of non-comparable replacement situations.

Linking

29. The linking approach is perhaps the most often criticized procedure in economic measurement.[18] This is despite the fact that its motivating assumption—that relative market prices reflect relative consumer valuations—is entirely consistent with economic theory and is related to the assumptions needed for the hedonic or production-cost direct approaches.

30. Linking is commonly applied when a sample item priced in period t is unavailable in period t+1 and must be replaced by a new item, when the two items cannot be judged comparable in quality, and when no direct quality adjustment method can be employed. The linking procedure can be described in two equivalent ways:

- The old and new items are deleted from the calculation of price change in period t+1.

- The pure price component of the difference between the prices of the old and new items is computed using the remainder of the item sample. The remainder of the price difference is assumed to be due to quality.

31. Thus, the category index change for period t+1 is calculated without reference to the old and replacement items' prices. The replacement item is used in the calculations for subsequent periods. Implicitly or explicitly (depending on the index formula and calculation algorithm, as described below in section IV), the price of the old item is extrapolated to period t+1 using the category index values, and the ratio of this extrapolated value to the replacement item's price is assumed to reflect the relative qualities of the two items.

32. Clearly, the linking method will lead to index distortions if new items are introduced at systematically different "pure prices" (that is, prices per unit of "quality") from those of the other items in the market. There are three prominent paradigms or heuristic examples of the ways in which this might occur.[19] First is the personal computer paradigm: new computers enter the market at prices equal to—or lower than—those of the previous models, but with greater speed and capability. Linking, by assuming that the new and old models have the same quality-adjusted price, will result in an index change that is too high. Second is the apparel paradigm: new items of clothing enter the market at higher quality-adjusted prices, because the items they replace were being discounted at the end of their season or style cycle. Linking then leads to an understatement of index change. Both these paradigms have motivated the expanded use of hedonic regression models in order to adjust for quality differences directly.

Class Mean Imputation

33. A third paradigm provides the motivation for the “class mean” (or “substitution relative”) method of implicit quality adjustment in the U.S. CPI. As discussed in Reinsdorf, Liegey and Stewart (1996), Armknecht, Lane, and Stewart (1997), and Armknecht and Maitland-Smith (1999), price change in practice is often associated with the introduction of new products. Manufacturers may, for example, take the opportunity of new model changeover to increase prices. Quantitative evidence in support of this scenario is presented by Moulton and Moses (1997), using U.S. CPI data for 1995. Over all items studied, the average pure price change was only 0.12 percent for identical items being repriced (on a monthly or bimonthly basis), compared to an average 2.51 percent change for comparable substitutes—items judged equivalent to the items they replaced.[20] Thus, the price movement of continuing items appears to be a flawed proxy for the pure price component of the difference between old and replacement items.

34. The class mean method, adopted in the U.S. CPI for automobiles in 1989 and phased in for most other non-food commodities beginning in 1992, differs from the linking method only in the source for the imputed rate of price change for the old item in period t+1. Rather than using the category index change, obtained using all the non-missing items in the category, the imputed rate of price change is based on constant-quality replacement items—those that were judged comparable or that were quality-adjusted directly.

Overlap

35. The overlap method is the simplest and most transparent technique for quality adjustment, and can be applied when the old and replacement item are both available in the same pricing period. Like the linking method, it proceeds from the assumption that the price per unit of quality is the same for all items in the product category for which the index is being produced. The quality difference between the old and new items is then equal to the price difference.

36. The data necessary for the overlap method seldom are present in the context of item substitution. Implicitly, however, the overlap method is employed when samples are rotated. That is, the old sample of items is used to compute the category index change between periods t-1 and t, and the new sample used between t and t+1. The “splicing” together of these index movements is justified by the assumption that—on a group-to-group rather than item-to-item level—differences in price levels at a common point in time accurately reflect differences in qualities.

The German Approach

37. Hoffman (1999) describes a possibly unique alternative for quality adjustment of replacement items in the German CPI. When a new product is more expensive than the item it replaces, a flexible adjustment factor can be

employed, attributing none, some, or all of the price difference to improved quality. In particular, when no precise information is available on which to make a quality determination, it is permissible to adjust by 50 percent of the price difference. The guidelines used in Germany since 1997 replaced flawed procedures in which the particular methods chosen for individual quality adjustments depended on the difference in price alone. As Hoffman notes, however, even in the current approach no quality adjustment is made if the new item is less expensive than the old. Consequently, problems could arise if an increase in quality is accompanied by a decrease in price (or *vice versa*).

38. The somewhat mechanical methods used in the German CPI are made necessary by the fact that quality adjustments for most goods are made not in the central CPI office but by price collectors in the field. Wide use of the hedonic and production-cost approaches is precluded under these conditions. Thus, the organizational structure of the statistical agency, as well as its funding level, will necessarily influence its choice of quality adjustment methods.

Link To Show No Change

39. Finally, mention should be made of the “link to show no change” method. In this approach the whole price difference between the old and new items is attributed to quality difference. In computing index change in period t+1, the previous-period price of the replaced item is carried forward as if its price had remained unchanged. Although this method is still common in practice, it is widely recognized as biased and, as noted by Astin and Sellwood (1998), Eurostat explicitly precludes its use in the Harmonized Indices of Consumer Prices.

IV. Implementation Formulas

40. The foregoing discussion has described, in general terms, various ways by which the price difference between an “old” and a “new” item can be decomposed into “quality” and “pure price” differences. This section presents mathematical examples of how these decompositions are used in the elementary indexes of a CPI.

41. It is sufficient for our present purposes to demonstrate two approaches: a direct quality adjustment, and the indirect linking method. Complicating the matter, however, is the fact that agencies employ numerous alternative formulas for their basic category indexes. Three formulas will be demonstrated here: the chained geometric mean, the so-called “Modified Laspeyres” formula as used in much of the U.S. CPI,[21] and the unweighted chained ratio-of-average-prices formula. These should be sufficient to convey how quality adjustments would be incorporated into other potential formulas.

42. The hypothetical price data for these index calculations are taken from Turvey (1989, Box 10, p. 96) and are replicated in Figures 3 and 4. In each of the months 0 through 5, there are three items, or varieties, whose prices are available for use in the index. Beginning in month 3, item A is unavailable and is replaced by item D; items B and C are available throughout.

43. Calculation of the three index formulas requires some discussion of weighting. By assumption, the ratio-of-average-prices index is unweighted; only prices are used in its computation. The calculation of weights is inherent in the Modified Laspeyres index, however. That approach defines the index objective for period t as

$$I_t = [\Sigma Q_{0i} P_{ti}]/[\Sigma Q_{0i} P_{ri}]$$

where the summations are over items i, the Q_{0i} are quantities purchased during a base period 0, and the P_{ri} are prices in a reference period r. Since quantities are not observed directly, the index is estimated as

$$I_t = [\Sigma w_{0i}(P_{ti}/P_{0i})]/[\Sigma w_{0i}(P_{ri}/P_{0i})]$$

where the w_{0i} are sampling weights representing base period expenditures, and the P_{0i} are estimated base-period prices.[22] For our calculations, we will assume that the sampling weights are all equal to unity, and that the quantity weights are therefore equal to the reciprocal of the month-0 price. We will also assume, for convenience, that the base and reference periods 0 and r are the same. Thus, for example, the implied quantity weight of item A, as shown in the first column of the Figures, is 0.2 (1/5). For the geometric mean index, the assumption of equal expenditure values for each item is equivalent to computing the index without weights.

44. Under these assumptions, the index relatives, or ratios, for month 1 are, for example:

Geometric Mean: $[(6*5*7)/(5*4*8)]^{1/3} = 1.09$
Ratio of Averages: $(6+5+7)/(5+4+8) = 1.06$
Modified Laspeyres: $[(6/5)+(5/4)+(7/8)]/[[(5/5)+(4/4)+(8/8)] = 1.11$

Direct quality adjustment

45. Figure 3 demonstrates the implementation of a production cost, hedonic, or other direct quality adjustment analysis. Assume that the analysis has yielded an estimate that item D has 20 percent higher quality than item A. Equivalently, one unit of item D is judged to be equivalent to 1.2 units of item A. In each of the three formulas illustrated in the figure, the adjustment is accomplished by imputing a month-2 price of 6 (=5*1.2) for item D. In addition, the Modified Laspeyres method requires that the base price for item D also be scaled upward by a factor of 1.2 from its value for

item A. Thus, the base price for item D is 6 and its implicit quantity weight is 1/6.

46. The index relatives for month 3 are then:

Geometric Mean: $[(7*9*7.5)/(6*9*6)]^{1/3} = 1.13$
Ratio of Averages: $(7+9+7.5)/(6+9+6) = 1.12$
Modified Laspeyres: $[(7/4)+(9/8)+(7.5/6)]/[[(6/4)+(9/8)+(6/6)] = 1.14$

47. An important issue to note is that the ratio-of-averages index is not invariant to the scaling of the new item. That is, had item D been introduced at a price of 15 and a relative quality of 2.4, rather than at 7.5 and 1.2, respectively, both the geometric mean and Modified Laspeyres indexes would have yielded the same result as in Figure 3. The ratio-of-averages index relative, however, would have been 1.148 in month 3 and would also have been different in the later periods, as the higher price for item D would have given it a greater importance relative to items B and C.[23]

Linking

48. Figure 4 demonstrates the application of linking. The relative qualities of items A and D are inferred using the index relative between months 2 and 3. That index relative is estimated using only items B and C, and is given by:

Geometric Mean: $[(7*9)/(6*9)]^{1/2} = 1.08$
Ratio of Averages: $(7+9)/(6+9) = 1.07$
Modified Laspeyres: $[(7/4)+(9/8)]/[[(6/4)+(9/8)] = 1.10$

49. In months 4 and thereafter, the first two indexes are computed using items B through D, in the same way that items A through C were used in the initial periods. As in the direct quality adjustment case, however, the Modified Laspeyres index additionally requires the calculation of a base-period price and implicit quantity weight for item D. This is accomplished in four steps:

(1) Extrapolate the month-2 price of item A to period 3, using the index relative 1.10; this yields an imputed period-3 price of 5.48 (the precise calculation is 5*1.095=5.476).

(2) Estimate the quality of item D relative to item A by the ratio of item D’s price in period 3 to item A’s imputed price; this ratio is 1.370 (7.5/5.476 = 1.370).

(3) Compute the base period price of item D by multiplying item A’s base period price by the quality ratio of the two items; this yields 6.85 (5*1.370 = 6.848).

(4) The quantity weight for item D is then 0.15, the inverse of the base-period price (1/6.848 = 0.146).

50. The new base price for item D is used in the subsequent periods. For example, in month 4 the Modified Laspeyres relative is computed as [(7/4)+(8/8)+(8/6.848)]/[[(7/4)+(9/8)+(7.5/6.848)] = 0.99.

51. Also as in the direct quality adjustment case, the ratio-of-averages index will not be invariant to the scaling of the new item. For example, had item D been introduced at a price of 12.5 instead of 7.5, the resulting ratio-of-averages index would be different in months 4 and 5, ending at a level of 91.13 instead of 91.94, but the geometric mean and Modified Laspeyres indexes would be unaffected. This occurs because the price level of item D determines its relative importance in the ratio-of-averages index.

V. Concluding Remarks

52. This section briefly mentions a few of the most significant current developments and issues faced by statistical agencies in their continuing attempt to deal with quality change in consumer price indexes.

53. 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.

54. 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 college tuition, 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 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.

55. A related issue concerns quality change that is not associated with specific items. A supermarket, for example, may attract customers by providing wider aisles, faster checkouts, more attentive staff, or a wider range of brands. This sort of consumer benefit is not ordinarily reflected

in a CPI, because the services are provided without specific charge; rather, they are incorporated in the prices of the goods sold. That does not mean, however, that conceptually such quality improvements should be outside the scope of the index.

56. It is important also to recognize the inter-relationships among the methods for handling item rotation, item replacement, and quality adjustment. It was noted above that when CPI item samples are updated any difference in average quality between samples is dealt with in a way that is equivalent to the overlap adjustment technique. The overlap method, like the more frequently employed linking method, is widely viewed as sub-optimal because it requires that price movements for continuously-available items be an adequate proxy for the change in price per unit of quality between disappearing and replacement items. Thus, if this criticism is accepted, consideration should be given to methods for making quality adjustments at the time of sample rotation.[24]

57. A recognition of failures of the “Law of One Price” also has potentially important implications for the processes used to select replacement items. Traditionally, pricing agents are trained to find substitute items that are as similar as possible to the items being replaced. This maximizes the likelihood that the old and replacement item will be judged equivalent, and so minimizes the need to employ some method of quality adjustment. If new items enter the market at lower prices (per unit of quality), however, it becomes important to keep samples as representative as possible of the entire market. Moreover, in item categories where hedonic or other direct quality adjustment methods are in use, selecting a non-comparable replacement item does not automatically force the use of the problematic linking method. Consequently, as statistical agencies acquire a greater confidence in and willingness to employ the direct quality adjustment methods, they may wish to consider substituting to the newest, or most representative, items rather than to the most similar items. Subject to resource constraints, more frequent sample rotation or directed replacement may also be warranted.

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Figure 1
Announcement of Vehicle Production Cost Quality Adjustment
U.S. PPI and CPI

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REPORT ON QUALITY CHANGES FOR 1999 MODEL VEHICLES

Passenger Cars

The value of quality changes for a sample of 16 domestic passenger cars for the 1999 model year included in the Producer Price Index for October averaged $13.49, according to estimates by the Bureau of Labor Statistics (BLS) of the U.S. Department of Labor. This change represents 12.3 percent of the average $109.67 yearly increase in producers' prices.

The retail equivalent of these quality changes averaged $15.50, representing 10.0 percent of the average $155.27 yearly increase in manufacturers' suggested list prices.

These quality-change values represent modifications made to meet 1990 Clean Air Act amendments, changes in levels of standard or optional equipment, and upgrades to powertrains and corrosion protection.

Light Trucks

The value of quality changes for a sample of 15 domestic light trucks for the 1999 model year included in the Producer Price Index for October averaged $408.52. This change represents 95.0 percent of the average $430.08 yearly increase in producers' prices.

The retail equivalent of quality changes for domestic light trucks averaged $484.86, representing 98.6 percent of the average $491.63 yearly increase in manufacturers' suggested list prices.

The $484.86 estimated retail level of quality change breaks down as follows:

- $76.61 for changes in accordance with 1990 Clean Air Act Amendments
- $408.25 for other quality changes such as powertrain improvements, corrosion protection upgrades, and changes in levels of standard or optional equipment.

Estimates of the value of quality change are based on a review by the BLS of data supplied by producers for similarly equipped 1998 and 1999 domestic models priced for the Producer Price Index. Most of the estimates of quality changes in this release are derived from information supplied for the Producer Price Index for October.

Figure 2
Hedonic Model for Dishwashers, 1998
French CPI

Independent Variable	Observations (%)	Coefficient	t statistic
Model Intercept		5195	24.607
Number of Programs	100	120	8.397
Water Consumption	100	-54	-4.64
Power Consumption	100	-606	-4.416
Sales Outlet			
Hypermarkets and Specialized Stores	72.5	Reference	
Department Stores	4.2	250	3.012
Conventional Stores	23.3	251	6.359
Delayed Start			
Without	81.7	Reference	
With	18.3	248	5.296
Noise Level			
Very Noisy	36.7	-284	-5.427
Average Noise	54.5	Reference	
Low Noise	8.9	735	11.413
Brand Reputation			
General Class	81.1	Reference	
Fair	6.4	350	5.051
Good	3.6	475	5.188
Very Good	8.9	1764	21.653

$R^2 = 0.87$
Adjusted $R^2 = 0.86$
Prob>F=0.0001

Source: Bascher and Lacroix (1999)

Figure 3
Example of Direct Quality Adjustment

	Quantity Weight	Month 0	1	2	3	4	5
Prices							
Item A	0.20	5.00	6.00	5.00			
Item B	0.25	4.00	5.00	6.00	7.00	7.00	4.00
Item C	0.13	8.00	7.00	9.00	9.00	8.00	8.00
Item D	**0.17**	**6.00**		**6.00**	7.50	8.00	5.22
Geometric Mean							
Relative			1.09	1.09	1.13	0.98	0.72
Index		100.00	109.49	119.06	135.01	132.64	95.45
Ratio of Averages							
Relative			1.06	1.11	1.12	0.98	0.75
Index		100.00	105.88	117.65	131.65	128.85	96.46
Modified Laspeyres							
Relative			1.11	1.09	1.14	0.99	0.70
Index		100.00	110.83	120.83	137.50	136.11	95.65

Numbers in bold represent imputed values.

Figure 4
Example of Linking

	Quantity Weight	Month 0	1	2	3	4	5
Prices							
Item A	0.20	5.00	6.00	5.00	**5.48**		
Item B	0.25	4.00	5.00	6.00	7.00	7.00	4.00
Item C	0.13	8.00	7.00	9.00	9.00	8.00	8.00
Item D	**0.15**	**6.85**			7.50	8.00	5.22
Geometric Mean							
Relative			1.09	1.09	1.08	0.98	0.72
Index		100.00	109.49	119.06	128.59	126.33	90.91
Ratio of Averages							
Relative			1.06	1.11	1.07	0.98	0.75
Index		100.00	105.88	117.65	125.49	122.82	91.94
Modified Laspeyres							
Relative			1.11	1.09	1.10	0.99	0.70
Index		100.00	110.83	120.83	132.34	130.61	92.06

Numbers in bold represent imputed values.

END NOTES

[1] The present paper draws heavily on the sections entitled “Quality and Output Changes: A Major Problem” and “Linking When Quality or Outlet Has Changed” in the ILO manual by Ralph Turvey (1989), as well as his recent updates (Turvey 1999a, 1999b). Much of the material also follows the excellent descriptions of alternative methods presented by Armknecht and Maitland-Smith (1999) and Moulton and Moses (1997). Finally, note should also be taken of the very detailed description in U.S. General Accounting Office (1999) of U.S. CPI procedures for handling of replacement items.

[2] The years analyzed were 1983, 1984, and 1995. Rent, Owners’ Equivalent Rent, and certain other item categories were excluded from consideration.

[3] See U.S. Senate (1996).

[4] Another 0.1 percentage point was attributed to new outlet bias, which can also be viewed as a quality adjustment problem, the quality being associated with a sales outlet rather than with a product.

[5] See, for example, Armknecht and Maitland-Smith (1999).

[6] For example, Boskin *et al* (1998) comment “Yes, the BLS does lots of ‘price adjustments’ … it does not adjust explicitly for quality *change*, as we were defining it, except in the case of automobiles, apparel, and possibly rental apartment units ...”

[7] The U.S. General Accounting Office (1999), in its discussion of “what BLS refers to as quality adjustments,” states that CPI analysts “sometimes make adjustments for differences not necessarily related to quality. For example, they make adjustments … to account for differences in size or quantity.”

[8] See the discussion of implementation methods in section IV below for a comparison of adjustments to the current and previous price.

[9] Triplett (1983) provides a detailed discussion of the relationship in market equilibrium between resource costs of product characteristics and user valuations of those characteristics.

[10] As noted by Schultz (1999), overestimation of automobile quality adjustments has sometimes been cited as an upward bias in the CPI. See also Griliches (1971) and Triplett (1997).

[11] The same proportional adjustments are applied to the index for used cars and trucks as the corresponding vehicles enter that index.

[12] See U.S. Bureau of Labor Statistics (1999) and U.S. General Accounting Office (1999, Appendix IV). Schultz (1999) notes that automobile quality adjustments in the Canadian CPI similarly distinguish between improvements to performance, durability, or safety and changes considered cosmetic.

[13] See Triplett (1983).

[14] Note that if the air quality improvement were accomplished through an indirect tax on automobiles, no quality adjustment would be applied in the CPI. The treatment of pollution mandates has provoked controversy in the past, although most economists have been in support of the view expressed here. See, for example, U.S. Senate (1996, p.34) and Popkin (1998).

[15] This policy was implemented in the U.S. CPI in 1999, reversing a long-standing policy of allowing production cost-based quality adjustments for air quality mandates in vehicles and motor fuel. See Fixler (1998) for a description and justification of the change.

[16] There is a voluminous economic and econometric literature on hedonic quality adjustment. Recent discussions include those by Kokoski (1993), Feenstra (1995), Kokoski, Moulton, and Zieschang (1998), and Silver and Heravi (1999), and the citations therein. The papers presented at recent meetings of the International Working Group on Price Indices (the Ottawa Group) contain several describing hedonic research or application by CPI programs; see, for example, Bascher and Lacroix (1999), Fixler *et al* (1999), Kinnunen (1999), Lowe (1999), and Moulton, LaFleur, and Moses (1999).

[17] See, for example, Reinsdorf, Liegey, and Stewart (1996).

[18] There has been a confusing variety of terminology used for indirect quality adjustment procedures. What we refer to here as linking has sometimes been called splicing, the deletion method or the overlap method.

[19] Lowe (1999) lists several other potential problems in the case of durable goods; for example, manufacturers or retailers may misjudge the value of the new item and introduce it an inappropriately high or low price.

[20] The corresponding average price change was 2.66 percent for directly-quality-adjusted substitute items.

[21] The Modified Laspeyres is used also in Germany and elsewhere; implementation details, however, may be specific to countries, and the specific statements in the text regarding the Modified Laspeyres may not necessarily apply outside the U.S. CPI. In January 1999 the United States adopted the geometric mean for most item categories.

[22] The specific alternative formulas for base prices in the U.S. CPI are given in the appendix to Moulton (1996).

[23] The sensitivity of the ratio-of-averages method to the initial price of an item, and the implications for its use in heterogeneous item categories, have long been recognized. See, for example, Szulc (1989).

[24] See, for example, Moulton, LaFleur, and Moses (1999) and Moulton (1999).
