The Consumer Price Index: underlying concepts and caveats

To properly use the Consumer Price Index, one must understand its relationship to an ideal cost-of-living index and the problems of implementation

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In 1927, Irving Fisher, in *The Making of Index Numbers*, wrote:

> Most people have at least a rudimentary idea of a "high cost of living" or of a "low level of prices," but usually have very little idea of how the height of the high cost or the lowness of the low level is to be measured. It is to measure such magnitudes that "index numbers" were invented.[1]

The Consumer Price Index (CPI), produced by the Bureau of Labor Statistics, serves as an approximation of an ideal cost-of-living index (CLI).[2] The CPI is "a measure of the average change in the prices paid by urban consumers for a fixed market basket of goods and services." Measuring price change through the use of a fixed market basket has a long history, dating to the early 1700's.[3] The theory underlying the CLI is much more recent, having been developed by A. A. Konus in 1924.[4]

This article reviews how the theory of the CLI provides the conceptual foundation for the CPI and the caveats governing the use of the CPI as an approximation for a CLI. To understand these warnings it is necessary to know the sources of measurement errors in prices and weights that unavoidably impede the construction of the CPI. If the measurement error is systematic, then a systematic difference may exist between the computed CPI and the true CLI, which would, in turn, affect the measured rate of price change. In this article such systematic differences are called systematic effects.[5]

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A description of some of the prominent features of the structure and market dynamics of prices is useful because they are relevant to understanding sources of measurement error. First, consumers face a large number of different products; those who design indexes must aggregate the prices of nonidentical products into groups or strata. Second, within a product stratum, consumers face a variety of prices arising from such factors as differences in the production technology of manufacturers and the location of retail outlets. Third, price changes stem from market dynamics such as entry and exit of firms, and the expansion of existing firms. Fourth, prices routinely oscillate, due to, among other reasons, seasonal factors and periodic sales.

Although BLS uses procedures to account for these influences, the task is complicated by the frequency of price change induced by them. Firms cannot change prices without cost; for example, costs are associated with changing price lists ("menu" costs). Firms therefore change their prices when the benefit of the change exceeds the cost. Consequently, the observed price oscillation among retail firms depends on the pressure for price change arising from the influences mentioned earlier and the costs of price change for a given firm.

Conceptual framework underlying the CPI

The measurement of the change in the cost of living stemming from a change in price is based on an assessment of how a change in the price of goods and services affects consumers' well-being. Consumer well-being can be defined as the level of utility achieved by the consumer through the consumption of goods and services. The underlying assumption is that consumers choose the bundle of goods and services that maximizes their utility for a given expenditure level or, equivalently, minimizes expenditures to achieve a given level of utility.

Because a cost-of-living index measures how price changes affect a consumer, one can look at how the minimum expenditure necessary to obtain a certain level of utility responds to price changes. Let the minimum expenditure needed to achieve the level of utility u be denoted by $E(p;u)$, where p denotes the set of prices of goods and services. The cost of living index for a consumer between period t and the base period b can be expressed as a ratio of the minimum expenditures:

$$I(p^t,p^b,u^b) = \frac{E(p^t;u^b)}{E(p^b;u^b)} .$$

The level of utility in the base period underpins the comparison between the two expenditure levels.

Utility functions are unobservable and specific to a consumer. Thus, one question immediately arises: How can a CLI be approximated for a consumer? Because index makers generally are interested in group indexes rather than individual indexes a second question arises: How can individual CLI's be aggregated to form an average CLI? The answers to these questions are fundamental to the construction of consumer-oriented indexes that approximate an ideal CLI.

When aggregating individual CLI's to form an average CLI for the United States, a key issue is determining the weight that should be given to each consumer or consumer unit in the aggregation process.[6] Laspeyres price indexes based on aggregate consumption patterns (such as the CPI) implicitly weight households in proportion to their spending on consumer items. They have, therefore, been termed *plutocratic* indexes. An alternative aggregation in which all individuals (consumer units) are given equal weight is called a *democratic* index.[7]

Having laid out the theory behind a CLI, attention now turns to the selection of an index number formula to compute one. There are essentially two general schools of thought on how to select a formula for constructing an index. The economic ap-

Glossary of terms

Consumer Price Index: A Laspeyres fixed-quantity price index that measures the price change of a fixed market basket of goods and services of constant quality bought on average by urban consumers (CPI-U). The CPI-U focuses on urban consumers and the CPI-W focuses on urban wage earners and clerical workers. It is the ratio of the value of a market basket in two periods: the numerator is the value of the market basket at, say, current prices and the denominator is the value of the market basket at base period prices.

Cost of living index (CLI): A ratio that measures the impact of price change on consumer well-being. The numerator is a hypothetical expenditure—the lowest expenditure level necessary at current prices to achieve the base period's living standard. The denominator is the lowest expenditure at base period prices to achieve the base period's living standard.

Point-of-Purchase Survey: Conducted by the Bureau of the Census, this survey furnishes current data on retail outlets from which urban households made purchases of defined groups of commodities and services. The survey is conducted annually over a period of 4 to 6 weeks, usually beginning in April, in approximately one-fifth of the primary sampling units in the CPI.

Primary sampling units (PSU's): The 1987 CPI area sample defined 1,088 primary sampling units from which 94 were selected. In 1988, budget constraints required that 6 PSU's be dropped from the design, leaving 88 PSU's.

Metropolitan statistical area: Each metropolitan statistical area as defined by the Federal Office of Management and Budget in 1983 is a primary sampling unit.

Sampling: The use of statistical procedures to select samples that make the CPI representative of the prices paid for all goods and services purchased by consumers in all urban areas of the United States. Samples are selected for urban areas; consumer units in each selected urban area; outlets from which these consumer units purchased goods and services; specific, unique goods and services purchased by consumer units; and housing units in each urban area for the shelter component of the CPI.

Link to show no change procedure: Linking items in the new and old outlet sample is done by establishing a month in which the price in both the old and new outlets is recorded, but only the old is used in calculating the index. The next month in the new outlets, the price is compared to the price collected in the previous month.

proach posits that index number formulas should correspond to the optimizing behavior of consumers. This approach is presented by W. Erwin Diewert[8] and Franklin Fisher and Karl Shell.[9] The axiomatic approach sets the desired properties of an index number and selects the formula that "best" satisfies these properties. A classic work in this area is by Irving Fisher.[10]

Diewert has shown that index number formulas exist that equal or closely approximate a cost-of-living index under a broad range of circumstances. These indexes, which he termed "superlative," also perform well when judged by the criteria of the axiomatic approach. Ana Aizcorbe and Patrick Jackman use two superlative indexes, a Tornqvist index formula and the Fisher ideal index formula, to calculate alternative consumer price indexes and then compare them to the CPI (see pp. 25–33, this issue).

Other approximation techniques are found in the literature. In one technique, a utility function is specified and the corresponding system of demand equations is estimated to calculate the CLI. An example of this technique is given by Laurits Christensen and Marilyn Manser.[11] In another technique, a formula for a CLI is derived from a specification of the utility function. For example, if consumers purchase fixed proportions of commodities (no substitution between commodities), then the CLI has a Laspeyres (or Paasche) form.[12]

The CPI is an approximation for a CLI computed with the Laspeyres formula. This formula uses a system of fixed weights, which are ideally the quantities of goods and services consumed in the base period. The Laspeyres price index between period t and the base period b is given by

$$L(p^b,p^t,x^b) = \frac{\sum_i p_i^t x_i^b}{\sum_i p_i^b x_i^b} = \sum \frac{p_i^t}{p_i^b} \times s_i^b$$

where x^b denotes the set of x_i^b, the individual quantities consumed in the base period, and s_i^b denotes the expenditure share of the ith good in the base period; that is, $s_i^b = p_i^b x_i^b / \sum_i p_i^b x_i^b$. In other words, the Laspeyres index is an expenditure share weighted average of the price ratios, which also are called price relatives. The appeal of a Laspeyres formula is that the market basket formed from the base period quantities corresponds to the underlying concept of well-being. Furthermore, holding these quantities fixed over time corresponds to the notion of constant utility or well-being that underlies the CLI.

The CPI answers the question, "How much would the base period market basket cost at the comparison period prices?" It is important to note that the CPI represents hypothetical expenditures and that the quality of the goods and services in a market basket is assumed not to change. These two features are discussed in detail later in this article.

Konus demonstrated that

$$(1) \qquad I(p^t,p^b,u^b) \leq L(p^t,p^b,x^b).$$

That is, the Laspeyres price index is an upper bound to the CLI. The reason for this inequality is as follows. The use of fixed base period quantities as weights in the Laspeyres index does not enable that index to capture changes in consumption arising from changes in relative prices. When relative prices change, consumers substitute the relatively cheaper commodity for the relatively more expensive commodity to minimize the expenditure needed to maintain the initial level of utility. However, with fixed quantities, consumers must spend more to maintain the initial level of utility.

It is important to note that the CPI is an estimate of a Laspeyres price index. Thus, the CPI is subject to sampling and nonsampling errors, and may not be an upper bound to the CLI.

In addition, the CPI is not a true Laspeyres index. The reasons for this include the nonconstant quality of commodities, the item changes arising from the sample rotation, and the change in the base period for elementary aggregates arising from sample rotation. The elementary (or basic) aggregates, further discussed below, are the first combinations of prices of similar commodities.

Structure of the CPI

The structure of the CPI can be described as consisting of two types of indexes. The first type consists of elementary aggregates. More specifically, the 1-month price change in the CPI (known as the relative price change) for item i is given by

$$(2) \qquad R_{i,t,t-1} = \frac{\sum_z W_z \left(\frac{p_z^t}{p_z^b}\right)}{\sum_z W_z \left(\frac{p_z^{t-1}}{p_z^b}\right)}$$

where p_z^t represents the zth price quote of the ith item in period t, and W_z is the corresponding expenditure weight for the ith item and reflects the probability of selection. The price p_z^b is an estimated price; it is the price when the sample item is first introduced into the index deflated to the time period of the weight determination, that is, the base period. It follows that (W_z/p_z^b) is the imputed quantity of the ith item in the base period and, as in the Laspeyres index, constitutes the weight of the price quote.

The elementary indexes are the item strata indexes constructed by area level from the prices collected for specific items in specific outlets. The construction of these indexes involves the use of an aggregation formula and the random sampling of a selection of outlets and areas. The 27 largest Metropolitan Statistical Areas, with Anchorage, AK, and Honolulu, HI, are selected as self-representing primary sampling units in the CPI sample design.[13] A random sample of the remaining urban areas is selected as nonself-representing primary sampling units. Recently, attention has focused on the implications of the BLS item and outlet sampling mechanism for various index number formulas at the elementary aggregate level.[14] (Brent Moulton discusses this topic in more detail on pages 13–24, this issue.)

The second type of index also is of the Laspeyres type and it aggregates the 207 item strata indexes formulated for the 44 basic index areas for which indexes are prepared. In short, the overall CPI is an aggregation of 9,108 indexes.

BLS uses information from the consumer expenditure survey to construct the market basket of expenditures. Price data, however, are collected from a sample of outlets identified by households in the Point-of-Purchase Survey, which is conducted by the Bureau of the Census. Thus, the value of the market basket captures a "quantity" dimension and an "outlet" dimension. The importance of the outlet dimension derives from the earlier discussion of factors affecting price dynamics and the distribution of prices for a given commodity or service.

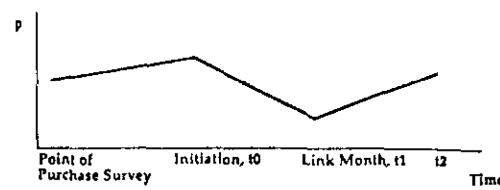
Given a distribution of prices, consumers will likely search for outlets with the lowest price, taking into account their preferences for services (for example, no waiting in a check-out line) and transportation/transaction costs. To keep up with changing shopping patterns, BLS changes about 20 percent of the outlet sample each year, completely turning over the sample every 5 years. The rotated outlets in a given year are in specific geographic areas. Approximately 17 primary sampling units have their samples rotated each year. A potentially complicating feature of the rotation is that it introduces shocks into the price trend, as demonstrated by Moulton. For the goods examined, the index levels are lower with a fixed outlet sample and market basket than with rotated outlets and linked old and new market baskets.[15]

The rotation process entails a choice of new outlets on the basis of the Point-of-Purchase Survey. When the BLS field representative visits the new outlet (known as initiation), the type of item to be priced already has been determined, but the representative must determine the specific item of that type for which the price is collected.[16] For example, a representative may visit an outlet to price cookies; if many types of cookies are offered, he or she must determine the specific cookies that will be priced. The selection of a unique item is random: the probability of selection derives from the outlet's sales of its cookie offerings.[17] By looking at sales, the representative would, through successive random selections, choose an item such as, say, a 12-ounce package of a brand name chocolate chip cookies.

The next step is to link items in the new and old outlet sample. This is done by establishing a link month in which the price in both the old and new outlets is recorded, but only the price in the old outlet is used in calculating the index. In the next month the price change is measured by comparing the price at the new outlet to the new outlet's price quote collected the previous month.[18]

The implementation of the rotation requires time, which unavoidably involves the use of expenditure weights that are determined (as much as 6 months) before an item is priced in the reference period.[19] Complicating the rotation is price oscillation, as prices fluctuate from high to low.

To examine the consequences for the CPI, consider the time path of an item price that oscillates, and suppose that the item is priced in both the new and old outlet samples.



The expenditure weight W_z in equation (2) is determined from information collected in the Point-of-Purchase Survey period and at initiation, t0. The price of the item is collected in the link month at t1. The collected price is then deflated to the base period, which currently in the CPI is the Point-of-Purchase Survey period.[20] This yields the estimated base price p_z^b in equation (2) and it casts the relative importance of the quote, (W_z/p_z^b), in dollars of the Point-of-Purchase Survey period.

In the case illustrated, the item price in the Point-of-Purchase Survey period is greater than it is at t1 and p_z^b is thus a low estimate of the price, as it rises again in t2 to the level in the Point-of-Purchase Survey period. Consequently, the quote weight, (W_z/p_z^b), is too high. The implication is that in the CPI, items with oscillating prices having relatively low prices in the link month have too large a weight, and items having relatively high prices too small a weight. Because items with relatively low prices are likely to experience price increases, and items with relatively high prices are likely to experience price decreases, the net effect is to overstate the average price change.

In a true Laspeyres index, the same (constant quality) item must be priced in each collection period. Because the CPI is a Laspeyres-type index, an accounting for changes in product quality must be conducted. For most commodities, the quality changes over short periods of time are probably small and have a small impact on the CPI. But many products, such as electronic goods, experience frequent changes in quality that must be accounted for. In addition, if consumers switch outlets to obtain a lower price for a given commodity, then any change in the quality of the retail service provided by the new lower cost outlet also must be accounted for.

Because the price–quality relationship is unknown, it must be estimated. BLS uses three methods to adjust changes in prices for changes in product quality.[21] These methods are overlap pricing, link pricing, and direct adjustments. The direct adjustments are based on information about changes in price determining characteristics provided by suppliers or gleaned from hedonic regressions.[22] Mary Kokoski uses the hedonic method to measure the impact of quality change on a set of commodities. (See pages 34–46, this issue.) With the overlap method, the price of both the improved version and the old version are recorded in a single month with the difference in price treated as arising from a difference in quality.

With link pricing, which is the most often used, the price change between new and old versions is broken down into a pure price change that is imputed from the price movement of other items in the same product category and a quality induced price change that is treated as the difference between the observed price change and the imputed pure price change. Because these adjustment methods do not systematically raise or lower the index, it is not possible to identify the effect of these methods on the status of the CPI as an upper bound.

The Consumer Price Index program also must confront the problem of new goods and disappearing goods. One issue is how to assign the price and expenditure weight of such goods in the period when they do not exist. Another issue is the timing of the introduction of the new item into the index. New goods typically are introduced into the market at high prices; over time the price declines as the result of many factors such as economies of scale or the entry of imitators. Consequently, the ability of the index to measure the price decline depends on when the new good is introduced into the index.

Measurement errors

Thus far, the focus has been on the sources of possible measurement error. Although there are many kinds, the attention will now be directed to the potential systematic measurement errors arising from changes in consumer selection of products or outlets. The benchmark will be an ideal CLI. The following list of effects represents potential sources of systematic differences between the computed CPI and an ideal CLI.

Commodity substitution effect is the error resulting from the use of a fixed-weight index that precludes product substitution by consumers when relative prices change. For example, if the price of coffee were to rise substantially while all other prices of similar products remain the same, then consumers would likely consume less coffee and more tea and cola drinks, but weights in the index still would reflect the initial expenditure share for coffee.

Seller substitution effect is similar to the commodity substitution effect as it relates to the inability of the index to capture the response by individuals to price changes among sellers for the identical or nearly identical commodity. This effect concerns the routine switching by consumers between, say, grocery or department stores for the lowest price of a commodity.

Outlet substitution effect is the inability of an index to capture the impact on prices of changes in the retail industry, such as the entry of new types of outlets. This effect entails more than a switch between outlets, as in the seller substitution effect, because it concerns the change in consumer purchasing habits arising from the increase in the number of retail outlets such as factory outlets, membership warehouse outlets, and other "discount" retail outlets promising low prices.

Estimation of substitution effects

Most of the attention in the literature has been directed toward measuring the commodity substitution effect, intuitively the most significant source of measurement error because of the fixed-quantity restriction in the CPI. In 1980, Steven Braithwait estimated the substitution error in the CPI at about 0.1 percent per year for the 1958–73 period.[23] In addition, he found that the size of the effect depends on the degree of relative price change and the magnitude of commodity substitution. In 1988, Marilyn Manser and Richard McDonald examined the substitution effect with a larger set of commodities[24] than did Braithwait (101 commodities versus 53) over the 1959–85 period and also found that the substitution effect is not very large, averaging 0.18 percent per year.[25] Both studies found that the length of time is important to the size of the effect—the longer the time period, the greater the effect. A small substitution effect is implied by the results presented by Mary Lynn Schmidt (pages 59–62, this issue) and the results presented by Aizcorbe and Jackman (pages 25–33, this issue).

The seller substitution effect arises because BLS measures price change for an item from a particular seller while consumers search among sellers for the best price. The BLS rotation of samples may not fully account for the switching of outlets by consumers. The direct measurement of the seller substitution effect, which requires that items be held constant, is difficult because when outlets are rotated, the sample selection procedures do not attempt to match items in the new outlet sample to those in the old sample.[26] Perhaps more importantly, BLS does not collect the quantity or sales data that are needed to measure the substitution effect. Brent Moulton (pages 13–24, this issue) and Marshall Reinsdorf[27] attempt to estimate the seller substitution effect.

The outlet substitution effect has recently received attention because of the increase in the number of discount stores and the accompanying change in shopping habits. Reinsdorf empirically examined the effect of outlet substitution on the CPI by comparing the movement of the average prices for food at home items and gasoline with the movement in the corresponding CPI strata (collections of similar items) and found evidence of a systematic difference between the two price series.[28]

The underlying assumption in Reinsdorf's work is that a comparison between average prices and the corresponding CPI strata reveals information about the existence and size of the outlet substitution. The basis for this assumption derives from how average prices are computed by BLS.[29] For a specific commodity, the average price is computed as a quantity weighted average of collected price quotes. The quantity weights are based on implicit quantities similar to those used in the CPI. Although the price quotes used in the production of the average prices and the CPI are the same, the average price series immediately incorporates the price quotes from new outlets, while in the CPI rotation procedure described earlier, a comparison is never made between a quote from an old outlet and a quote from a new outlet. Consequently, the average price of an item will decrease as consumers switch to relatively low priced outlets.

A comparison between the movements of average prices and their corresponding CPI strata, however, cannot provide direct evidence of the outlet substitution effect because outlet switching is not the only possible cause of the differences in the movements of the two series. Differences in index formula, in treatment of product quality change, and in coverage of average prices and CPI strata indexes also may have played important roles. The coverage differences arise because average prices are computed for highly specified items, while price indexes for CPI strata contain prices from collections of similar items. Thus, the CPI strata have many more price quotes than are used in the calculation of average prices: for example, only 25 percent of CPI food at home price quotes are used to calculate average prices.[30]

The idea behind the seller substitution effect and the outlet substitution effect is that consumers switch retail outlets in search of lower prices. The idea rests on two principal presumptions, both of which are supported by casual empirical observation and academic studies: (1) prices differ for given items and (2) consumers respond to prices.[31] BLS rotates outlets in an attempt to gain information on the switching of outlets by consumers. When low price outlets are rotated into the sample, the price difference between items in the old outlet and the new outlet is treated in the link month as stemming from differences in the quality of the retail service. Because this link to show no change procedure is identified as a source of both the seller substitution and outlet substitution effects, it is useful to examine it in detail.

Consider three types of stores: regular (R), discount (D), and high priced (H). Each store provides retail services, which include such features as ambiance, product availability, and scope of selection. Consumers value these services, which play a major role in determining where they shop.

First, consider the switch of a consumer from a regular store to a discount store. Let r_j denote the value that the jth consumer places on the retail services at a regular store, and let p_s $s=R,D,H$ be the prices at the respective stores and $p_D \leq p_R \leq p_H$. A consumer will switch to the discount store when

$$p_R - r_j \geq p_D \, .$$

The equality holds when the consumer is indifferent between the two stores. In such an event, the difference between the prices of products offered by the two stores is an accurate estimate of the change in the quality of the retail service. That the equality holds is the fundamental assumption underlying the current rotation methodology. It is based on the long-run competitive adjustment process in which market forces tend to equalize price across outlets after quality factors are accounted for. However, if market forces do not achieve such an equilibrium, then the inequality holds, and one obtains

$$p_R - p_D > r_j$$

which means that price difference is an overestimate of actual change in quality. Of course, the dynamic nature of markets makes the identification of a long-run equilibrium nearly impossible, which raises the possibility that the quality difference is mismeasured.

In addition, the use of the outlet price difference as an estimate of r is complicated by the fact that the value of r is consumer specific and thus likely to vary among consumers. For certain distributions of r, the use of the price difference as an estimate of the quality difference is appropriate.[32] An additional complication is that the values of r as well as its distribution are likely to change over time. These features make the distribution of r difficult to specify and make necessary the assumed equilibrium.

The above analysis also applies to the case in which a consumer switches from a regular store to a high-priced store. In this case, the value of the retail service at the high-priced store becomes the focus of attention, because consumers will purchase the same commodity at a high-priced store only if there is some compensation for doing so. Let h_j denote the value of the retail services at the high-priced store. A consumer will switch to a high-priced store when

$$p_R + h_j > p_H .$$

This expression implies that the difference in prices represents a lower bound approximation of the value of the retail services at the high-priced store. It follows that except for an indifferent consumer, the link to show no change method underestimates the quality change. As in the case of a switch from a regular store to a discount store, the values of h are unlikely to be the same among all consumers at a particular time, or that for a given consumer, the value remains constant over time.

The above examples show that an appraisal of the estimation of the value of the retail service obtained from a price differential depends on the designated reference outlet. It also is shown that the impact of seller and outlet substitution effects depends on the relative increase in the number of discount and high-priced stores because the corresponding effects are in opposite directions. However, it is clear that when a consumer is indifferent between the current outlet and the new outlet, the price difference between outlets is an accurate measure of quality change.

The implications of the above for the CPI become evident if one considers the measured price change in the month after the link to show no change. As described earlier, under the rotation procedure, in some month (the link month), both the prices at the old and new outlets are recorded, although only prices in the old outlet are reported. In the next month, the price at the new outlet is compared to the price collected the previous month in that outlet. For simplicity, suppose the price of only one good is collected. Expression (1), which expresses the Laspeyres as an upper bound to the ideal cost-of-living index, becomes

$$(3) \qquad I(p^t,p^b,u^b) \leq (p^t/p^b) .$$

Consider now a consumer's switch from a regular store to a discount store. In the month following the link to change the Laspeyres price relative would be (p_D^t / p_D^b). But we know that the price differential can overestimate the change in the value of the quality of the retail service. Define $\lambda \geq 0$ such that $p_R - p_D = r_j + \lambda$, implying that $p_D + \lambda = p_R - r_j$. That is, $p_D + \lambda$ is the true quality corrected price of the good at the discount outlet and it is the one that should be used in t to form the Laspeyres price relative. Clearly, $(p_D^t / p_D^b) \geq (p_D^t / p_D^b + \lambda)$. The implication from expression (3) is that without the adjustment λ the upper bound to the ideal CLI provided by the Laspeyres price index is too large. In this way, the link to show no change procedure in the CPI can overstate the difference between it and an ideal CLI.

Similar reasoning can be applied to the case where the consumer switches from a regular store to a high priced store and the high priced store becomes the reference store. It was shown earlier that $h_j \geq p_H - p_R$. Again, define $\lambda \geq 0$ such that $p_R + h_j = p_H + \lambda$. Following the analysis of the previous case, one can see that the price relative without the adjustment λ is greater than the price relative with the adjustment λ. This result also suggests that the current link to show no change procedure provides too large an upper bound to an ideal CLI.

To summarize, the above shows that the link to show no change method can cause the difference between the CPI and an ideal CLI to be larger than it would be if value of retail services were properly accounted for. Also, the overstatement exists whether the consumer switches from a regular store to a discount store or to a high-priced store. However, this result depends on the designated reference store type.

Measurement error and quality change

The quality adjustment techniques applied by BLS are, at best, approximations for the true change in quality. At issue is the magnitude and direction of any substitution effect that arises from measurement error. In general, the quality adjustment technique most frequently applied is the "linking" procedure.[33] This technique is generally adopted because of the absence of information about the difference between the new and old products. Information about pure price change is obtained from the movement in prices of the other commodities in the same stratum and any residual price change between the new product and the price of its previous version is allocated to quality change. Although direct methods of quality adjustment, such as those deriving from hedonic regressions, would provide more precise adjustments, such methods require either larger samples than are currently collected to estimate price changes or a level of detail about product specifications that is typically not collected.

Paul Liegey compared traditional CPI methods for two apparel categories (women's coats and jackets and women's suits) to hedonic-quality indexes and found no single direction of difference between the two.[34] While Robert Gordon[35] finds evidence of a systematic effect arising from quality adjustment procedures, in some durable goods, Jack Triplett notes a nonsystematic effect of quality adjustment procedures for items such as new and used automobiles, airlines, and services.[36] Thus, evidence does not exist that the quality adjustment procedures lead to systematic measurement error.

As discussed earlier, the treatment of new goods is often linked to quality adjustment. For many goods, the distinction between a change in the quality of a product and new product is fuzzy. A quality change is generally perceived as a change in a product's characteristics, and a new good is often defined as a rebundling of a product's characteristics or the addition of new characteristics. For example, in the case of electronic goods it is often difficult to determine whether a new version is simply a product change or a new product.

To further illustrate, consider the case of brand name pharmaceuticals and generics. Although the Federal Food and Drug Administration has determined that generics are equivalent to their brand name counterparts, generics are usually treated as if they are new goods in the CPI program. To bring a new product into the index, some imputation would have to be made about how consumers would have valued the new product had it been available in the previous period. Hedonic methods or other methods that focus on valuing product characteristic changes can be used to estimate this price.

However, as Manuel Trajtenberg points out, in the case of new products, the hedonic methods may not accurately record the quality change.[37] The hedonic approach is based on the idea that a product is composed of a bundle of characteristics, and it yields an estimate of the value of changes in the quantities of the various characteristics in that bundle. It follows that the hedonic approach may miss the quality change arising from new characteristics.

To estimate the possible measurement error, Trajtenberg compared two price indexes for computed tomography (CT) scanners beginning in 1974, the year after their introduction, to 1982. One price index (more akin to the Producer Price Index [PPI] than the CPI) used the hedonic method for measuring changes in quality, the other used another procedure based on measuring consumer surplus. The hedonic-based index indicated that the price of CT scanners declined at an average annual rate of 13 percent, while the alternative index measured the average annual rate of decline at 55 percent. With no adjustment, the price index for CT scanners rose by more than 250 percent for the period. This suggests that the hedonic approach is more appropriate for the changes in the quality of established products. Considerable measurement error may occur for new products.

Another measurement error arising with new goods concerns the introduction date of the good into the index. As discussed earlier, new goods generally exhibit price declines over time, and thus a "too late" inclusion of the new good into the index can result in an overstatement of the price level and rates of change. Zvi Griliches and Iain Cockburn look at the implications of the inclusion date in the PPI for pharmaceuticals and show how the path of the index differs depending on the introduction date.[38] Observe that even if a new good was immediately included in the index, the measurement error described in the previous paragraph would still be possible, in which case the importance of the new good would be understated.

Measurement error and price dispersion

For a given product in a specific area at a particular time, there is, generally, a distribution of prices. This distribution largely derives from transaction costs for the consumer and the producer. Consumers bear "shoe leather costs," the cost of searching for the best combination of prices and services given their preferences. Firms bear the usual explicit costs of production (such as labor, rent, inventory, and so forth) and implicit costs (such as location and contracting costs). Thus, if all the cost data were available, the differences between prices could be removed and the law of one price (as found in the textbook definition of competition), would prevail.

But such data are not available; consequently, the CPI consists of observed prices that may be different from their true values and this may be a source of measurement error. The article by Moulton examines some of the effects of price dispersion on the CPI.

THE CONSUMER PRICE INDEX is a fixed market basket approximation to a true cost-of-living index.

Although the character of the approximation is affected by many factors, this article focuses on sources of possible measurement error. Broadly speaking, these errors are due to the dynamic character of markets: the quality of goods and services change, retail services change, new goods enter the market and existing goods disappear. In addition, for most items, a distribution of prices arises partly from these market factors, but also derives from cost–benefit calculations consumers make to determine how much they will shop for the lowest price, given a retail store's level of service and location.

Capturing these changes presents a formidable task and necessarily involves making some assumptions about equilibrium in the marketplace. Furthermore, because the CPI is not a census of the prices of the items included in the index, sampling issues about selecting prices and outlets also must be addressed in constructing the index. The three articles that follow examine the effects of some of the measurement errors on the CPI. □

Footnotes

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[1] Irving Fisher, *The Making of Index Numbers*, third edition (New York, Houghton Mifflin, 1927), p. 2.

[2] In fact, the theory of the cost-of-living index serves as the framework in which practical questions concerning the assembly of the Consumer Price Index are discussed. See *BLS Handbook of Methods*, Bulletin 2414 (Bureau of Labor Statistics, September 1992), pp. 176–77. See also R. Gillingham, "A Conceptual Framework for the Revised Consumer Price Index," *Proceedings of the Business and Economic Statistics Section*, 1974.

[3] W. Erwin Diewert, "The Early History of Price Index Research," Working Paper 2713 (Cambridge, MA, National Bureau of Economic Research, Inc., September 1988).

[4] A. A. Konus, "The Problem of the True Index of the Cost-of-Living," (1924), *Econometrica* 7, 1939, pp. 10–29.

[5] A commonly used term for a systematic difference is bias. However, there are many kinds of bias, for example, statistical bias; to avoid confusion, the term "effect" will be used instead.

[6] In the CPI, the 'consumer unit,' defined here as a collection of individuals who share expenditures, is taken as the reference for discussion and it is assumed that a single utility function represents the preference of that unit.

[7] For a discussion of the importance of weighting schemes to group cost-of-living indexes, see Robert A. Pollack, *The Theory of the Cost-of-Living Index* (New York, Oxford University Press, 1989), chapter 6.

[8] W. Erwin Diewert, "The Economic Theory of Index Numbers: a Survey," in A. Deaton, ed., *Essays in the Theory and Measurement of Consumer Behavior in Honor of Sir Richard Stone* (London, Cambridge University Press, 1981).

[9] Franklin M. Fisher and Karl Shell, *The Economic Theory of Price Indices* (New York, Academic Press, 1972).

[10] Fisher, *The Making of Index Numbers.*

[11] Laurits Christensen and Marilyn Manser, "Cost of Living Indexes and Price Indexes for U.S. Meat and Produce, 1947–1971," in N. Terlecky, ed., *Household Behavior and Consumption* (New York, National Bureau of Economic Research Studies in Income and Wealth, 40, 1976).

[12] Pollack, *The Theory of the Cost-of-Living Index*, chapter 1.

[13] A self-representing primary sampling unit is an index area that consists of a large metropolitan area. For some of the largest Metropolitan Statistical Areas, the Consolidated Metropolitan Statistical Area is used.

[14] Marshall Reinsdorf, "Changes in Comparative Price and Changes in Market Share," *Managerial and Decision Economics*, 13, 1992, pp. 233–45; and "The Effect of Outlet Price Differentials on the U.S. Consumer Price Index," in Murray Foss, Marilyn Manser, and Alan Young, eds. *Price Measurements and Their Uses* (Chicago, University of Chicago Press, 1993).

[15] This phenomenon derives from the introduction of new weights when a new sample of items is priced. With rotation, the index over time becomes a sequence of new weight introductions. The rotation of outlets causes the drift in the index to be greater than it would be with a fixed market basket. For a general discussion of this point, see F.G. Forsyth and R.F. Fowler, "The Theory and Practice of Chain Index Numbers," *Journal of Royal Statistical Society*, Series A, 1981, pp. 224–46; and B. J. Szulc, "Linking Price Index Numbers," in *Price Level Measurement: Proceedings from a Conference Sponsored by Statistics Canada*, 1983, pp. 537–66. For an application to outlet rotation in the CPI, see Reinsdorf, "Changes in Comparative Price."

[16] As described in the *BLS Handbook of Methods* (page 188), the item and outlet samples are selected separately. Briefly, price quotes from groups of items are allocated to outlets.

[17] For a fuller description of the selection processes, see *BLS Handbook of Methods*, page 188.

[18] Only food is priced monthly; nonfood items are priced bimonthly.

[19] The existence of the time gap causes the upper bound to the CLI provided by the CPI to be overstated. The reason is that the time difference does not capture any outlet substitution that may have occurred for the same commodity. See J. Dalén, "Computing Elementary Aggregates in the Swedish Consumer Price Index," *Journal of Official Statistics*, 8, 1992, pp. 129–47.

[20] The Point-of-Purchase survey period is the base period at the item level. Higher levels of aggregation have a different base period.

[21] See Paul Armknecht and D. Weback, "Adjustments for Quality Change in the U.S. Consumer Price Index," *Journal of Official Statistics*, 5, 1989, pp. 107–23.

[22] A hedonic regression is one in which the dependent variable is price and the independent variables are product characteristics that influence price. The regression coefficients enable one to estimate how changes in the characteristics influence price.

[23] Steven D. Braithwait, "The Substitution Bias of the Laspeyres Price Index: An Analysis Using Estimated Cost-of-Living Indexes," *The American Economic Review*, 70, 1980, pp. 64–77.

[24] Marilyn Manser and Richard McDonald, "An Analysis of

Substitution Bias in Measuring Inflation, 1959-85." *Econometrica*, July 1988, pp. 909–930.

[25] A study by A. Crawford, "Measurement Biases in the Canadian CPI: A Technical Note," *Bank of Canada Review*, Summer, 1993, pp. 21–36, finds similar results for the Canadian CPI. The substitution effect is about 0.1 percent per year, and varies with the degree of movement in relative prices.

[26] With the selection procedure for outlets and items described earlier, it is possible for an outlet to be in the new and old samples, and to have different items priced in each sample. Similarly, price quotes for the same items (for example, food items) may be sought in both the old and new samples, but from different outlets.

[27] Reinsdorf, "Changes in Comparative Price," and "Effects of Outlet Price Differentials."

[28] Reinsdorf's work does not distinguish between seller substitution and outlet substitution as done here.

[29] Average prices are computed for selected food items, gasoline, utility (piped) gas, electricity, and fuel oil.

[30] In a more recent paper, Reinsdorf emphasized the difference in index number formula as an explanation for the difference between the two price series. See "Price Dispersion, Seller Substitution and the U.S. CPI," paper presented at Statistics Canada, Ottawa, Canada, April 1993. Research is continuing on this issue and results will be reported in a future issue of the *Monthly Labor Review*.

[31] See references in Reinsdorf, "Changes in Comparative Price," for studies of price dispersion and Tellis, G., "The Price Elasticity of Selective Demand: A Meta-Analysis of Econometric Models of Sales," *Journal of Marketing Research*, November 1988, pp. 331-41, for evidence of price elasticities of demand greater than 1 at the retail level.

[32] For example, if the distribution of r were symmetric about a single peak (for example, a normal distribution) and the mean of the distribution corresponds to consumers indifferent between the two store types, then the price difference would be an appropriate estimate of the quality difference.

[33] During 1992, 3.5 percent of retail outlet prices collected resulted in product substitutions. More than half of these substitutions, 2 percent, were considered comparable and no quality adjustment was made. About 0.9 percent of prices was "linked" into the index. Of the remainder, 0.4 percent was directly quality adjusted.

[34] Paul R. Liegey, Jr., "Adjusting Apparel Indexes in the Consumer Price Index for Quality Differences," in Murray F. Foss, Marilyn E. Manser, and Allan H. Young, eds., *Price Measurements and Their Uses* (Chicago, University of Chicago Press, 1993). This article provided the research that led to the introduction of hedonic procedures for these strata in January 1991. Before 1991, quality adjustment in these strata was generally done with the linking procedure.

[35] Robert Gordon, *The Measurement of Durable Goods Prices* (Chicago, University of Chicago Press, 1990).

[36] Jack Triplett, "Price Index Number Research and its Influence on Data: A Historical Review," paper presented at the 50th anniversary conference of the Conference on Research in Income and Wealth, Washington, May 12, 1988. Also, hedonic techniques are being applied to used cars, see Jeffrey H. Kellar, "New Methodology Reduces Importance of Used Cars in CPI," *Monthly Labor Review*, December, 1988, pp. 34-36.

[37] Manuel Trajtenberg, "Product Innovations, Price Indices and the (Mis)Measurement of Economic Performance," Working Paper 3261 (Cambridge, MA, National Bureau of Economic Research, Inc., 1990).

[38] Zvi Griliches and Iain Cockburn, "Generics and New Goods in Pharmaceutical Price Indexes," (Harvard University, Department of Economics, December 1992).