Report from the

Bureau of Labor Statistics

for the

House Budget Committee

UNITED STATES CONGRESS

April 28, 1995

This report on the Consumer Price Index (CPI) has been prepared in response to a recommendation contained in the House Budget Committee's 1995 Budget Resolution (Report 103-428) that "the Department of Labor report...with findings on possible biases implicit in the current formula (for the CPI), an evaluation of whether the current formula accurately reflects the current inflation rate, an evaluation of whether factors included in the current formula are applicable to revenues and outlays which are indexed to inflation, and a recommendation on whether a change in the calculation of the CPI is warranted or whether a formula other than the CPI should be developed for indexing revenues and outlays within the federal budget."

Since the report language was introduced, there have been a number of meetings between Bureau of Labor Statistics (BLS) staff and Committee staff concerning the CPI. The following pages address questions concerning the relationship between the CPI and a cost-of-living measure, alternative measures of inflation that are available or could be produced, biases implicit in the CPI that may cause it to overstate inflation, and BLS research into potential solutions to these problems. Information also is provided on relevant characteristics of the CPI and alternative price index formulations that bear on the indexes' use as escalators; decisions concerning whether and how any particular measure should be used in escalation, however, lie outside the purview of a statistical agency such as BLS.

I. Background and History

A price index attempts to reduce the comparison of prices of goods and services at two different points in time to that of a single number. The calculation of the index should reflect the purpose for which the index has been constructed. The point that there is no one price measure that answers all questions was made prior to the existence of the U.S. Consumer Price Index by Dr. Wesley C. Mitchell, Director of Research of the National Bureau of Economic Research, 1920-45:

> "The choice of methods to be employed in making an index number should be guided by the purpose for which the results are to be used. These purposes are so numerous and so diverse that it is impossible to make a single series well adapted to them all. Probably the time is near when certain uses will be so standardized that several divergent types of index numbers will be regularly compiled to serve the needs of various groups of users."[1]

The Consumer Price Index,[2] originally called the cost of living index, was initiated during World War I "...when rapid changes in living costs, particularly in shipbuilding centers, made such an index essential in wage negotiations."[3] Its function was to adjudicate labor disputes so that national defense production would not be interrupted. Despite its original title as a cost of living index, "it has always been merely a measure of changes in prices of goods and services purchased for family living."[4] Since its inception the CPI's uses have multiplied and, as one of the most widely used statistical measures, it has perhaps been the subject of more analysis and appraisal than any other series. One of the first comprehensive reviews of the index was made in

[1] Wesley C. Mitchell, The Making and Using of Index Numbers, Bureau of Labor Statistics Bulletin 173, 1915, page 112.

[2] Although this report uses the phrase "the Consumer Price Index" throughout, the BLS actually has produced two CPI's since 1978. One, the Consumer Price Index for All Urban Consumers (CPI-U), covers approximately 80 percent of the U.S. urban population. The second, the Consumer Price Index for Urban Wage Earners and Clerical Workers (CPI-W), covers about 34 percent of the U.S. urban population.

[3] Changes in the Cost of Living in Large Cities in the United States, 1913-41, Bureau of Labor Statistics Bulletin 699, 1941, page 1.

[4] The Consumer Price Index: History and Techniques, Bureau of Labor Statistics Bulletin 1517, 1966, page 2.

1933-34 by the Advisory Committee appointed by the American Statistical Association (ASA) at the request of the Secretary of Labor. This review led to a number of improvements that were introduced as part of the first CPI revision in 1940. A description of the revised CPI, however, noted that "The Bureau's cost-of-living indexes have certain limitations which should be remembered by those who use them. They represent changes in the living costs of wage earners and lower-salaried workers, not of all urban families. They cannot take account currently of the way in which moderate-income families adjust their purchases to changes in prices, and, for example, buy more pork and less beef when pork is relatively cheap and beef is relatively dear, more rayon and less wool when rayon prices remain stable and wool prices go up."[5]

Another ASA committee was appointed in 1943 to review and appraise the index, principally with respect to the issues concerned with price controls and rationing. Failure to resolve a number of issues resulted in a tripartite committee representing labor, business, and Government being appointed at the instigation of President Roosevelt. Following this review, the title of the index was changed from "cost-of-living index" to "Consumer Price Index for Moderate Income Families in Large Cities." The committee recommended that an allowance (estimated later at 5 percentage points as of September 1945) be used in the application of the index to wage stabilization in the war economy, but that the allowance not be incorporated into the official figures. From June 1944 through December 1946, each month's report on the CPI explained that "the index does not show the full wartime effect on the cost of living of such factors as lowered quality, disappearance of low-priced goods, and forced changes in housing and eating away from home." By the end of 1946, a number of these factors had disappeared or decreased in importance and the statement was dropped from BLS reports.

In 1951, a subcommittee of the Committee on Education and Labor of the House of Representatives under the chairmanship of Representative Tom Steed initiated an investigation of the CPI, for the following reasons: "1) The Consumers' Price Index has become an extremely

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[5]Changes in Cost of Living in Large Cities in the United States, 1913-41, Bureau of Labor Statistics Bulletin 699, 1941, page 8.

important factor in maintaining harmonious labor-management relations. 2) The Consumers' Price Index affects, in numerous ways, all the citizens of the country. 3) Since the index is a statistic promulgated by a governmental agency, it should be the best and most accurate available. 4) Any governmental statistics of such paramount importance as the Consumer Price Index should be understood by the public so that it will receive proper confidence and respect."[6] The hearings clarified the meaning, construction, uses, and limitations of the index. On the basis of testimony presented, the subcommittee concluded that "the Consumer Price Index of the Bureau of Labor Statistics is an excellent index and that it enjoys widespread confidence among labor and management groups and the general public."[7]

In 1959 the Joint Economic Committee of the Congress in its report on Employment, Growth, and Price Levels included a brief evaluation of the nature and limitations of the CPI. This report mentioned "several important deficiencies, most of which are extremely difficult to deal with by precise statistical techniques."[8] These included problems faced in dealing with changes in quality of items included in the index, and in determining when, which, and by what methods entirely new items are to be introduced into the index.

In July 1959, a Price Statistics Review Committee under the chairmanship of Professor George Stigler was created by the National Bureau of Economic Research under contract with the Office of Statistical Standards of the Bureau of the Budget. The committee's function was to review the basic concepts and procedures underlying data collection and calculation procedures for the various price series published by the Federal Government and to make suggestions for their extension and improvement. The Review Committee's major recommendation was that the CPI should be moved toward becoming an index of welfare or constant utility rather than remaining a price index. The concept of a constant utility index, which bases price change upon a comparison of different market baskets which are judged to be equivalent in some objective

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[6]Consumers' Price Index (U.S. House of Representatives, Special Subcommittee of the Committee on Education and Labor, 80th Congress 2nd session, 1951), page 1.
[7]Ibid., page 31.
[8]Employment, Growth and Price Levels (Staff Report, Joint Economic Committee, 86th Congress, 2nd session, December 1959).

sense, is extremely complex and has not been formulated in operational terms. After serious consideration, the BLS decided to maintain the basic historical orientation of the index as a "constant market basket" index, but many of the Review Committee's other recommendations did influence the structure of the revised CPI first published in 1964.

Although there has not been a comprehensive external evaluation of the CPI since the Stigler Report, examinations of selected issues related to the program--the measurement of homeowners' costs, the use of the CPI for indexation, the construction of a CPI for the elderly-- were provided to the Congress by the Comptroller General during the early 1980's. In addition, the annual budget submissions, particularly those immediately preceding a major revision of the CPI, have offered the Administration and Congress the opportunity to evaluate its theoretical underpinnings and the operational procedures used in its construction. At the end of World War II, formal advisory relations were established with the labor and business communities, providing them with the opportunity to evaluate the Bureau's programs and propose changes in them. Although the Bureau has never established a formal advisory relationship with the academic community, a research and evaluation seminar series has been maintained with a series of guest speakers and the Bureau has directly supported research on specific topics of interest. In particular, a series of papers on theoretical aspects of the "cost of living" index by Professor Robert Pollak were written with support of the BLS. These papers were later collected and published under the title "The Theory of the Cost of Living Index" by Oxford University Press in 1989.

Following its original purpose as a measure to be used in wage negotiation in World War I, the CPI has been put to numerous uses. The three principal areas of use are: 1) as an economic indicator, 2) as a deflator of other economic series, and 3) as an escalator used in adjusting wages, income payments, and tax brackets. The acceleration of inflation in the late 1960's in particular led to a sharp increase in the number of legal or statutory uses of the CPI. These included the indexation of Social Security payments in 1972 and, later, in 1985, the adjustment

of the Federal income tax structure to prevent inflation-induced increases in taxes.[9] The proliferation of uses makes it unlikely that any one index is optimal for each such use, even within one of the three general groups.

In addition to the CPI, there are several other price measures produced by the Federal Government. These include the Producer Price Index (PPI) and the Export and Import Price Indexes, all of which are produced by the Bureau of Labor Statistics, and several price series compiled by the Bureau of Economic Analysis (BEA) of the Department of Commerce in conjunction with the National Income and Product Accounts. The PPI measures the average changes in selling prices received by domestic producers for their output. The export and import price indexes measure changes in price levels within the foreign trade sector; the former provides a measure of price change for domestically produced U.S. products sold to purchasers in other countries, the latter for goods purchased from other countries by U.S. residents. The BEA produces four price measures associated with the gross domestic product--the implicit price deflator, a fixed weight price index, a benchmark-years weighted price index, and a chain-type annual-weighted price index. Each of the four measures is calculated for the entire GDP and for the consumer, investment, government, and international sectors. These measures use different weighting schemes and are developed using price information primarily collected for the CPI, PPI, and export and import price surveys that BLS conducts. The measure most similar to the CPI is the fixed-weight index for personal consumption expenditures (PCE), although there are important differences in definition and coverage between the two.[10] The fixed-weighted index reflects 1987 quantities and data are available beginning in 1982. The chain-type annual-weighted price index and the benchmark-years weighted price index are superlative-type indexes

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[9] The former are tied to the CPI-W, and the latter to the CPI-U.

[10] First, the PCE measure includes items such as purchases by nonprofit institutions, casino gambling, and imputed transactions that are not covered by weights underlying the CPI. Second, PCE items such as auto insurance and purchases at nonprofit hospitals and universities are covered in the CPI, but are defined differently. Third, other PCE items, such as computers and airline tickets, are covered in the CPI, but in the PCE use non-CPI price indexes. Fourth, comparable PCE and CPI items also differ in the weights assigned to them. The PCE weights are based largely on BEA's input-output table; the CPI weights are based on consumer expenditure surveys. Finally, the Laspeyres PCE measure is based on weights for 1987; the CPI Laspeyres measure uses 1982-84 expenditure weights.

using the Fisher Ideal formula.[11] The quantity weights for these measures are the geometric means of the two bounding periods. For the chain-type annual-weighted index, weights for the two consecutive years that the change refers to are used (i.e. the 1993 index employs weights for 1992 and 1993). For the benchmark-years index, 1982 and 1987 weights are used for that interim period, and 1987 and 1992 weights are used for the next period. In the time period after 1992, the benchmark-years price index uses quantity weights for 1992 and the most recent year. Thus, until data for the next benchmark year--1997--become available, published indexes for 1993 forward are subject to annual revision. The implicit price deflator is not, in a technical sense, a price index, since it reflects changes in both prices and quantities. It is derived as a byproduct of the estimation of the constant dollar PCE simply by dividing the current-dollar PCE by the constant-dollar PCE and does not require conventional index number construction in its calculation. Further details on the BEA measures are contained in the April 1992 issue of the Survey of Current Business.[12] Inflation rates as measured by the CPI and PCE series for recent years appear in Table 1.

II. Alternative Measures of Price Change

Conceptual Considerations

Economic theory provides alternatives to the fixed weight, expenditure-based Laspeyres index that is the current CPI. These include alternative formulas for expenditure-based indexes, as well as index formulas for expanded "cost-of-living" concepts.

Within the class of expenditure-based indexes, the choice of formula depends upon assumptions about consumer preferences and what is considered the relevant market basket of expenditures for use as the reference or index base. Some of these other formulas have superior properties in theoretical terms, but present severe or even insurmountable operational problems

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[11] See the mathematical appendix for the index number formula.

[12] Allan H. Young, "Alternative Measures of Change in Real Output and Prices," and Jack E. Triplett, "Economic Theory and BEA's Alternative Quantity and Price Indexes," *Survey of Current Business*, April 1992, pages 32-52.

that probably preclude their use to constru t the CPI. Two examples are the Fisher Ideal index and the Tornqvist index, which belong to a class of index formulas termed "superlative."[13] Unlike the Laspeyres formula, these indexes take into explicit consideration the behavior of consumers when confronting changes in relative prices and are closer to the theoretical concept of an expenditure-based "cost-of-living" index. These formulas incorporate expenditure weights from both the reference and comparison periods, so that the problem of substitution bias inherent in the Laspeyres formula is mitigated. Suppose one wishes to estimate price change between 1984 and 1994, and that over this period, the relative price of butter has increased substantially, causing consumers to substitute margarine for butter. The Fisher or Tornqvist price index formula includes both the 1984 and 1994 expenditure weights, so that the price increase for butter reflects the average expenditure weight it held in the consumer's budget for both years. The importance of the price increase for butter, given by its expenditure weight, is not overstated relative to how much butter consumers are purchasing in 1994.

The superlative formulas have been demonstrated in theoretical terms to be good approximations to a cost-of-living index based on flexible consumer preferences, without requiring that one make explicit assumptions about the parameters that define those preferences. The Fisher and Tornqvist formulas, however, require expenditure weights, and thus consumer expenditure data, from both the reference and comparison periods. This means that, if these formulas were used to produce official "CPI" measures, they would not provide current, timely index statistics, because they could not be produced without a significant lag.

The "cost-of-living" concept embodied by the CPI and alternative expenditure-based formulas is not the only, and certainly not the most comprehensive, one possible. The general idea of a cost-of-living measure incorporates the state of many economic factors: the level of private market goods and services that can be purchased; the level of public or government-provided goods and services one enjoys; and the quality of the environment. In this general

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[13] For a detailed discussion of these index formulas and their properties, see Diewert, W. E., "The Theory of the Cost-of-Living Index and the Measurement of Welfare Change," in Diewert, W. E., and C. Montmarquette (eds.), Price Level Measurement, Ottawa: Statistics Canada, 1983, pp. 163-233.

context the cost-of-living index is the answer to the following question: "What is the minimum amount of expenditure that is required for a consumer to be equally satisfied in one economic situation versus another?" The two economic situations being compared may be two different time periods such as 1984 and 1994. If one situation involves higher prices for goods the consumer consumes than the other, for example, then some amount of compensation would be required to enable the consumer to enjoy the same degree of satisfaction after the price increase as he or she did before the price increase. Similarly, if a new situation involved a lower level of government-provided services than had previously been supplied, the consumer might require compensation to remain as well off as before the decline. One can imagine a family of cost-of-living index concepts that vary with respect to how, and for what, compensation to the consumer is contemplated. Any xpenditure-based index, such as the CPI, is only one member of this family and is, thus, a "subindex" of the general cost-of-living index concept.[14] When evaluating the effects of changes in prices in the expenditure-based income context, one is implicitly assuming that all other factors that affect overall well-being or compose a standard of living remain the same. Other cost-of-living index definitions include the income-based cost-of-living index, a nonmarket goods-inclusive index, and a partial-income index.

The specific question posed by an expenditure-based cost-of-living index is: "What is the ratio of expenditures on private goods and services that is required to maintain a given, fixed standard of living under two price regimes?" The relevant question for an income-based cost-of-living index is: "What ratio of (pretax) incomes would be required to maintain a given, fixed standard of living under two price regimes?" Since compensation for inflation is usually provided through increases in income (or some component of income), the income-based definition would appear to be theoretically more appropriate. It does, however, present some theoretical and practical difficulties as an escalation measure. First, since income in a given period may be allocated between expenditures on goods and services in that period and savings

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[14] For a general discussion of the concept of subindexes, see Pollak, Robert, "Subindexes of the Cost-of-Living Index," *International Economic Review*, vol. 16, 1975, pp. 135-150.

(which represent expenditures in the future), economists must include the preferences of consumers over several time periods in framing the index. This presents theoretical problems that seem unlikely to be resolvable, absent futures markets for all goods and services.[15]

From a practical perspective, an income-based index requires reliable data on consumer income and savings, which are more difficult to acquire than expenditure data. Also, in an economy where there are taxes imposed directly on income, an income-based cost-of-living index would increase with any increase in those taxes (including the Social Security payroll tax), even if the prices of goods and services remained the same. Whereas an expenditure-based index would show an inflationary effect from increases in sales or excise taxes, an income-based index would show the effects on the consumer's ability to purchase market goods and services of changes in both sales and income taxes. If, for example, a sales tax were to be substituted for an income tax as a means of raising the same level of government revenue, an income-based index would not show the same inflationary impact as an expenditure-based index.

In the income-based framework, an increase in income taxes that was used to purchase an increased level of government-provided goods and services, such as an improvement in environmental quality,[16] would be reflected in the index as an increase in the price level. If consumers value those government-provided amenities, then a more appropriate index would include them in its definition of expenditures, creating a nonmarket-goods inclusive index. This more comprehensive cost-of-living index concept would answer the question: "What change in income is required to maintain a given, base period standard of living, defined in terms of private goods and services, public goods and services, and environmental amenities?" Despite much research effort over many years, no one has developed a method of constructing a reliable estimate of the value to consumers of a given level or "quantity" of public goods and services or environmental amenities. Because these services are not exchanged in market transactions,

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[15] See Pollak, Robert, "The Intertemporal Cost-of-Living Index," *Annals of Economic and Social Measurement*, vol. 4, 1975, pp. 179-196.

[16] For an explicit theoretical framework for the inclusion of environmental amenities in the cost-of-living index, see Pollak, Robert, "The Treatment of the Environment in the Cost-of-Living Index," in Pollak, R. (ed.), The Theory of the Cost-of-Living Index, Oxford University Press, 1989.

prices that reflect their value to consumers cannot be observed. Because they are public goods, meaning that the provision of a given level of them to one consumer automatically provides that same level to other consumers, each consumer has the incentive to understate his or her true willingness to pay for them. This makes an assessment of their true value to consumers difficult to obtain, even by survey methods. Thus, this comprehensive cost-of-living index concept, while theoretically desirable, is impractical at the present time.

Another alternative cost-of-living concept is the partial-income index, based on the recognition that compensation for inflation may be provided through only one component of income. It answers the question: "What change in a specified income component is required to achieve a level of total income that maintains a given, base period standard of living?" For example, if a consumer receives income from both Social Security, which is escalated, and a pension, which is not, then the escalation needed to maintain a constant level of satisfaction would be greater than if all sources of income were escalated. If the purpose of escalating the given income component is to provide the individual consumer a given level of satisfaction, then this measure is the appropriate one. However, because of the many sources of income that may be adjusted for inflation, it is difficult to imagine a scenario in which one would become the vehicle for compensation for overall changes in the consumer's economic circumstances.

Use in Escalation for Federal Programs

While responsible for the compilation and publication of the CPI, the BLS of course does not have responsibility for its use in escalation provisions, which are determined either by specific legislation or by the contracting parties to the agreement. Nevertheless, it may be useful to particularize the general points made above to the use of the CPI as an escalator for Federal expenditures and revenues. The appropriateness of an escalation measure depends upon the purpose of escalation and the economic variable(s) that are to be adjusted by the measure. Generally, in the government context, the stated purpose of escalation is to provide some degree of inflation protection to the recipients of a benefit or the contributors of government revenue.

This suggests that a cost-of-living index of some type is the desired measure. In practice, however, there may be subsidiary reasons for applying an escalation measure. For example, the use of the CPI to adjust Social Security benefits removes the element of political discretion and policy judgment from the amount of escalation to be applied; the process has become institutionalized and tied to a nonpolitical, objectively-derived index of price change. In this particular case the decision to tie government benefits to the CPI lowered the rate of increase in per person benefits.[17]

The choice of a particular cost-of-living concept to use depends upon both economic theory and any practical limitations of an empirical representation of the theoretically desired concept. If the purpose of escalation is to protect citizens completely from inflationary erosion of their incomes, then, in theory, an income-based cost-of-living index is the appropriate measure. As discussed above, partial-income cost-of-living indexes may be applicable if only one component of income is to be adjusted, and it is assumed that other components are not protected.[18] If the purpose of escalation is to maintain the purchasing power of particular benefit payments or pretax income, where purchasing power is defined as the ability to maintain current consumption of goods and services, then an expenditure-based index, for which the CPI is a practical approximation, may be appropriate.

The history of the Consumer Price Index suggests the importance of such a measure of price change to policy-makers and analysts, even before the theoretical context of the published index had been established. The CPI has been subject to careful review and economic analysis over its history. Its definition has been specifically established, and changes have been made over the years to improve the index and to recognize its importance as an upper bound to a true expenditure-based cost-of-living index. The CPI is produced in a timely manner in a complex and changing economy, and, as a real world statistic, is subject to constraints such as the

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[17] Before indexing was adopted in 1975, Social Security benefits per recipient rose more rapidly than the CPI. (Goldfeld, S., V.D. Ooms, Report on Indexing Federal Programs, Washington, D.C.: Executive Office of the President, Council of Economic Advisers and Office of Management and Budget, 1981.)

[18] See Triplett, Jack, "Escalation Measures: What is the Answer? What is the Question?," BLS working paper 132, December, 1982.

appearance of new goods and lack of observable information on the value of quality changes. Increasingly sophisticated quality adjustment procedures, analysis of sampling and the formulas used to construct the index, and other ongoing research within the BLS continues to address the problems of producing a practical index that is theoretically valid. This index is not intended to serve any and all escalation needs; indeed, it is impossible for any single index measure to do so.

III.   Summary of Recent Criticisms of the CPI

Given its policy target of keeping inflation in check, the Federal Reserve is extremely interested in the measurement of price change. There have been two comprehensive reviews of BLS price indexes produced within the Federal Reserve System. One was produced by staff economists at the Board of Governors of the Federal Reserve System (FRB)[19] and the other was produced by staff economists at the Federal Reserve Bank of Dallas (FRB-Dallas).[20] At the request of the House Budget Committee, the Congressional Budget Office (CBO) also produced a report.[21] Each report discusses similar aspects of the CPI. These may be placed into three categories: Substitution Bias, Functional Form Effects, and Quality Effects. The reports, however, differ in their evaluation of the empirical evidence and the attending implications for measurement error in the CPI. It should be emphasized that most of the empirical work cited in these studies was conducted by BLS researchers. One also should note that the effects of these problems have not been derived independently and thus are not additive.

Substitution Bias: The concern here is with the inability of a fixed-weight index such as the CPI to account for changes in consumption induced by changes in relative prices. For example, if the price of margarine falls relative to the price of butter, then consumers will purchase more margarine and less butter. In the CPI, however, the quantities of both goods are

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[19] Lebow, D.E., Roberts, J.M., and Stockton, D.J., "Monetary Policy and the Price Level," Division of Research and Statistics, Board of Governors of the Federal Reserve, August 1994.

[20] Wynne, M.A., and Sigalla, F.D., "The Consumer Price Index," *Economic Review*, Federal Reserve Bank of Dallas, Second Quarter 1994.

[21] "Is the Growth of the CPI a Biased Measure of Changes in the Cost of Living?," Congressional Budget Office, October 1994.

fixed, so that the impact of this switch, which softens the fall in the consumer's satisfaction, is missed. There is little disagreement about the magnitude of this bias. The FRB report puts its estimate in the interval 0.1 to 0.2 percentage points per year, while the CBO report puts its estimate in the interval 0.1 to 0.3 percentage points per year. The report from FRB-Dallas concludes "The bottom line on substitution bias is that this particular form of bias in the CPI is probably relatively unimportant quantitatively, amounting to at most 0.2 percentage points per year."[22]

Functional Form Effects: This designation is not specifically given in any of the reports. It is used here to combine related issues that have received much recent attention.

As part of an effort to ensure that new stores and new products are represented in the index, the BLS regularly replenishes, or rotates, the sample of outlets from which it collects the prices of products. Although the adoption of this procedure in 1978 eliminated some of the problems with a fixed-weight index, it has been discovered that the new procedure has some weaknesses. First, there is a concern about whether the Laspeyres form of the index used to estimate price change at this level is appropriate.[23] Second, for many goods, the rotation happens to catch the goods on sale, which turns out to mean that subsequent price increases (when the good comes off sale) are accorded a higher weight than they should receive. The rotation also involves the issue of quality measurement. BLS treats any price differential between outlets, for the same good, as deriving from a difference in the quality of the associated retail services the outlets provide. These aspects of the BLS procedures have come under close scrutiny and have led to a re-evaluation. The BLS presented estimates and a discussion of these factors in the December 1993 issue of *The Monthly Labor Review*.

The FRB report concludes that the total impact of this effect is between 0.3 and 0.5 percentage points per year. The report uses the estimates provided in Moulton (1993)[24] and

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[22] Wynne and Sigalla, page 5.

[23] Statistical agencies in several other countries also are examining the appropriate form of the index that should be used at the basic level of the index.

[24] Moulton, B., "Basic Components of the CPI: Estimation of Price Change," *Monthly Labor Review*, December 1993.

Reinsdorf (1993),[25] to arrive at this number. Moulton's paper provides a comparison of indexes estimated using the current formula and a geometric mean formula, an index form that makes different assumptions about consumers' substitution behavior and that does not produce a systematic overweighting of prices introduced into the sample at sale levels. But there are two caveats that need to be kept in mind: only one year's worth of data was used and the data only pertained to 70 percent of the CPI. The Reinsdorf paper focused exclusively on the food-at-home and energy components which together account for just 13 percent of the CPI expenditure weight. The FRB report takes these estimates and extrapolates them to other components of the CPI— "It seems reasonable to assume that similar trends may be at work for goods and services other than food and energy."[26] The report goes on to specify categories where it is thought that retail substitution bias, as it is called, is present.

The CBO report focuses on what it calls the sample rotation bias and estimates its value to be between 0.2 and 0.3 percentage points per year. Because this estimate is based on the same empirical work that forms the basis of the FRB estimate, the disparity is interesting. It arises out of caution by the CBO in light of the caveats cited above. The report goes on to state that "The conclusion of a bias of 0.3 percentage points should be considered tentative until more work can be done."[27]

The FRB-Dallas Report references the findings of the above cited studies, making no estimation of its own. It does, however, go to great length to stress the caveats associated with these estimates.

Quality Effects: This is a broad category. It includes consideration of how well changes in the quality of existing products (changes in their characteristics) and the introduction of new products are accounted for in the CPI. In many cases it is difficult to differentiate clearly

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[25] Reinsdorf, M., "The Effect of Outlet Price Differentials on the U.S. Consumer Price Index," in M.F. Foss, M.E. Manser, and A.H. Young, (eds.), Price Measurements and Their Uses, NBER Studies in Income and Wealth, vol. 57, Chicago, University of Chicago Press.

[26] Lebow, et. al., page 9.

[27] CBO Report, page 6.

between a change in quality and the introduction of a new good.[28] The concern, however, need not be restricted to product characteristics. As noted above, during sample rotation, outlets change and different outlets often charge different prices for the same item. One may think of the price differential between outlets as arising from a difference in the quality of retail services.

Because of its product (service) specificity, it is extremely difficult to measure the effects of changes in quality on prices. More specifically, one cannot assume that the empirical evidence relating to one type of good can be extrapolated to all goods. For example, work by BLS staff has shown that in the apparel category, one obtains quality effects for men's clothing that are different from those for women's clothing.[29]

All three reports cite previous studies about quality measurement for selected goods or classes of goods. There has been no systematic study across the various goods/services classes comprising the CPI. That is important to keep in mind as one considers the various estimates.

The FRB report estimates that quality effects add between 0.0 and 0.8 percentage points per year to the CPI. This estimate is a combination of two estimates: the effect arising from inadequate quality adjustment, amounting to at most 0.3 percentage points a year, and the effect arising from a failure to correctly account for new goods, amounting to at most 0.5 percentage points per year. The first estimate is obtained by taking a result obtained in a study of consumer durable good prices and applying it to "categories where year-to-year quality adjustment difficulties appear most acute...."[30] In making their second estimate the authors "make some rather extreme assumptions to estimate a rough order of magnitude for this effect. ... Our assumptions surely make the estimate an upper limit on this effect."[31]

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[28] This is especially true for electronic goods such as computers. Though one can view the incorporation of a new characteristic as a dividing line between quality change in an existing good and a new good, in many cases the change in a characteristic is so extreme that, in effect, the good is a new good.

[29] Liegey, P.R., Jr., "Apparel Price Indexes: Effect of Hedonic Adjustments," *Monthly Labor Review*, May 1994.

[30] The study referred to is Gordon, R., The Measurement of Durable Goods Price, Chicago: University of Chicago Press. The quote is on page 10 of Lebow, et. al.

[31] Lebow, et. al., page 11. The assumptions are: a rate of price decline equal to that experienced for computer equipment and the selection of categories of consumer expenditures for which new products purchased by consumers are likely to be a major factor.

The CBO report, recognizing that it is difficult to make general statements about the magnitude of quality effects, focuses on selected product groups: Prescription drugs, Major appliances, and Anti-pollution adjustment. The estimated magnitudes respectively are 0.0 to 0.1, 0.0 to 0.1, and -0.1 to 0.0 percentage points. The report estimates the overall quality effect as falling between -0.1 and 0.2 percentage points. A negative quality effect would mean that the BLS was over-adjusting for quality change. This perhaps occurs with pollution equipment because the benefits accrue to "society at large, and there is no indication that consumers would have valued it at the full cost of the improvement."[32]

The FRB-Dallas report summarizes various studies of the impact of mismeasured quality change and the introduction of new goods. Again, the report devotes a considerable amount of space to identifying measurement problems and the weaknesses of the studies cited. In commenting on the FRB report, the Dallas report concludes "New goods bias could well be a lot higher or a lot lower than their calculation suggests; we simply do not know."[33]

Were it possible to add the values of all the estimated effects, the FRB report suggests that the total bias in the CPI lies between 0.4 and 1.5 percentage points per year. The CBO report suggests that the total bias lies between 0.2 and 0.8 percentage points per year. The FRB-Dallas report concludes that a figure of less than 1 percentage point is a plausible estimate for the overall bias. The one conclusion that can be unambiguously drawn is that there is a great deal of uncertainty about the magnitude of the overall bias in the CPI.

IV. Summary of BLS Research Relating to Recent Criticisms

Commodity Substitution

The Consumer Price Index is designed to measure price change for a fixed market basket of goods and services representing average consumption patterns during a base period. An

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[32] CBO Report, page 13.
[33] Wynne and Sigalla, page 14.

economic cost-of-living index, on the other hand, would measure the change in the cost of obtaining a fixed level of economic well-being. Although the CPI is designed to measure a different concept than a cost-of-living index, some use it as a proxy for a cost-of-living measure. Thus, there has been considerable interest in estimating the differences between the CPI and a cost-of-living measure.

Researchers at the Bureau of Labor Statistics have conducted several empirical studies of the differences between the CPI and alternative index number measures that allow for the substitution of commodities by consumers as relative prices change. These studies have consistently found that a Laspeyres index tends to grow 0.1 to 0.2 percentage points per year faster than alternative measures that allow for consumer substitution, such as the Fisher or Tornqvist indexes.[34]

These BLS studies represent the state of the art in empirical measurement of commodity substitution effects, but several important caveats should be attached to these measurements. These measurements have assumed that consumer tastes have remained constant over the measurement period. They have largely been based on the expenditures of a representative consumer, thus overlooking issues of aggregation across consumers. Thus, the effects of geographical shifts, demographic changes, and changes in consumption motivated by factors other than changes in relative prices may be confounded with the measurement of substitution effects. Also, these studies have treated prices and expenditures as known amounts rather than as estimates subject to sampling error. Finally, a true cost-of-living index would be affected by non-market goods, which are not measured in a study of commodity substitution effects.

The alternative indexes that take account of consumer substitution all require current-period information on consumer expenditures. Because expenditure information is unavoidably

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[34] Braithwait, S.D., "Substitution Bias of the Laspeyres Price Index: An Analysis Using Estimated Cost-of-Living Indexes," *American Economic Review*, March 1980; Kokoski, M.F., "Consumer Price Indexes by Demographic Group," working paper 167, Bureau of Labor Statistics, 1987; Manser, M.E., and McDonald, R.J., "An Analysis of Substitution Bias in Measuring Inflation, 1959-85," *Econometrica*, July 1988; Aizcorbe, A.M., and Jackman, P.C., "The Commodity Substitution Effect in CPI Data, 1982-91," *Monthly Labor Review*, December 1993.

collected and processed with a delay, the alternative indexes can be calculated only with a delay of at least one year (more realistically two years).

Sampling and Estimation

In 1978 BLS, in response to the recommendations of the Stigler commission and leading economists and statisticians, changed the CPI sampling and estimation procedures to begin collecting samples that are representative of all goods and services that are purchased by consumers. The sampling procedures (for items representing about 70 percent of the CPI market basket) were designed to select items for pricing with probability proportional to consumer expenditures. Statistical theory then was used to show that a particular estimation formula, consisting of averages of the ratios of prices to base-period prices, produces an unbiased estimate of a Laspeyres price index.

Shortly after 1978 the BLS began routinely replacing (or "rotating") one-fifth of the sample each year to prevent deterioration in sample size and to capture price changes for currently purchased items. Expenditures are estimated from the Point-of-Purchase Survey, which is conducted 1-2 years before a sample is selected. When the sample in a particular city is replaced, prices are collected for both the old and new samples during one month and the indexes from the old sample are "linked" to the indexes from the new sample.

Recent research by BLS researchers has uncovered a problem in the estimation procedures as sample items are introduced into the CPI. The base price for the sample item should represent its price during the expenditure base period. Because the sample item had not yet been selected during the base period, a method is required for estimating or approximating the base price. The procedure used by BLS has been to take the price of the sample item during the link month and deflate it to the base period using the price index for the item. BLS research has shown that this procedure causes items that are on sale when they are introduced to the sample to receive a disproportionately large weight—the expenditure weight is divided by an atypically low base price for the item on sale. These items are likely to go off sale the next

period, and thus show a price rise. Conver ely, a relatively smaller weight is applied to items that are off sale when the new sample is introduced, and may go on sale the following period. The net effect is that the estimator may apply too much weight to price increases and too little weight to price decreases immediately after the introduction of a new sample or a new sample item.[35]

At least three methods have been considered by BLS for improving the estimation procedure. Improvements to the method for estimating the base prices have been considered. Another possible approach that has been examined in some of the research articles is to change the estimation formula to an alternative formula (such as a geometric mean or a ratio of averages) that does not involve the use of base prices. This is an alternative that requires careful deliberation, however, since a change of the estimation formula may involve a change in the index concept that is being estimated. The method that BLS adopted in January 1995 for addressing the estimation issue for food-at-home items is to hold out the new samples for three months after the base prices are set. This procedural change helps to remove the mechanical correlation between estimated base prices and price changes for new samples of food-at-home items, which because of frequent sales are the items that are most affected.[36]

Another potential problem related to sample rotation also has been raised by BLS research and received significant attention from the press. This is the treatment of new discount outlets in BLS sampling and estimation procedures. Discount outlets, like all other types of outlets, are selected for CPI samples in proportion to consumer expenditures as reported in the Point-of-Purchase Survey. The estimation procedures never directly compare prices between new outlets and old outlets. Thus any savings (after netting out quality differences) that consumers potentially receive from switching to discount outlets are not reflected by the CPI.

[35] Reinsdorf, M., "Price Dispersion, Seller Substitution, and the U.S. CPI," working paper 252, Bureau of Labor Statistics, 1994; Fixler, D., "The Consumer Price Index: Underlying Concepts and Caveats," Monthly Labor Review, December 1993; Moulton, B.R., "Basic Components of the CPI: Estimation of Price Changes," Monthly Labor Review, December 1993; Reinsdorf, M., and Moulton, B.R., "The Construction of Basic Components of Cost of Living Indexes," working paper 261, Bureau of Labor Statistics, 1995.

[36] Armknecht, P.A., Moulton, B.R., and Stewart, K.J., "Improvements to the Food at Home, Shelter, and Prescription Drug Indexes in the U.S. Consumer Price Index," working paper 263, Bureau of Labor Statistics, 1995.

There are several reasons for thinking that consumer switching to discount outlets is not a serious problem for the CPI as a measure of price change. Any failure of the CPI to incorporate price declines due to entry of discount outlets in principle can not exceed the rate of growth of discount outlets in the market, and reasonably must be only a fraction of that growth, representing the size of the price decline realized from switching. During the 1980s the share of discount stores in the supermarket sector has grown less than 1 percentage point per year. Furthermore, some of the price differences between discount stores and full-service stores reflect differences in retail services. The original article by a BLS researcher on the effects of discount stores confounded the effects of the sample estimator issue with the discount stores effects, resulting in an unreasonably large estimate for the effect of discount outlets.[37]

Because BLS research to date has not determined the ideal method for dealing with the sample estimator and discount store issues, it is not possible to determine precisely the quantitative magnitude of the problem. Many of the research findings to date remain tentative and somewhat difficult to interpret. The combined magnitude of these two effects may be in the range of 0.1 to 0.3 percentage points overstatement per year, depending on the assumptions that are made about the standard against which the CPI should be compared.

Quality Adjustment

The entire CPI process is designed for separating price changes from quality changes. The procedures begin with detailed checklists that the field representatives use to assure that precisely the same item is priced this period as last period. If the sample item has changed in any observable way, a set of procedures is implemented for separating the quality changes from the price changes. An economist examines information on the two versions of the item and determines that (a) the change has not resulted in a significant change in the quality of the item, so that the prices of the old version and the new version can be directly compared, or (b) a

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[37] Reinsdorf, M., "The Effect of Outlet Price Differentials in the U.S. Consumer Price Index," in Price Measurements and Their Uses, M.F. Foss, M.E. Manser, and A.H. Young (eds.), 1993.

significant change in quality occurred and information is available for estimating the dollar value of the change in quality, or (c) a significant change in quality occurred and information on the value of the observed quality change is not available, so the price change is imputed. BLS has continually re-examined its procedures, and improvements in procedures are implemented from time to time. For example, since 1991 hedonic methods (i.e., methods based on statistical regression analysis) have been used to adjust for quality changes in apparel. Improved methods for imputing price changes to account for quality changes in new versions of products were introduced in 1992.

Separating quality changes from price changes is not a simple process. Some economists have suggested that BLS should make greater use of hedonic methods for quality adjustment. The CPI has adopted direct hedonic adjustments for apparel and the depreciation of housing, and BLS research studies on the use of these methods have been conducted for a number of other commodities and services. Even when the results of hedonic analysis have not been sufficiently reliable to use for direct quality adjustment, they have influenced other aspects of the BLS quality adjustment process—for example, guiding the design of the checklists, or providing guidance to economists on the decision between directly comparing prices of two versions or imputing the price change. Reliable use of hedonic methods for quality adjustment in some cases may require increased sample sizes and improved information on item characteristics.

Certainly the quality adjustment problem is a difficult one for the CPI--especially in areas like consumer electronics and medical care where technological progress has been evident. It also is a difficult problem for items like apparel, where changes in fashion lead to frequent changes in product characteristics. The notion that the CPI does not adjust for quality changes is simply incorrect. Whether the procedures used by the CPI systematically over-adjust or under-adjust for change in quality has not been systematically examined across the full range of items that the CPI program prices. Indeed this is a question that may not have a scientific answer, in the sense that reasonable people may draw different conclusions about the effects of quality changes from the same data.

An issue that is tied closely to quality adjustment is the issue of accounting for new goods. This problem has two aspects—bringing new goods into the samples on a timely basis and accounting for differences in price between new goods and the old goods that provided the same or similar services.[38]

The procedures described previously for sample replacement are designed to bring most new goods into the sample in a timely manner. Currently new goods enter the sample through sample rotations, with one-fifth of the sample replaced each year. BLS is planning to change the Point-of-Purchase Survey procedures during the next CPI revision so that more frequent sample replacements could be made as needed for specific categories of items. In addition to entering in the sample rotation process, new goods also can enter the sample in the course of routine price collection if they displace an item that was previously priced in the sample.

The treatment of price comparisons between new goods and the old goods that they replace is more problematic. If an item enters the sample as a replacement version for a sample item that is no longer available, then BLS procedures for quality adjustment or price imputation are used. On the other hand, new items that enter through sample rotation are never directly compared to the items that they replace. Economists have asserted that this may be a source of upward bias for the CPI. In cases where the new item represents a major technological improvement over previous items, the sample rotation procedure will tend to miss the gains to consumers from substituting to a superior new good. In other cases price increases occur with the introduction of a new item, especially for items such as apparel that have important elements of fashion or style. In these cases, the failure to compare a new item with the item that it replaces may cause the CPI to understate the price increases that consumers face.

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[38] Arnknecht, P., Lane, W., and Stewart, K., "New Products and the U.S. Consumer Price Indexes," unpublished working paper, Bureau of Labor Statistics, 1994.

V. Ongoing Improvements to the CPI

In the period since the CPI was initiated during World War I, it has undergone many changes in concept and structure, reflecting both the Bureau's experience and research as well as criticisms and investigations of outsiders. Many of these changes have coincided with one of the five comprehensive revisions of the index, the last of which was completed in 1987, such as the inclusion of owner-occupied housing in 1952 and the extension of coverage to all urban consumers and the introduction of full-probability sampling in 1978. However, substantial improvements to the index also have been made between these major revisions. These include the annual adjustment for changes in the quality of new cars after model change-overs, which began in 1967, and the shift to a flow-of-services approach in measuring the shelter costs of homeowners, which took place in 1983 in the CPI-U (and in 1985 in the CPI-W). A chronology of some of these improvements is contained in Table 2 of this report.

In addition to the research that culminated with the publication of the five articles on the CPI in the December 1993 *Monthly Labor Review*, BLS staff have continued to evaluate the methods and procedures used to compile the CPI. In January 1995, as a direct result of additional research, BLS made three improvements to make the index a more accurate measure of price change. These improvements affected the food-at-home, shelter and prescription drug components of the CPI.

The change to the food-at-home component, which has already been discussed, improved the outlet sample rotation process. As indicated earlier, empirical evidence had established that the prior procedures for the routine introduction of new samples tended to overstate price change for the newly sampled items immediately following their introduction. Since the food-at-home component of the index is particularly sensitive to this effect, new measures designed to lessen its impact have been introduced.

Also, two changes have been made in the way in which the shelter component of the CPI is calculated. First, the imputation formula for estimation of owners' equivalent rent, which relies upon a matching of a sample of residential rental units to a sample of homeowner units, has

been improved. Second, previous procedures both for residential rent and for owners' equivalent rent tended to understate the short-term rent change. BLS has incorporated an improved estimation formula. Research on this issue will continue during the course of the upcoming CPI revision, and, if this research yields further improvements that can be made to the estimates of rent changes, they will be incorporated into the index as part of the revision effort.

The other change related to the prescription drug component of the CPI. The procedure for handling the introduction into the index of generic versions of formerly patented drugs has been changed. The prior practice of directly comparing the prices of patented and generic drugs only when the patented drug is no longer available in the sampled outlet has been changed. A new procedure, which reflects the rate at which consumers switch their purchases from patented to generic versions of a drug, has been implemented.

The BLS has received approval for another major CPI revision. With release of the index for January 1998, the CPI will be based on an updated market basket reflecting consumption patterns for the 1993-95 period. In addition to this updating of the CPI samples, expenditure weights, and population weights, the Bureau expects to improve the ongoing process of updating of the outlet samples, by modifying the Point-of-Purchase Survey so that particular item categories can be resampled in all geographical areas at one time. This will enable the Bureau to reflect the introduction of new items in a more timely manner. The BLS also expects to make improvements in the indexes for medical care services, which would address some of the quality improvements due to the advances in technology that have characterized this component. Additional changes also might be made, depending upon the outcome of some of the ongoing research detailed below.

A continuing area of research involves the functional form of the estimator. The CPI is a fixed weight measure of changes in consumer prices. The current formula for computing basic level indexes (one of the 9,108 subindexes estimated for each month's CPI) uses a weighted average of price ratios. BLS has been investigating, through its research, the effects of using different index number formulas and the assumptions underlying each usage. There are several

ways in which the same data can be used to calculate the rate of price change. Other possible basic indexes the Bureau has explored computing are a weighted geometric mean of price ratios or a ratio of weighted average prices. Each of these index forms can provide a different result. The formulas for computing these indexes are presented at the end of the mathematical appendix. Within the next year, the Bureau hopes to publish the results of this research with an evaluation of which method is appropriate for the CPI.

BLS will continue to develop alternative price indexes in a research mode. Such alternative measures as chained Laspeyres and Paasche indexes and superlative indexes using the Fisher Ideal and Tornqvist formulas will be produced on an annual basis. As previously discussed, the superlative indexes are closer approximations to a cost-of-living index than the CPI because they account for substitution effects. These indexes require both current and previous expenditure patterns and, because of the lags in the availability of Consumer Expenditure (CE) Survey data, can be produced only with a 2-year lag. With additional resources, other experimental indexes could be produced on a regular basis. BLS could develop a test index that uses a geometric mean estimation form. Other possibilities include an annually reweighted CPI-U from 1987 forward, simulating the effect of introducing a new market basket each year using the latest 3 years of information from the CE, and a 5-year reweighted CPI-U that shows what effect updating the market basket in 1992 would have had on the CPI. BLS also could test methods for projecting CE data forward to the current year so that more timely test superlative indexes might be produced. Such indexes would be subject to revision for several years until actual expenditure patterns were available and could be incorporated.

Research staff also have been exploring a number of other issues. One of these issues is the use of scanner technology as a way of securing price and expenditure data, and using such data to evaluate the use of different index estimation methods. This research has just started with no results to report as yet.

Other areas that could benefit from additional funding are research on hedonic quality adjustment both at the individual item level and across outlets. An interagency statistical policy

group chaired by Michael Boskin recommended that BLS receive funds to expand data collection to include the additional price and product characteristic information needed to support expanded use of hedonic quality adjustment methods. BLS would investigate the development of statistically-based measures for the adjustment of price changes in the home electronics and home appliance categories. Research also would be conducted to investigate differences in quality between outlets, the extent to which such differences may account for price differences when one type of outlet replaces another during sample rotation, and the extent to which this difference should be reflected in the CPI. If the research proved successful, new model-based quality factors could be used to account for differences between items and outlets.

In conclusion, the Bureau is intensely aware of the sensitive nature of the data it produces, and of the critical need for these data to be as accurate as possible. As the revised methods that were introduced with release of the January 1995 index indicate, the BLS is, within the limits of its resources, pursuing these issues and introducing improvements as quickly as it can. In addition, now that the comprehensive updating of the CPI, normally conducted at ten-year intervals, has been funded, it is moving as expeditiously as possible to complete that major undertaking, while, of course, adhering to its normal standards of care and thoroughness to assure that mistakes are not made. The Bureau will continue to investigate the measurement issues that it and others have identified, and will address them to the full extent possible.

Mathematical Appendix:

The superlative formulas can be understood as geometric averages of index formulas which have reference (base) period expenditure weights and comparison (current) period expenditure weights by examining the formulas for these indexes. Let x^0 be reference period quantities of goods, x^1 be comparison period quantities, p^0 be reference period prices and p^1 be comparison period prices. The Laspeyres index is then defined as:

(1) $L = \sum_i p_i^1 x_i^0 / \sum_i p_i^0 x_i^0$,

where the index i refers to a specific good or service in the market basket. The Paasche price index is the price of a comparison-period market basket of goods and is defined as:

(2) $P = \sum_i p_i^1 x_i^1 / \sum_i p_i^0 x_i^1$,

Fisher's Ideal price index is the square root of the product of the Laspeyres and Paasche price indexes:

(3) $F = (L \cdot P)^{1/2}$,

and the Tornqvist price index is defined as:

(4) $T = \prod_i (\frac{p_i^1}{p_i^0})^{((s_i^1 + s_i^0)/2)}$,

where s_i^1 and s_i^0 are the shares of the consumer's total expenditures devoted to good or service i in the comparison and reference periods, respectively.

In order to understand the relationship of the expenditure-based cost-of-living index to the more comprehensive definitions of cost-of-living indexes, we can express the theory mathematically in terms of the consumer's expenditure function. This function describes the minimum amount of total expenditure required by the consumer to achieve a given level of standard of living or, more generally, well-being. Without providing an explicit description of the mathematical form of this function, it is defined as follows:

(5) $E^0 = E(P^0, X^0, R, S^0, \varepsilon^0),$

where: E^0 is period 0 minimum expenditure, P^0 is period 0 prices, X^0 is period 0 quantities of goods and services, R is a formal description of the consumer's preferences, S^0 is savings in period 0, and ε^0 is period 0 levels of public goods and services and environmental amenities. The true measure of the ratio of the consumer's standard of living in the comparison period (period 1) to the reference period (period 0) is then described by equation (6) below:

(6) $TCLI = \dfrac{E(P^1, X^1, R, S^1, \varepsilon^1)}{E(P^0, X^0, R, S^0, \varepsilon^0)}.$

This is the consumer's "true cost-of-living index," most broadly defined.

In this context, if we assume that certain factors affecting the consumer's standard of living do not change, we can construct a subindex of equation (6) by including only those factors that have changed. If we include only prices and quantities of goods and services, then we have the expenditure-based index, of which the indexes in equations (1) through (4) are examples. In the income-based context, one would include savings and, because there are many sources of

income as well as income taxes to consider, a much more detailed version of equation (6) would need to be specified as the theoretical model for the index formula implemented. Explicitly incorporating public goods and services and environmental amenities provides a nonmarket goods-inclusive index.

In the context of the elementary price quotes which comprise the higher level aggregates which then comprise the CPI, there are three basic formulas which may be applied when weight information is not available. These formulas may be used to construct the basic price ratios which are then weighted by the expenditure share information from the Consumer Expenditure Survey to construct aggregate category price indexes (such as an index for flour and flour mixes). Let the price of specific item i in pricing period 0 be p_i^0, its corresponding price in the following pricing period 1 be p_i^1 and let there be N items in the elementary aggregate. The three unweighted formulas for constructing the elementary price ratios are, then, as follows:

$$(7) \quad CA = \sum_{i=1}^{N}(1/N)(p_i^1/p_i^0),$$

$$(8) \quad DU = \sum_{i=1}^{N}(1/N)p_i^1 / \sum_{i=1}^{N}(1/N)p_i^0, \text{ and}$$

$$(9) \quad JE = \prod_{i=1}^{N}(p_i^1/p_i^0)^{1/N},$$

where CA is the Carli formula, DU is the Dutot formula, and JE is a geometric mean formula of Jevons.[39]

The CPI formula for commodities and services (other than shelter) uses weighting information from the Point-of-Purchase Survey to estimate a "Modified" Laspeyres index. In other words, since the expenditure data are available with a lag, new samples are linked into the

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[39] See Diewert, W. E. "Index Numbers," in Eatwell, J, M. Milgate, and P. Newman (eds.), The New Palgrave: A Dictionary of Economics, vol. 2, London: The MacMillan Press, pp. 767-768.

index about 2 years after their expenditure data are collected from the Point-of-Purchase Survey. The modified Laspeyres for period t, denoted ML^t, is calculated as:

$$(10) \quad ML^t = \frac{\sum x_i^0 p_i^t}{\sum x_i^0 p_i^l} \times ML^l ,$$

where the x_i^0 are quantities during the base (i.e., Point-of-Purchase) period, the p_i^l are prices and ML^l is the index during the "link" period when the new sample is chained to the old sample, and the p_i^t are prices during period t.

The Point-of-Purchase Survey collects information on expenditures, rather than quantities, so rewrite (10) in terms of base-period expenditure shares as:

$$(11) \quad ML^t = \frac{\sum s_i^0 (p_i^t / p_i^0)}{\sum s_i^0 (p_i^l / p_i^0)} \times ML^l .$$

The base-period prices of the sample items, p_i^0, are not known, because the sample was not yet selected when the Point-of-Purchase Survey was conducted. (The Point-of-Purchase Survey provides a sampling frame for the selection of outlets and items.)

The CPI uses a procedure by which the base price is approximated using the price during link month rebased to the base-period: $\hat{p}_i^0 = p_i^l (ML^0 / ML^l)$. If the entire sample is replaced at the same time, then the CPI procedure for setting base prices causes (11) to simplify to:

$$(12) \quad ML^t = \sum s_i^0 (p_i^t / p_i^l) \times ML^l .$$

Recent BLS research suggests that (12) tends to behave like a Carli index.[40]

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[40] Reinsdorf, M., and Moulton, B.R., "The Construction of Basic Components of Cost of Living Indexes," BLS working paper no. 261, 1995.

Table 1. Comparison of the Consumer Price Index for All Urban Consumers (CPI-U) and Urban Wage Earner and Clerical Workers (CPI-W) with the Price Measures for Personal Consumption Expenditures, annual percentage changes, 1983-94

| Year | CPI | | Personal Consumption Expenditures (PCE) | | | |
	CPI-U	CPI-W	Implicit price deflator index	Chain-type annual weighted index	Benchmark-years weighted price index	Fixed-weighted price index
1983	3.2	3.0	4.9	4.5	4.5	4.3
1984	4.3	3.5	3.9	3.8	3.8	3.7
1985	3.6	3.5	3.9	3.8	3.9	3.8
1986	1.9	1.6	3.1	3.0	3.0	3.0
1987	3.6	3.6	4.2	4.1	4.2	4.1
1988	4.1	4.0	4.2	4.2	4.2	4.3
1989	4.8	4.8	4.9	5.0	4.9	5.0
1990	5.4	5.2	5.1	5.1	5.2	5.3
1991	4.2	4.1	4.2	4.3	4.3	4.4
1992	3.0	2.9	3.2	3.4	3.5	3.5
1993	3.0	2.8	2.5	2.8	2.8	2.8
1994	2.6	2.5	2.1	2.5	2.5	2.5
1982-94						
Total	53.6	50.3	54.3	54.9	55.0	52.0
Ann. Rate	3.6	3.5	3.7	3.7	3.7	3.6

Table 2. IMPROVEMENTS TO THE CPI

CHANGE	DATE IMPLEMENTED	DESCRIPTION
First Comprehensive Revision	1940	Introduced the concept of a sample of cities and items, and the principal of imputation, permitting the CPI to represent price change in all cities and all items purchased.
Adjustment of Item Weights	1943	Commodity expenditure weights adjusted for items disappearing from market place.
Interim Market Basket Update	1951	a. Revised city population weights; b. Corrected new unit bias in rent index; c. Added a number of new products, including TV and group health insurance payments; d. Revised commodity weights.
Second Major Revision	1953	Added coverage of homeowners' shelter costs and restaurant meals. Small cities added to area sample.
Third Major Revision	1964	Single-person families included for the first time. Probability sampling extended.
New Construction	1966	Rent samples augmented with units built after 1960.
Quality Adjustment of New Automobile Prices	1967	New automobile prices adjusted for quality differences after model change-overs.
Fourth Major Revision	1978	Population coverage expanded to all urban consumers. New survey introduced to identify where consumers shop for different items. Store weight reflected in probability selection of items.
Sample rotation	1981	Introduced a systematic replacement of outlets between major revisions.
Rental Equivalence	1983	Changed homeowners' component from cost of purchase to value of rental services for CPI-U.

Table 2. IMPROVEMENTS TO THE CPI

CHANGE	DATE IMPLEMENTED	DESCRIPTION
Return from Sale Price Imputation	1984	Introduced procedure to eliminate downward bias for items discontinued by outlets that went out of index with discounted prices.
Rental Equivalence	1985	Changed CPI-W homeowners' component to value of services.
Fifth Major Revision	1987	Expanded scope of systematic outlet rotation. Introduced systematic reselection of entry level items during outlet rotation.
Enhanced Seasonal Products Methodology	1987	Enhanced methodology used for seasonal items by expanding the number of price quotations to select products from alternate seasons and eliminate under-representation of such items.
Quality Adjustment of Used Car Prices	1987	Prices of used cars adjusted for differences in quality after model change-overs.
Aging Bias Correction	1988	Rental values adjusted for aging of the housing stock.
New Models Imputation	1992	Refined imputation methods used when introducing new models of products into the CPI.
Discount Air Fares	1992	Substitution rules modified to expand pricing of discount airline fares.
Quality Adjustment of Apparel Prices	1992	Regression models used to adjust apparel prices for changes in quality when new clothing lines introduced and eliminate bias due to linking product substitutions into the CPI.
Hotels & Motels	1993	Samples for hotels and motels quadrupled to reduce variances related to seasonal pricing.
Seasonal Adjustment	1994	Procedures for seasonal adjustment revised to eliminate residual seasonality effects.

Table 2. IMPROVEMENTS TO THE CPI

CHANGE	DATE IMPLEMENTED	DESCRIPTION
Generic Drugs	1995	Introduced new procedures which allow generic drugs to be priced when a brand drug loses its patent.
Commodity & Services Base Period Prices	1995	Introduced seasoning procedures to eliminate upward bias in setting of base period prices of newly initiated items.
Rental Equivalence Imputation	1995	Modified imputation of homeowners' implicit rent to eliminate the upward drift property of the current estimator.
Composite Estimator Used in Housing	1995	Replaced current composite estimator with a six-month chain estimator. Under-reporting of one month rent changes had resulted in missing price change in residential rent and home-owners' equivalent rent. Old estimator also produced higher variances.