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How do we measure inflation?

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One goal of monetary policy is price stability, which requires a measure of prices over time.[1] The gold standard maintained the stability of one price, that of gold. Today, we need to consider a broad array of prices. The Federal Reserve's policymaking body, the Federal Open Market Committee (FOMC), uses the personal consumption expenditures (PCE) deflator as its index of prices. But what is it, and why does the Fed consider this measure the most suitable?

The two major price indexes in the U.S., the CPI and the PCE deflator, have long historical roots.

In this *Chicago Fed Letter*, I provide a brief history of price indexes and examine the two most common ones in the United States, the PCE deflator (formally the Chain Price Index for Personal Consumption Expenditures or PCEPI, produced by the U.S. Bureau of Economic Analysis) and the Consumer Price Index (CPI), produced by the U.S. Bureau of Labor Statistics (BLS).

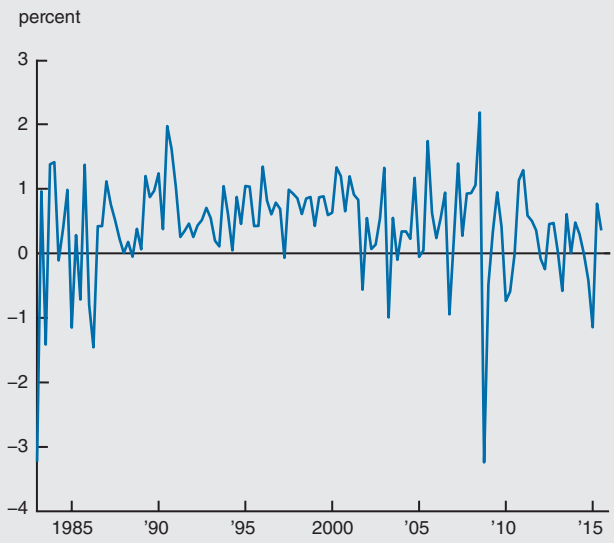
Brief history of index numbers

People have tracked the prices of important commodities and services for a long time and have long understood that their variations convey information about the value of the money that purchases them. The first to grapple explicitly with the problem of devising a single measure out of disparate prices was an English cleric, William Fleetwood. In the early eighteenth century a fellow at All Souls College in Oxford was in a bind. The terms of his scholarship, set by the founder in the fifteenth century, required him to resign if he had an annual income greater than £5. He had just inherited an annual income of £6, but surely £6 in 1700 was worth much less than £5 in 1440. The fellow consulted Fleetwood, who had been collecting historical data on prices. Fleetwood considered that it was enough to show that a basket of goods that £5 bought in 1440 would cost much more in 1700.[2] He then showed that the prices of wheat, beer, cloth, and other commodities had increased sixfold since the mid-fifteenth century. Fleetwood did not actually have to compute an index, fundamentally because his only concern was to prove an inequality and because the price increases he computed for different commodities were quite close.

A few years later the Frenchman Dutot,[3] who wanted to compare the real value of the French government's revenues at various dates, collected prices on a half-dozen commodities, as well as services, averaged the prices at each date, and took ratios. Carli[4] carried out a similar exercise to compute the change in the real value of silver between 1500 and 1750. He computed changes in the prices of wheat, oil, and wine in various Italian regions, and took an average of the changes. These two methods have come to be known as the Dutot index and the Carli index.

Fleetwood, Dutot, and Carli were all trying to solve the same basic problem: How can one compare the value of money at different times? For Fleetwood and Dutot, the problem was a practical one of comparing nominal sums of money in different time periods. Carli was trying

1. Difference between CPI and PCE deflator from 1983



NOTES: CPI indicates Consumer Price Index; PCE indicates personal consumption expenditures. Data are quarterly at an annual rate.
SOURCE: Haver Analytics.

to address a related, but different question: How can one measure a general rise in prices?—in his case the rise due to the inflow of precious metals after the colonization of the New World. These early works show the beginnings of what Diewert[5] calls the basket approach and the statistical approach. The first starts from money's primary function, which is to buy goods and services, and asks: How much money is needed to buy a given basket at different times? The statistical approach follows a different intuition. Prices of goods and services vary over time, but there is a general underlying trend that can be recovered by removing the random variations among prices. Both the Dutot and Carli indexes start from a basket (the choice of goods and services whose prices are included in the index) but take simple averages (of prices for Dutot, of price changes for Carli) to recover a general trend.

This confusion of the two approaches cleared up over time as recurring periods of inflation prompted further research on index numbers. Thus, the Scottish writer Joseph Lowe[6] was trying to measure inflation in England during the Napoleonic wars, when he concluded that treating all prices equally was mistaken and that goods and services should be weighted according to their importance in everyday consumption. The California gold discoveries of 1849 led to another round of efforts at measuring inflation in Europe. There was increasing interest in collecting and publishing data: In 1869, the London *Economist* began publishing an index of commodities prices and was followed by other newspapers and statistical agencies. Attempts at measuring inflation also spurred theoretical work, notably by Jevons,[7] who used an unweighted geometric index; and Laspeyres[8] and Paasche,[9] who proposed two basic index formulas for computing an index of prices between two periods (the former uses the quantities of the first period, while the latter uses the quantities of the second period).

By the early twentieth century, with the works of Walsh[10] and Fisher,[11] a sound theoretical basis had been developed, which remains the foundation for most modern price indexes. One way to evaluate the suitability of a price index is to compare it to the goal of measuring the amount of money that allows a consumer to reach a constant level of utilities as prices change over time (the cost-of-living approach). Another way is to see whether it fulfills a number of criteria or tests dictated by common sense or some axiomatic approach. Fisher proposed an index that combines the Laspeyres and Paasche indexes by taking their geometric mean.[12] It turns out to be a good approximation of a cost-of-living index, and it passes a number of desirable tests, which is why it remains heavily favored in practice.[13]

The two major price indexes in the U.S., the CPI and the PCE deflator, have long historical roots.

The forerunner of the BLS first produced indexes of food prices in the late nineteenth century, in the context of labor disputes over wage increases and noticeable trends in inflation (20 years of deflation from the mid-1870s were followed by 20 years of inflation up to World War I). From 1919, the BLS began publishing a retail price index, the ancestor of the CPI, using expenditure surveys to determine the weights.[14] From its beginnings, the CPI was thus informed by a cost-of-living concern.

The origins of the PCE deflator reflect different concerns. At the forerunner of the U.S. Bureau of Economic Analysis (BEA), a team led by economist Simon Kuznets began producing estimates of national income in the midst of the Great Depression. The goal was to quantify the extent of the Great Depression and understand its mechanisms. After World War II, the BEA began to publish National Income and Product Accounts (NIPAs) regularly. As its name suggests, the PCE deflator, like other deflators in the NIPAs, was originally a tool designed to eliminate the effects of inflation on estimates of national aggregates, one of which was PCE, the aggregate consumption expenditures of the household sector. Originally based on a Laspeyres formula, the NIPA deflators became Fisher indexes in 1996 when chain-weighting was adopted for all NIPAs.

CPI and PCE deflator, compared

The differences in histories and purposes of the two indexes help explain the numerical differences.[15]

A price index is the product of a formula that combines the prices and quantities of a basket of goods into a sequence of numbers. Therefore, the differences between two price indexes can come from different formulas, different goods in the baskets, different quantities of goods, or different price series. In the case of the PCE deflator and the CPI, the prices are mostly the same (as much as possible, the BEA uses the price data collected by the BLS in its construction of the CPI), so the differences are in the formula, the basket, and the quantities.[16]

Formula effects

The CPI and the PCE deflator use two different formulas.

2. Decomposition of the difference between CPI and PCE deflator, 2002:Q1–2015:Q3

	Contribution (b.p.)	Inflation rate (%)	% weight in CPI	% weight in PCE
Formula effect	**17**			
Video and audio equipment	4	–9.7	0.3	0.9
Personal computers and peripheral equipment	2	–12.2	0.3	0.5
Gasoline and other motor fuel	2	13.7	3.6	2.4
Electricity, gas, fuel oil, and other household fuels	1	4.3	4.6	2.0
Other	8			
Scope effect	**–35**			
Physician services	–1	1.3	1.6	3.8
Hospital and nursing home services	–16	3.3	2.2	9.3
Financial services furnished without payment	–7	2.8	—	2.7
Foreign travel by U.S. residents	–3	3.3	—	1.2
Other	–9			
Weight effect	**47**			
Rent of shelter	35	2.4	32.8	15.4
Gasoline and other motor fuel	6	13.7	3.6	2.4
Electricity, gas, fuel oil, and other household fuels	4	4.3	4.6	2.0
Other	1			
Other	**1**			
Total	**29**			
CPI inflation		2.19		
PCE inflation		1.90		

Notes: CPI indicates Consumer Price Index; PCE indicates personal consumption expenditures. Contributions to the difference are expressed in basis points (b.p. = 0.01%). The weights are as of September 2015.

Sources: U.S. Bureau of Economic Analysis, Table 9.1U of the National Income and Product Accounts, and U.S. Bureau of Labor Statistics.

Changes in the CPI are computed using a Laspeyres formula, in which changes in prices between two different dates are weighted by the quantities of the earlier date. The reason is essentially practical. It is much easier to collect data on prices than on quantities. All it takes to collect the price of apples is to send an observer to the market or the store. Collecting data on the quantity of apples requires many observers to record all the apples purchased. In practice, the BLS collects prices from a large sample of stores every month and is able to use them fairly rapidly, but it derives its information on quantities from the *Consumer Expenditure Survey* (CE). The information from this survey cannot be put to use as readily. Thus, the price information is updated every month, but the quantity information is only updated every two years (every ten years prior to 2002). For example, during 2014 and 2015, the weights are derived from the CE for the 2011–12 reference period.

The PCE deflator, like other deflators in the NIPAs since 1996, uses the Fisher index. This is possible because the PCE deflator is, effectively, a byproduct. The main purpose of national accounts is to provide estimates of aggregate quantities: How much is produced, consumed, and invested? Although all the data collected that form the basis for these estimates are in current dollars, the reality of inflation requires that some adjustment be made to give them the meaning of "real" quantities, hence the need to construct indexes. When the Fisher index is used to aggregate quantities, the Fisher index for prices is a natural byproduct, and the product of the two is proportional to the original nominal quantities.

The main shortcoming of the Laspeyres index, from a cost-of-living point of view, is that by keeping quantities constant at the original values, it will fail to capture consumers' tendency to substitute away from goods with rising prices toward goods with falling prices. Hence, it tends to overweight fast-rising prices, and overstate inflation. For similar reasons, the Paasche index will tend to understate inflation, while the Fisher index better captures consumer substitution.

The formula effect tends to be pronounced for goods whose prices have marked trends. If the price of a good has a constant upward trend, consumers will be constantly reducing their consumption of that good, but a Laspeyres index (or an index, like the CPI, which uses the same weights for a long period) will always overweight that good. Likewise, the Laspeyres index underweights goods whose prices trend down. In both cases, the Laspeyres index overstates inflation.

A good whose price is very volatile will be overweighted by the Laspeyres index when its price rises and underweighted when it falls. To the extent that upswings and downswings in price are roughly symmetrical, the effects will cancel out.

Scope effects

The CPI and PCE baskets are not the same, which accounts for some of the difference between the two. The technical difference is that the source data are different, but this also reflects the different purposes of the two indexes. The CPI comprises what is purchased by individual consumers, while the PCE deflator comprises what is consumed by consumers as a whole.

The CPI is designed to approximate a cost-of-living index and is based on a basket approach. The weights are derived

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from the CE, in which households are asked about their actual expenditures. This means that only out-of-pocket expenditures will be recorded. The concepts underlying the PCE data are slightly different. The household sector is seen as a whole, thus intrasector purchases (e.g., used cars) are ignored. Conversely, consumption made by or on behalf of households is included, whether or not it is paid for directly by the consuming household. Much of health care is provided through insurance systems, and these services are consumed but not directly purchased. The PCE deflator, therefore, includes medical care services paid for by programs such as employer-provided health insurance, Medicare, and Medicaid, while the CPI price index includes only services purchased by consumers.

Weight effects

Even for categories of goods or services that are present in both surveys, the weights can be different. To some degree this is simply a result of the scope effect: Removing an item from a basket changes the relative weights of the remaining items. But it is also a consequence of the different source data. The CPI quantity data are based on individual consumers' responses to the CE survey, while the PCE quantity data are based on surveys of businesses. There are well-known divergences between the two, partly due to differences in definitions and partly reflecting different data quality.

Quantifying the difference

Figure 1 plots the difference between CPI and the PCE deflator from 1983. CPI inflation is above the PCE deflator most of the time, and the difference is positive on average. During the 1990s, the difference averaged 0.7% and was persistent. Moreover, the CPI was subject of a number of criticisms for its upward biases. As a result, in 2000 the Fed switched to using the PCE deflator because of its greater comprehensiveness and accuracy; and in January 2012, the FOMC adopted a target of 2% inflation in the PCE deflator. But over time the differences have narrowed, as the CPI has been improved and has come to resemble the PCE deflator more and more. Since 2002, the difference has only been 0.3% on average.

Figure 2 decomposes the difference between the PCE deflator and the CPI since 2002. As one would expect, the formula effect is positive. The overweighting of trending prices is noticeable for computers and video and audio equipment. Volatile energy goods have also been a source of difference. The weight and scope effects are larger in absolute value than the formula effect, but they tend to offset each other.

Note that the items that contribute to these two effects tend to have higher-than-average inflation. Since the scope effect is mostly due to items in the PCE but not the CPI, it tends to reduce inflation in the CPI. But most of the weight effect involves items that have a higher weight in the CPI, hence they add to CPI inflation relative to PCE.

Some differences are likely to persist, because there are limits to the changes that can be made to the CPI. One key issue is timeliness. The CPI is published monthly and is never revised, in contrast to the PCE deflator, which is revised repeatedly in the years following its publication. Another issue is consistency. Because of its long history, the CPI has become embedded in our economy. It has been used to index many private contracts, as well as Social Security payments and the payments made on U.S. Treasury inflation-indexed bonds.

Conclusion

The two indexes, the PCE deflator and the CPI, have different histories and purposes. They have tended to converge over time, although differences in scope and methods will remain. The differences are unavoidable, but quantifiable, and by now relatively small. Both indexes remain closely watched measures of price stability.

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[1] Yogi Berra saw price instability when "a dime isn't worth a nickel anymore," but central banks need more operational definitions.

[2] The basket he gave as an example was five quarters of wheat, four hogsheads of beer, and six yards of cloth (which works out to four pounds of bread and a generous six pints of beer per day). See William Fleetwood, 1707, *Chronicon Preciosum: Or, an Account of English Money, the Price of Corn, and Other Commodities, for the Last 600 Years*, London: Charles Harper, p. 61.

[3] Nicolas Dutot, 1738, *Réflexions Politiques sur les Finances et le Commerce*, 1935 ed., Paris: E. Droz.

[4] Gianrinaldo Carli, 1760, *Delle Monete e dell'Instituzione delle Zecche d'Italia*, Vol. 3, Lucca, Italy: Jacopo Giusti.

[5] W. E. Diewert, 1993, "The early history of price index research," in *Essays in Index Number Theory*, W. E. Diewert and A. O. Nakamura (eds.), Vol. 1, Amsterdam: Elsevier Science, pp. 33–71.

[6] Joseph Lowe, 1823, *The Present State of England in Regard to Agriculture, Trade, and Finance: With a Comparison of the Prospects of England and France*, 2nd ed., London: Longman, Hurst, Rees, Orme, and Brown.

[7] W. Stanley Jevons, 1863, *A Serious Fall in the Value of Gold Ascertained, and its Social Effects Set Forth*, London: Edward Stanford.

[8] Étienne Laspeyres, 1871, "Die Berechnung einer mittleren Waarenpreissteigerung," *Jahrbücher für Nationalökonomie und Statistik*, Vol. 16, pp. 296–314.

[9] Hermann Paasche, 1874, "Über die Preisentwicklung der letzten Jahre nach den Hamburger Börsennotirungen," *Jahrbücher für Nationalökonomie und Statistik*, Vol. 23, pp. 168–178.

[10] Correa Moylan Walsh, 1901, *The Measurement of General Exchange-Value*, New York: Macmillan Company.

[11] Irving Fisher, 1922, *The Making of Index Numbers: A Study of Their Varieties, Tests, and Reliability*, New York: Houghton Mifflin Company.

[12] An arithmetic mean sums two numbers and divides the result by two; a geometric mean takes their product and then their square root.

[13] Another favorite is the Törnqvist–Theil index, which is a geometric mean of price changes between two periods weighted by an arithmetic mean of the quantities in the two periods.

[14] The BLS received advice from Irving Fisher and Wesley Mitchell.

[15] See Clinton P. McCully, Brian C. Moyer, and Kenneth J. Stewart, 2007, "Comparing the Consumer Price Index and the Personal Consumption Expenditures Price Index," *Survey of Current Business*, Vol. 87, No. 11, November, pp. 26–33.

[16] There are other minor differences arising from seasonal adjustments and treatments of price series.