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?

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. Carli⁴ 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
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, who used an unweighted geometric index; and Laspeyres and Paasche, 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 and Fisher, 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. 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.

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. 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.

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.

**Formula effects**

The CPI and the PCE deflator use two different formulas.
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...
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 intra-sector 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 data are based on surveys of responses to the CE survey, 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 intra-sector 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.

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 to a number of criticisms for its upward bias. 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 over-weighting 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.

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