Math calculations to better utilize CPI data

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The Consumer Price Index (CPI) is published as an index number that shows the change in the price of a defined market basket of goods and services over time from a base period which is defined as 100.0. An increase of 7 percent from that base period, for example, is shown as 107.0. Alternately, that relationship can also be expressed as the price of a base period "market basket" of goods and services rising from $100 to $107. Currently, the reference base for most CPI indexes is 1982-84=100 but some indexes have other references bases. The reference base years refer to the period in which the index is set to 100.0. In addition, expenditure weights are updated every two years to keep the CPI current with changing consumer preferences.

Index numbers are not dollar values, but measures of the change over time relative to their base period value of 100.0 (for example, 280.0 or 30.3). Index numbers also are commonly used to measure the *size and direction* of price movements between various time periods such as monthly, quarterly, semi-annual, and annual percent changes.

Effective with the January 2007 CPI, the Bureau of Labor Statistics began to publish its consumer price indexes rounded to three decimal places rather than one. As a result, all percent changes in this document have been calculated from three decimal place indexes regardless of date. However, the resulting percent changes will continue to be published to one decimal place. Note: using three decimal place values to compute percent changes eliminates nearly all rounding errors in the resulting percent change that occasionally occurred when using indexes rounded to one decimal place. Additional information on this conversion can be found at www.bls.gov/cpi/cpithreedec.htm.

What follows are mathematical concepts and formulae that are useful in a variety of index applications.

Percent change

Movements of an index from one month to another are usually expressed as percent changes rather than as changes in index points, because index point changes are affected by the level of the index in relation to its base period, while percent changes are not.

The following illustration shows a hypothetical CPI one-month change between November 2007 and December 2007 using the 1982-84=100 reference base.

	Reference Base 1982-84=100
December 2007	210.036
November 2007	210.177
Index point change	-0.141
Divided by the earlier index	-0.141/210.177
Equals	-0.00067
Multiplied by 100	-0.067
Equals percent change	-0.1

Over-the-year percent change

To arrive at a percent change over an entire year, the beginning and ending periods of a CPI series must always be the same month, such as December 2006 and December 2007. Note: A calculation using January and December data would result in an 11-month change, not a 12-month/over-the-year change.

The calculation below shows the over-the-year change from December 2006 to December 2007 for both the 1982-84=100 and 1967=100 reference bases. The percent change is rounded:

	Reference Base	
	1982-84=100	1967=100
December 2007	210.036	629.174
December 2006	201.8	604.5
Index point change	8.236	24.674
Divided by the earlier index	8.236 /201.8	24.674/604.5
Equals	0.04081	0.04082
Multiplied by 100	4.081	4.082
Equals percent change	4.1	4.1

There are two critical points to remember:

1. *Always use the same reference base period for all calculations. If the first point uses the 1982-84=100 base, the end point must also use that base.*

2. Calculating an over-the-year percent change, such as December 2006 to December 2007, is not equal to the sum of the over-the-month changes between those two time periods.

Annual averages

Annual averages are the sum of the 12 monthly data points (i.e. indexes), divided by 12. They represent an average index for a given year, not a particular month. An annual average change should not be confused with the over the year percent change, such as the calculation of the December to December changes mentioned above.

The percent change from December 2006 to December 2007 is unlikely to be the same as the change in the annual average from 2006 to 2007. Users should take care to examine the data with which the CPI is being compared to determine whether the annual average or 12-month change is more appropriate for their purposes.

In addition, users should note that, for an All-items CPI that is published every other month, the annual average is based on 12 months of data. Many food and energy prices are collected for the "off" months, and the unpublished "off-cycle" indexes are interpolated and used in the annual average. Most All-item CPIs for metropolitan areas are published every other month.

Purchasing power

The CPI can be used to show how the purchasing power of a dollar changes over time.

The purchasing power of a dollar in 2007 was about 97 percent of the purchasing power of a dollar in 2006. This can be calculated as follows:

201.6/207.342 X 100 = 97.2%

with 201.6 being the CPI annual average index for 2006, and 207.342 being the 2007 annual average index. This means that the purchasing power of the dollar declined about 3 percent between 2006 and 2007 because of inflation. Or stated another way, a dollar in 2007 could only buy 97 percent of what it could buy, on average, in 2006. An automatic "CPI Inflation Calculator" is available online for annual comparisons of purchasing power at www.bls.gov/data/inflation_calculator.htm.

Similarly, one can calculate equivalent dollar amounts for any two months in different years using a ratio of those monthly indexes. For example, to determine how much money one would need in December 2007 to have the same spending power as $500 in December 2006, multiply the dollar amount by the ratio of the indexes for December 2007 and December 2006:

$$\frac{\text{Dec. 2007}=210.036}{\text{Dec. 2006}=201.8} \times \$500$$

or, 1.04081 x $500 = $520.41

This means that a basket of goods costing $500 in December 2006 would cost $520.41 in December 2007.

Constant dollars

For analysis involving long time periods, it is frequently necessary to convert *current* or *nominal* dollars into *constant* or *real* dollars. This is done by multiplying each dollar amount by a ratio of price indexes, as shown below.

Suppose one's salary was $25,000 in 1995, $30,000 in 2000, and $35,000 in 2005. The All items CPI was 152.4 in 1995, 172.2 in 2000, and 195.3 in 2005. The conversion to constant 1995 dollars would be as follows:

1995: (152.4/152.4) x $25,000 = $25,000
2000: (152.4/172.2) x $30,000 = $26,551
2005: (152.4/195.3) x $35,000 = $27,312

To convert the same data to constant 2005 dollars, use 2005 as the base:

1995: (195.3/152.4) x $25,000 = $32,037
2000: (195.3/172.2) x $30,000 = $34,024
2005: (195.3/195.3) x $35,000 = $35,000

In this example, while one's nominal salary rose from $25,000 to $35,000 from 1995 to 2005, an increase of 40 percent, the growth in real salary, *after adjusting for inflation, was more modest, slightly less than 10 percent.*

Conversion to other base periods

It is sometimes necessary to use index values on a reference base that is no longer published. In these instances, the Bureau provides rebasing factors.

A situation that requires such action could be a long-term contract requiring the use of 1957-59=100 as the base period where the parties cannot agree to a successor index. This often occurs when index points rather than percent change are the basis for escalation. In such a case, contact the BLS for the specific rebasing factor needed for the computation.

Rebasing factors are unique to their index series and can not be substituted. Once calculated, the rebasing factor to move a specific index from a specific base year to another specific base year will not change.

To convert the December 2006 (1982-84=100) CPI-U All items index to the 1957-59=100 base, use the rebasing factor of 0.2870447. Divide the current index by the rebasing factor to calculate the index on a 1957-59 basis.

Example:

All items, CPI-U, December 2006, 1982-84=100	201.8
Rebasing factor	0.2870447
Dec. 2006 / Rebasing factor………	703.0
All items, CPI-U, December 2006, Rebased 1957-59=100	703.0

When new base years are introduced, BLS recalculates each index back to the beginning of that series to provide a consistent stream of data. Using the official series will minimize rounding differences occasionally caused by the rebasing factors. To move from a discontinued index to a current index, the easiest method is to request a historical table from any BLS office.

Constructing special CPI indexes and their percent change

The Bureau calculates thousands of special indexes that are available online or from either the National CPI Information Office or the eight Regional Economic Analysis and Information (EA&I) Offices. Examples include All items less food and energy, All items less energy, and All items less food.

Occasionally, a user needs to estimate a price change that is not published by BLS. For instance, suppose a user needs a CPI measure that includes everything except gasoline. This can be done by estimating a special index, in this case, All items less gasoline. Just remember, this estimate will not be an official CPI, though it can be used to estimate changes in prices for item categories not published by the Bureau.

When creating a special index, the *relative importance* of published indexes is a key component. To reflect the differences in the average amount of the various items purchased, weights are assigned to each item. As the prices of the individual items change, the relative weight of each item is reported in values known as *relative importance*. The relative importance for each published index component is available for December of each year.

The first step in making a special index is to calculate an adjusted relative importance for the component being removed from All items, in this case Gasoline. Multiply the published December relative importance of the component index by the index value for the month of interest. Then divide that amount by the component's index for the same month and year as the relative importance.

For example, using the December 2007 relative importance data and the December 2007 and February 2008 CPI-U Gasoline component indexes for the U.S. city average (1982-84=100):

Relative importance, Gasoline, December 2007 .... 5.215

Index for Gasoline
December 2007 .... 256.790
February 2008 .... 257.845

$$\text{(Rel. imp.) } 5.215 \times \frac{(\text{Feb. 2008})}{(\text{Dec. 2007})} = \frac{257.845}{256.790}$$

or, 5.215 x 1.004108 = 5.2364

Do the same calculation using the same periods for the other index, in this case All items. The All items adjusted relative importance result is 100.7889, where the original relative importance was 100 and the index rose from 210.036 (December 2007) to 211.693 (February 2008).

Next, calculate the *base relative importance* of the All items less gasoline index. Do this by subtracting the original relative importance of gasoline from the original relative importance of the All items index.

December 2007:

Relative importance, All items, December 2007	100.0
Less relative importance, Gasoline, December 2007	- 5.2150
Relative importance, All items less gasoline, December 2007	94.7850

Then do the same with the adjusted relative importances for the second month:

February 2008:

Relative importance, All items, February 2008	100.7889
Less relative importance, Gasoline, February 2008	- 5.2364
Relative importance, All items less gasoline, February 2008	95.5525

Finally, calculate the percent change between the results for the two months:

$$\frac{(\text{Rel. imp. Feb. 2008})(\ 95.5525)}{(\text{Rel. imp. Dec. 2007})(\ 94.7850)} \times 100 - 100 =$$

1.00809 x 100 - 100 = 0.809 = 0.8%

In short, one could estimate that prices for All items less gasoline rose 0.8 percent from December 2007 to February 2008. As before, this is an estimate and does not represent an official BLS index.

In short, the *relative importance* of a component is its expenditure or value weight, expressed as a percentage of All items within an area. These ratios represent an estimate of how consumers would distribute their expenditures over time.

Relative importance ratios cannot, however, be used as estimates of current spending patterns or as indicators of changing consumer expenditures in the intervals between weight revisions, because consumption patterns are influenced by factors other than price change. These factors include income, variations in climate, family size, and the availability of new and different kinds of goods and services.

Discontinued indexes and publication changes

There will be occasions where, especially for longer-term contracts, a specified index may not be precisely available for the duration of the contract. An example of such an occurrence is the index for Washington, D.C.-Md.-Va., which is now part of the larger Washington-Baltimore, D.C.-Md.-Va.-W.Va., metropolitan area. It is not possible to directly calculate a five-year change starting in 1995 and ending in 2000 since publication of Washington data only stopped in 1997. In its place, data for the Washington-Baltimore consolidated area has been published since 1998.

In a case where both parties have agreed upon an index to replace the discontinued (original) one, the calculation can be performed in two steps. First, for the series of interest, calculate the percent change from the beginning period month and year until an agreed upon month and year where data exist for both the discontinued and the successor (new) series. Adjust the dollar value in the contract based upon this percent change. The dollar value should be the amount estimated to start on, or closest to, the month and year chosen for the beginning index.

Second, choose the end-period month and year for the *new* successor series. The month and year you defined as the previous step's end period will now become the *first* period month and year in this step. Calculate the percent change from this beginning period to the selected end period of the new series. Use the calculated percent change to adjust the contract dollar value from the first step. This is the contract's new dollar amount adjusted for the overlap between the discontinued and successor indexes.

In the following example, Index A is now discontinued and the parties have agreed to use Index B as the successor index.

Value of contract in January 1995 ....$9,000.00

Index A

January 1995	158.7
January 1998	178.9
Percent change	12.7
9,000 x (1+ 0.127)	10,143.00

Value of contract in January 1998
after adjustment of 1995 amount $10,143.00

Index B

January 1998	104.7
January 2000	110.9
Percent change	5.9
10,143 x (1+0.059)	10,741.44

Value of contract in January 2000
after adjustment of 1998 amount $10,741.44

Approximating missing data points

Many indexes are published every other month. BLS publishes CPI information for All items and for major components (Food and beverages, Housing, Apparel, Transportation, Medical care, Recreation, Education and communication, and Other goods and services) for 11 metropolitan areas on a bimonthly basis. Some of these metropolitan areas, as defined by the U.S. Census Bureau, include suburbs or counties that extend across state boundaries. These 11 bimonthly metropolitan areas are available on the following schedule: Boston-Brockton-Nashua, Mass.-N.H.-Maine-Conn.; Cleveland-Akron, Ohio; Dallas-Fort Worth, Texas; and Washington-Baltimore, D.C.-Md.-Va.-W.Va.; in odd months (January, March, etc.) and Atlanta, Ga.; Detroit-Ann Arbor-Flint, Mich.; Houston-Galveston-Brazoria, Texas; Miami-Fort Lauderdale, Fla.; Philadelphia-Wilmington-Atlantic City, Pa.-N.J.-Del.-Md.; San Francisco-Oakland-San Jose, Calif.; and Seattle-Tacoma-Bremerton, Wash.; in even months (February, April, etc.).

In a few instances, this is a change from prior years and a contract might call for a specific month which is no longer available. If both parties agree, the missing data point can be *approximated* using the month immediately before and immediately after the missing month.

For example, to approximate the June 2007 All items (CPI-U) index for the Washington-Baltimore, D.C.-Md.-Va.-W.Va. metropolitan area, multiply the May index by the July index and take the square root of the product:

May 2007	132.982
July 2007	134.442
Product	17,878.366
Square root	133.710

Note: data calculated in this way cannot be interpreted as official CPI indexes, as the calculation is based on two data points and not on CPI's aggregation method.

Furthermore, if bimonthly CPI data are volatile, then less confidence should be placed in estimates for the missing months. Percent changes based on approximated data should also be considered as unofficial estimates. Examples of volatile series would be apparel, household furnishings and operations, and fuels and utilities.

Cost of living comparisons not appropriate

Each CPI index represents the change in inflation for a good or service in the market basket over time for various areas and the nation. However, CPI indexes for one metropolitan area can not be compared with those in other areas to determine where it is more or less expensive to live. It is still possible to calculate the percentage change, that is, how fast or slow prices are rising in a given metropolitan area, but that can not be equated to higher or lower actual costs, as the next example illustrates.

Bread was priced in City A and City B.

	City A	City B
Price of bread in:		
September 2005	$1.00	$0.50
September 2006	1.50	1.00

Index values (Sep. 2005=100):

September 2005	100.0	100.0
September 2006	150.0	200.0
Index point change	50.0	100.0
Divided by the earlier index	50.0/100.0	100.0/100.0
Equals	0.50	1.0
Multiplied by 100 equals percent change	50.0	100.0

Note: the price in City B rose at a faster pace than in City A, but the actual dollar price of bread in City A was still 50 cents above City B.

Which index should you use?

The CPI program publishes data for the U.S., geographic regions, and many metropolitan areas. For each of these, data are available for "All items" as well as for a variety of the components that are aggregated together to become the "All items" index.

Each of these many series are published for two population groups: All Urban Consumers (CPI-U) and Urban Wage Earners and Clerical Workers (CPI-W). When using the CPI for calculating price change, you must specify one population group or the other since the index values for the two groups will not be the same.

Contracting parties are free to determine what indexes they wish to use, but it is important to note that while the CPI is used for a variety of purposes, it measures only the change in the price of a representative market basket of consumer goods and services. At the All items and individual component levels, only items that would be purchased by consumers are eligible for pricing. Thus, an item like commercial rent would *not* be included in the "rent of primary residence" category.

Although BLS cannot make a decision as to which index a user should reference, it has published a reference guide, "Using the Consumer Price Index for Escalation," available at www.bls.gov/cpi/cpi1998d.htm. This publication and other information such as frequently asked questions, historical data, and rebasing factors are available through the national office's and eight regional offices' Web sites. (See table A.)

Table A. Regional Economic Analysis and Information Offices and the National Consumer Price Index Information Office in Washington, D.C.

Information Office	Web site	Phone	Email
Boston	www.bls.gov/ro1/	(617) 565-2327	BLSinfoBoston@bls.gov
New York	www.bls.gov/ro2/	(646) 264-3600	BLSinfoNY@bls.gov
Philadelphia	www.bls.gov/ro3/	(215) 597-3282	BLSinfoPhiladelphia@bls.gov
Atlanta	www.bls.gov/ro4/	(404) 893-4222	BLSinfoAtlanta@bls.gov
Chicago	www.bls.gov/ro5/	(312) 353-1880	BLSinfoChicago@bls.gov
Dallas	www.bls.gov/ro6/	(214) 767-6970	BLSinfoDallas@bls.gov
Kansas City	www.bls.gov/ro7/	(816) 285-7000	BLSinfoKansasCity@bls.gov
San Francisco	www.bls.gov/ro9/	(415) 625-2270	BLSinfoSF@bls.gov
Washington, D.C.	www.bls.gov/cpi/	(202) 691-7000	CPI_info@bls.gov