Economic variables measured in dollars (or other currency) are called nominal variables. "Real" variables are nominal variables adjusted for changes in the price level.

Most economic outcomes that we observe are measured in currency. The income of an individual, the price of a house, the GDP of a country or the balance of trade between two countries are all quantities of dollars or of some other currency. But since prices change over time, the amounts of real goods and services that a given number of dollars can purchases also changes over time. So if we want to compare the values of some economic variable in two different time periods, it is often desirable to adjust it for changes in the price level, or to "correct for inflation." The *price level* refers to the average price of goods and services in a country; *inflation* is the rate of change in the price level. Negative inflation (a fall in the prices of goods and services) is called *deflation*.

There are three different ways to correct for inflation, depending on the kind of variable we are adjusting. If the variable is a quantity of currency, we divide by the price index in the current year and multiply by the price index in the base year. If the variable is a rate or a percentage change, we subtract the inflation rate. And if the variable is an exchange rate, then subtract the inflation rate of one country and add the inflation rate of the other. A variable corrected for inflation is often called an *real* variable, while a variable that has not been corrected for inflation is a *nominal* variable.

Correcting for inflation always requires picking a particular **price index** to use. Every country's national statistical agency produces a number of different price indexes.[1] Different indexes will be suitable for different purposes. But for now, we will use the CPI.

[1] For historical reasons, the most widely used price index in the US, the CPI, is produced by the Bureau of Labor Statistics in the Labor Department, but most other price indexes are produced by the Bureau of Economic Analysis in the Commerce Department.

1. A variable with units of dollar (or of some other currency), such as the income of a person, the GDP of a country, or the value of an asset.

   To correct for inflation for a value in dollars, you first must choose which year we will convert the value to. For instance, if we want to compare a price in 2010 to a price in 2015, we can either convert the 2010 price to 2015 dollars, or convert the 2015 price to 2010 dollars. Then we look up a price index that includes both years, and apply the following formula:

$$\textit{price in year 2 dollars} = \textit{price in year 1 dollars} * \frac{\textit{index in year 2}}{\textit{index in year 1}}$$

   For example, suppose a house was purchased for \$400,000 five years ago and is being sold for \$420,000 today. So over the past five years, the nominal value of the house has increased by 5 percent. We want to know how much the real value has increased (or decreased, as the case may be). We can look up the CPI in many places online, such as the FRED website, where it is at `https://research.stlouisfed.org/fred2/series/CPIAUCSL`. We see there that the most recent value of the index, for December 2015, is 238. In December 2010 it was 220. So if we want to convert the $400,000 price of five years ago to today's dollars, we calculate:

$$\textit{price in year 2010 dollars} * \frac{\textit{index in 2015}}{\textit{index in 2010}} = \textit{price in year 2015 dollars}$$

$$\$400,000 * \frac{238}{220} = \$400,000 * 1.08 = \$433,000$$

So in 2015 dollars, the house has gone from a price of $433,000 to $420,000 - while its nominal value has increased, its real value has actually declined. To be exact, the change in its real value is equal to $(\$420,000 - \$433,000)/\$433,000 = -3\%$. Note that this is very close to the percentage increase in the percent change in the nominal value of the house (5%) minus in the price index (8%). For small changes this will always be true, but it becomes less so as the price changes get bigger.

Note that we could just as easily have converted the 2015 price to 2010 dollars, rather than converting the 2010 price to 2015 dollars. The two dollar values would have been different, but we would have come to the same conclusion, that the value of the house declined by 3 percent in real terms. Published price indexes always have a value of 100 for the **base year**, but it is arbitrary which year is used for this purpose. We follow the same procedure for converting two prices to a common year regardless of the base year for the index we are using.

2. A variable with units of percent, such as an interest rate or a growth rate.

   To correct for inflation for a rate or a percent change, you can simply subtract inflation. This is not exactly correct; it is an *approximation* that is very close to the correct value as long as we are talking about inflation rates of just a few percent a year, and periods of time of no more than a few years. For example, US GDP today is about 3.7 percent higher than it was a year ago. (GDP has been consistently growing at between 3.5 and 4 percent since the recession ended in 2010.) In other words, the growth rate of GDP is currently 3.7 percent. But this is a nominal growth rate; it does not take account of the fact that dollars are worth somewhat less today than they were a year ago. If we are interested in the change in the amount of goods and services produced in the US over the past year, we may want to correct the nominal growth rate for inflation. Inflation over the past year has averaged 1.6 percent. So to find the real growth rate of GDP, we calculate:

$$3.7\% - 1.6\% \approx 2.1\%$$

The real growth rate of GDP is just a bit over 2 percent. Again, this is an approximation, but for most inflation rates we see in the real world (and for all problem in this class), it will be good enough.

Another example: Suppose you were thinking of buying a house, and find that you can get a mortgage rate at a 5 percent rate of interest. Your parents tell you that when they bought their first house in the early 1990s, they had to borrow at a 7 percent interest rate, so you are getting a good deal. But are you? In the early 1990s, inflation was as high as 5 percent. That means that the *real interest rate* paid by your parents was only $7 - 5 = 2$ percent, while you are facing a real interest rate of $5 - 1.6 = 3.4$ percent. In other words, while nominal interest rates were higher then, the burden of the loan was less, because each year its value was eroded more by inflation than it will be today.

To get the exact correction for a rate or change over a large number of years, you will need to convert the inflation rate to a price index and use the rate or change to compute the levels at the beginning and end of the period, as described below. But for most purposes, the approximation of subtracting the inflation rate is good enough.

3. The change in the exchange rate between two countries.

   Correcting an exchange rate – the price of one currency in terms of another – for inflation is somewhat more complicated because you must take into account inflation in both of the countries concerned. We will discuss this when we study exchange rates.

To convertbetween a price index and an inflation rate, just remember that inflation is the change in the index between two dates.

You can think of the price index as being the price of a typical or representative good in the economy. So if the price index is, say, 100 in year 1, 104 in year 2, 108 in year 3, and so on, that means that a good that cost $100 in year 1 would cost $104 in year 2, $108 in year 3, and so on. Since inflation just means the average change in price of goods between two years, the inflation rate is the percentage change in the index. So if you have an index with two years, you can calculate the inflation rate as:

$$\textit{inflation between year 1 and year 2} = \frac{\textit{index in year 2}}{\textit{index in year 1}} - 1$$

This is the same as $\textit{inflation between year 1 and year 2} = \frac{\textit{index in year 2} - \textit{index in year 1}}{\textit{index in year 1}}$

If we have an inflation rate and want to go to an index, again we just rememebr that the inflation rate is the change in the index. So if we have two dates a year apart, then:

$$\textit{indexat date 2} = \textit{index at date 1} * (1 + \textit{inflation rate between dates 1 and 2})$$

What if the inflation continues at the same rate for a number of years? Well, each year the price index will be multiplied by $(1 + \textit{inflation})$. So if the same inflation rate continues for n years, then the price index at the end of that time will be equal to multiplying by $(1 + \textit{inflation})$ a total of n times. So:

$$\textit{price index index after n years of inflation rate i} = \textit{initial price index} * (1 + i)^n$$

If we want to go from two values of the price index to the average inflation rate in the intervening period, we just reverse this and write:[2]

$$i = \left(\frac{\textit{price index index at end}}{\textit{price index at start}}\right)^{\frac{1}{n}} - 1$$

As you can see, when $n = 1$ this is the same as the formula for two successive years given above.

When inflation rates are low and we are looking at just a few years, we can get an approximately correct answer by using the arithmetic mean instead:

$$i \approx \left(\frac{\textit{price index index at end}}{\textit{price index at start}} - 1\right)/n$$

Using the example above, the average inflation rate between 2010 and 2015 was $(\frac{238}{220})^{\frac{1}{5}} - 1 = 1.08^{0.2} - 1 = 1.0159 - 1 = 0.0159 = 1.59\%$. The approximation gives us $(1.08 - 1)/5 = 1.63\%$. So in this case they are very close.

[2] In math this is called the **geometric mean**, as opposed to the more familiar arithmetic mean.

Despite the names, nominal variables are the ones we directly observe in the world, while "real" variables are constructed by economists and depend on various assumptions.

Remember, a price level is the average price of a *basket* of goods and services. But many different goods and services are produced, and their prices do not all change at the same rate, so correcting for inflation requires choosing the most relevant basket of goods. For household income and goods and assets purchased by households, the Consumer Price Index (CPI) is normally used – it counts the prices of a basket of goods consumed by a representative urban household. If someone talks about “inflation" without saying which index, they are probably referring to the CPI. But for GDP and similar aggregate variables, the *GDP Deflator* is more relevant – it counts the prices of the same goods counted in GDP. Other indexes, such as the *Personal Consumption Expenditure Deflator*, or the *Producer Price Index*, may be used for other purposes. These different indexes do not always behave the same way, and it is not always obvious which is the right one for a given question. For example, Social security benefits are *indexed* (increased each year) to their real value constant using the cpi. But some economists argue that they should be indexed using the basket of goods typically consumed by retirees, rather than the basket of goods consumed by all households. since retirees consume more of goods whose prices rise rapidly, such as health care, and less of goods whose prices rise more slowly or even fall over time, like computers, it is arguable that they face a higher level of inflation than the general population, and the price index used for their income should reflect that.

In addition, when we are correcting an interest rate for inflation, we have to pick inflation over the right time period. For example, if you are taking out a 30-year mortgage today, the real burden of that loan depends not just on inflation today, but on inflation over the whole 30-year life of the loan. But of course, we do not know what inflation will be in future years. So while the nominal interest rate on the loan is a hard fact, written into the contract, the “real" rate is a more or less uncertain guess. (And the borrower and lender may have different guesses.) So despite the name, “real" variables are not really real – while nominal quantities really exist out there in the world, converting them to real quantities always involves a judgment call.