MEASURING THE PRICE LEVEL

There are always some prices that are rising and some that are falling. This means that the behavior of a single price, like the price of butter or bricks, may not be representative of the general movement in prices. We therefore need a measure of the average level of prices. Price levels or price indices measure the cost of living and they have two important uses in our study of the economy. They are used to calculate inflation and to adjust variables, like GDP, for changes in the average level of prices.

The best known price index is the consumer price index, or the CPI for short. In its role as a measure of the cost of living, the consumer price index is used to adjust the wages of millions of workers, the Social Security checks of more than 40 million beneficiaries, and literally millions of other prices and benefits. Because it is used to adjust wages, prices, and benefits for changes in the cost of living, the flow of billions of dollars hinges on relatively small changes in the CPI.

Calculating a Price Index

To begin we consider an economy with just three goods: milk, bread, and diamond rings. Milk and bread are the staples that sustain most households. Only a few households can afford the luster of a diamond ring. The prices of the three goods in time period 1 are

\[ p^{\text{milk}} = \$0.50/\text{gal} \quad p^{\text{bread}} = \$1.50/\text{loaf} \quad p^{\text{rings}} = \$1,000/\text{ring} \]

We want to find the average level of prices, and the simplest way to begin is with a simple average. The simple average of these three prices is just their sum divided by three
\[ P_a = \frac{(.50 + 1.50 + 1000)}{3} = 334. \]

Now suppose that in the next time period, time 2, the prices of milk and bread triple, but there is no change in the price of diamond rings. The new simple average of prices is

\[ P_a = \frac{(1.50 + 4.50 + 1000)}{3} = 335.33. \]

There is practically no change in this average even though the prices of the two most important goods in the economy tripled. In percentage terms the simple average changes by less than half of one percent. More precisely, the percentage change is given by

\[ \left( \frac{(335.33-334)}{344} \right) 100 = .399\%. \]

When the prices of the two staples triple, we want our measure of the average level of prices to come very close to tripling as well. In short, a useful index of prices should reflect the relative importance of bread and milk. A simple average gives each good the same weight, one-third in this case, but since the price of diamond rings is much higher than the prices of bread and milk, it dominates the simple average. The simple average thus fails as a price index because it gives too much importance to the price of diamond rings.

We therefore need a weighted average of prices, and the weights on bread and milk need to be far larger than the weight on diamond rings. How do we choose these weights? We already have a hint. Bread and milk are more important than diamond rings in the economy because people buy much more of these two goods than they do diamond rings. So it is reasonable to weight the goods in this economy by the amounts of bread, milk, and diamond rings that were purchased in some reference year. Suppose in the reference year the quantities of these goods were:

milk: 20,000 gallons  bread: 15,000 loaves  rings: 5 rings

We first calculate the weighted average of prices in time period 1. It is given by

\[ P_1 = (.50)(20,000) + (1.50)(15,000) + (1000)(5) \]
\[ = 37,500 \]
Again, assume that the prices of bread and milk triple, but the price of diamond rings stays the same. The new weighted average of prices is

\[ P_2 = (1.50)(20,000) + (4.50)(15,000) + (1000)(5) \]

\[ = 102,500. \]

This is an increase of 173% over the initial level of $37,500. A tripling of prices would be an increase of 200%. So, the weighted average nearly triples and clearly indicates a very large increase in the average level of prices. This is just what we wanted.

We are now ready to define a price index or the price level. A **price index** or **level** is a weighted average of the prices in an economy where the weights are based on the relative amounts of the goods (and services) purchased in the economy. It is important to note that it is the relative weights that matter. The weights 20,000, 15,000, and 5 could just as well have been 4,000, 3,000, and 1. The critical point is that milk is 1 1/3 times more important than bread, and bread is 3,000 times more important than rings, and so on.

A price index has another, often more convenient, interpretation. The weights used to calculate a price index may be thought of as a basket or bundle of goods. The bundle of goods in the above example consists of 20,000 gallons of milk, 15,000 loaves of bread, and 5 diamond rings. The weighted average of prices is just the cost of this bundle of goods. In general, a **price index or price level may be thought of as the cost of a bundle of goods**.

**The Consumer Price Index**

The best known price index is the consumer price index, or the CPI for short. It is the cost of the bundle of goods purchased by the average urban consumer. To find the bundle of goods
purchased by the average urban consumer the Bureau of Labor Statistics (BLS) periodically

counts a survey. They ask a sample of urban consumers to record and report their monthly purchases. The survey results are then used to construct the bundle of goods purchased by the typical survey respondent. The variety of goods included in the bundle is large, ranging from white cotton shirts to lines of bowling.

Each month BLS employees collect price information for a large sample of goods from a large sample of stores across major cities in the U.S. This information is used to calculate the CPI, and it is then reported to the public. It receives widespread media attention, usually making both national and local news programs. A plot of the CPI for the post-war U.S. is shown in Figure 3.1. The plot has two notable features. There is a distinct upward trend and in the 1970s prices rose faster than in any other decade.

The CPI can be broken into smaller categories such as food and beverages, apparel, and medical care. It is also calculated for individual cities such as Boston, New York, and Chicago. In short, each month the BLS provides the public with a substantial amount of price information. Table 3.1 gives the weights used to construct the CPI. The weights are in percentage form, but don't quite add to 100% because of rounding. Within each group there is a finer breakdown. For example, shelter accounts for about 28 percentage points of housing, fuel
and utility bills about 7 percentage points, and furnishings and operations about 6 percentage points. The category "other" includes smoking products, 1.6 points, personal care, 1.2 points; and personal and educational expenses, 3.8 points.

**Uses of a Price Index**

*a. real vs. nominal variables*

In our discussion of GDP we pointed out that a doubling of prices doubles GDP, but material well-being is not changed at all. We promised to adjust GDP to account for this shortcoming, and we do so now. A price index is used to make this adjustment. To see how this is done suppose that GDP is $2,000,000, and the price index is $100. We interpret the price index here as the cost of a bundle of goods. We may now ask how many bundles of goods does a $2,000,000 GDP represent? The answer is 20,000 bundles, because if you had $2,000,000 and each bundle costs $100, then you could buy 20,000 bundles. The calculation is

\[ 20,000 \text{ bundles} = \frac{2,000,000}{100} \text{ per bundles}. \]

A variable that is expressed in terms of bundles of goods is called a **real variable**. In contrast, a variable that is expressed in terms of dollars is called a **nominal variable**. In our

<table>
<thead>
<tr>
<th>Table 3.1</th>
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<tbody>
<tr>
<td><strong>Weights for the CPI</strong></td>
</tr>
<tr>
<td>food and beverage</td>
</tr>
<tr>
<td>housing</td>
</tr>
<tr>
<td>apparel and upkeep</td>
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<tr>
<td>transportation</td>
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<tr>
<td>medical care</td>
</tr>
<tr>
<td>entertainment</td>
</tr>
<tr>
<td>other</td>
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</tbody>
</table>
example, nominal GDP is $2,000,000 and real GDP is 20,000 bundles. In symbols the relationship between real GDP and nominal GDP in period t is

\[ \text{real GDP}_t = \frac{\text{GDP}_t}{P_t}. \]

In general, a nominal variable is converted to a real variable by dividing the nominal variable by the price level

\[ \text{real variable} = \frac{\text{nominal variable}}{\text{price level}}. \]

The distinction between nominal and real variables is essential. A person's real income determines his standard of living; the number of square feet in his home, the type of car he drives and clothes he wears. People are ultimately concerned about real variables, not nominal ones.

It is important to be aware of the distinction between real and nominal variables. Only in the special case when prices are constant, do we not have to worry about this distinction. As soon as prices vary, it is necessary to pay close attention to the difference between nominal and real variables. For example, if a newscaster announces that GDP increased by 5% last year, is this good news for standards of living? It depends. If this is real GDP growth, then growth was very high. However, if prices also rose by 5%, then there was no growth at all in real GDP over the past year.

b. inflation

**Inflation** is the rate of growth in the price level. Over the past 20 years inflation has averaged about 6% per year. The cumulative effect of this inflation on the price level has been substantial. A bundle of the goods that cost $40 in 1970 cost about $125 in 1990. If inflation happens to be negative, it is called **deflation**. The United States experienced long periods of deflation after the Civil War and during the depression in the 1930s. We last experienced deflation in 1986, but only for a few months. When inflation falls from one period to the next, say when it fell from 10.3% in 1980 to 6.2% in 1981, it is called **disinflation**. With disinflation the price level continues to grow, but at a slower pace.

The formula to calculate inflation is given by
\[ \pi_{t+1} = \frac{(P_{t+1} - P_t)}{P_t}, \]

where \( \pi_{t+1} \) is the rate of inflation from the time period \( t \) to \( t+1 \), \( P_{t+1} \) is the price level in time period \( t+1 \), and \( P_t \) is the price level in the previous period. If you want to express inflation in percentage terms, you just multiply \( \pi_{t+1} \) by 100.

Let's take a simple example to illustrate this calculation. The following are the actual CPI numbers for the U.S. for the years 1985, 1986, and 1987:

\[ P_{85} = 107.6 \quad P_{86} = 109.6 \quad P_{87} = 113.6. \]

We can use this data to find the inflation rate for the U.S. from 1985 to 1986. It is given by

\[ \pi_{86} = \frac{(109.6 - 107.6)}{107.6} = .019 \quad \text{or} \quad 1.9\% \]

The inflation rate from 1986 to 1987 is 3.65%. You should verify this calculation on your own.

The post-war path of inflation calculated using the CPI is given in Figure 3.2.

The figure clearly shows the sharp inflations immediately after World War II and at the start of the Korean War in 1950. After these dramatic episodes the inflation rate settled down to an average of 1.5% from 1952 through 1966. Beginning in the late 1960s inflation accelerated, reaching double digits in the mid 1970s and again in the early 1980s. From 1967 to 1982 inflation averaged 6.8%, increasing by more than a factor of four over the earlier period. We experienced disinflation in the 1980s as the average rate of inflation fell to an average of 3.7%.

**Standardizing the Price Index**

You may have noticed that the actual figures for the CPI were close to 100. This made the actual numbers much more manageable and easier to present than the $37,500 and $102,500 we calculated in our example. The actual numbers are close to 100 because the actual numbers are standardized. We are able to standardize because it is only the relative weights that matter. To illustrate the standardization procedure, we will standardize the figures in our example. The first step is to select a base year. In our example take time period 1 as the base year. The next
step is to divide the raw price index in each year by the price index in the base year. Finally, you take the resulting number and multiply it by 100. The standardized price level at time $t$, call it $P_t^s$, is therefore given by

$$P_t^s = \left( \frac{P_t}{\$37,500} \right) \times 100.$$ 

By definition the standardized price level in the base year is 100 (remember that time period 1 is the base year and $P_1 = \$37,500$). The standardized price level for year 2 in our example is

$$P_2^s = \left( \frac{\$102,500}{\$37,500} \right) \times 100$$

$$= 273.33$$

Since $P_1^s = 100$ and $P_2^s = 273.33$, the percentage change is easy to calculate with the standardized figures. It is just

$$\pi_2 = \frac{273.33 - 100}{100} = \frac{173.33}{100} = 1.7333 \quad \text{or} \quad 173.33\%,$$
This is exactly the percentage change we calculated with the original price levels (we rounded off .33 of a percentage point). Standardizing the price level does not affect the calculation of inflation, it only makes the price level figures easier to present.

The standardization procedure amounts to scaling the bundle of goods so that it costs $100 in the base year. If we look back at the CPI figures for 1985 and 1987, we can say that a bundle of goods that cost $107.60 in 1985 cost $113.60 in 1987. In practice, when a standardized price level is used to convert a nominal variable into a real variable, the real variable is said to be expressed in base year dollars, or sometimes the phrase in constant dollars is used. For example, if 1982 is the base year for the index used to calculate real GDP, real GDP is said to be in 1982 dollars or in constant dollars.

The standardization procedure makes a cosmetic change to the price level numbers. There is no change in the substantive meaning of the price levels or indices. In particular, the calculation of inflation and our interpretation of the price level as the cost of a bundle of goods are unaffected.

**Measurement Problems with the CPI**

Just as GDP had its measurement problems, so does the CPI; and all other price indices. The CPI is a so-called fixed weight index, because, once the bundle is determined, the weights do not change. Inflation rates calculated with fixed weight indices tend to be "too" high, and we say that these indices impart a positive bias to inflation rates. There are two sources of this bias. First, changes in the relative prices of goods cause people to change the bundle of goods they buy. Second, the quality of the goods in the bundle changes over time. We look at each of these problems in turn.

a. **changes in relative prices**

The easiest way to see the problems caused by changes in relative prices by looking at an example. Suppose the bundle and the prices are given by
bundle(1) = [10 bags of chips, 8 cans of almonds, 3 liters of Sprite].

\[ p_1^c = \$1/\text{bag} \quad p_1^a = \$2/\text{can} \quad p_1^s = \$3/\text{liter} \]

The price index, \( P_1 \), is just

\[ P_1 = \$1(10) + \$2(8) + \$3(3) = \$35. \]

In the next year prices change— not only dollar prices, but also relative prices. The new set of prices is

\[ p_2^c = \$1.10/\text{bag} \quad p_2^a = \$2.50/\text{can} \quad p_2^s = \$3/\text{liter} \]

With these prices, and using the same bundle, the price index for year 2 is

\[ P_2 = \$1.10(10) + \$2.50(8) + \$3(3) = \$40, \]

and the inflation rate is \( \frac{\$40 - \$35}{\$35} = .143 \) or 14.3%.

In year 2 the price of almonds increased relative to chips, it now takes 2.27 bags of chips to get a can of almonds instead of just the two bags it took in year 1. The price of Sprite has fallen relative to both goods. We expect that households will now substitute more bags of chips for the now more expensive almonds, and also drink more Sprite.\(^{11}\) Suppose the new bundle that they consume is

\[ \text{bundle}(2) = [11 \text{ bags of chips, 5 cans of almonds, 4 liters of Sprite}]. \]

This bundles differs from the earlier one in that it has more of the now relatively cheap goods, chips and Sprite, and less of the now relatively more expensive good, almonds.

It also leaves us with a problem. There is nothing inherently special about the bundle in year 1. We could just as well have chosen the year 2 bundle for our weights. But, something

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\(^{11}\) This assumes that our tastes for chips, almonds, and Sprite remain the same. If the price of almonds increased because we like almonds more this period than we did last period, then we would be willing to buy more almonds even if their price were higher.
happens when we make this change. If we calculate a price index in year 1 using the year 2 bundle, we get

\[ P'_1 = \$1(11) + \$2(5) + \$3(4) = \$33. \]

The price index in year 2 using the year 2 bundle will be

\[ P'_2 = \$1.10(11) + \$2.50(5) + \$3(4) = \$36.60. \]

The absolute numbers change, but this is not necessarily important since we know from our discussion of the standardization process that the specific numerical values of the index are not critical. However, this switch in weights also changes the inflation rate. With the year 2 bundle the inflation rate is \((\$36.60-\$330)/\$33 = .109\), or 10.9%. Simple standardization will not change inflation rates, but changing bundles does. Moreover, the inflation rate using the year 2 bundle is lower than the inflation rate using the year 1 bundle. This is a general feature. Once the weights are fixed, the inflation rates will be "too" high because in later years when the relative prices change, spending shifts toward goods with relatively low prices.

Does this mean that the "true" inflation rate is 10.9%? No. This rate is "too" low. We now have two rates, 14.3%, which is too high, and 10.9%, which is too low. The "best" estimate of the inflation rate will typically lie between these two numbers. Nevertheless, the official CPI does not make this adjustment, and so the implied inflation rates are too high.

b. changes in quality

The second source of error occurs when the quality of the goods in the bundle changes. To take a simple example suppose there are just two goods, bread and TV sets. The bundle and the prices of goods are
bundle = [100 loaves of bread, 1/2 of a TV set]

\[ p_1^b = \$0.50/\text{loaf} \quad p_1^{TV} = \$200/\text{set} \]

The price level in year 1 is $150. In year 2 the prices become

\[ p_2^b = \$0.55/\text{loaf} \quad p_2^{TV} = \$220/\text{set}. \]

The new price level is $165 and the inflation rate is 10%.

But, suppose that the quality of new TV sets improved over the year. The picture is clearer, the controls more user friendly. Strictly speaking, the year 2 TV set is not the same good as the year 1 TV set. However, there may be no year 1 sets left in stores, and any that were purchased the year before are now used sets. What we would like to do is to find a brand new year 1 set, one not even out of the box, to sell. If we were lucky enough to find such a set, we could use its price to calculate the price index in the second year. It seems pretty safe to assume that if we were to find a brand new year 1 set, it would sell for less than the new model. After all, the year 2 set is a better one. To make things concrete, suppose a year 1 set would sell for $205 in year 2. We can use this price to recalculate the price index, and we get

\[ P_2 = \$0.55(100) + \$205(.5) = \$157.50. \]

This is less than the $165, and yields an inflation rate of \((\$157.50 - \$150)/\$150 = 0.05\), or 5%. In the $220 price of the year 2 set, $15 reflects higher quality while only $5 reflects inflation. Omitting the effects of quality improvements leads to an overstatement of the rate of inflation, 10% instead of 5%.

c. consequences of the bias

The bias in the CPI causes the adjustments in prices, wages, and benefits that are based on it to be higher than is necessary to offset the effect of "true" inflation. For example, the government adjusts Social Security benefits to changes in the CPI. This means that if inflation is 3%, the dollar value of Social Security checks will increase by 3%. We say that Social Security benefits are indexed to the CPI, or that they contain a cost of living adjustment (COLAs).
positive bias in the CPI means that these adjustments are too large, and, instead of just making up for the lower purchasing power of a dollar, they make the recipients better off. Moreover, relatively small changes in the calculated inflation rate can have large effects. A reduction of 1 percentage point in the rate of inflation would reduce Social Security expenditures by literally billions of dollars. Recently, a panel of experts convened by the senate finance committee estimated the bias to be about one percentage point.\footnote{See the Wall Street Journal, September 18, 1995.}

This bias also affects the accuracy of real variables. Suppose, for example, that the nominal wage in one year is $3000 and in the next year it is $3400, and the respective fixed weight price indices are, say, $100 and $110, giving an inflation rate of 10%. Using these indices to convert the nominal wage into real wage gives us 30 bundles in year 1, and 30.91 bundles in year 2 for a growth rate in real wages of 3.03%. However, if the fixed weight price index overstates the inflation rate, an error arises in our real wage growth rate. Suppose that instead of 10%, a better guess at inflation is 8%, then the price index in year 2 should be $108, not $110. Using this new figure to calculate the real wage and its growth rate gives us 31.48 bundles for real wages, and a growth rate of 4.94%. This is a large error, the reported growth figure is off by nearly 40%.

**Extension: Other Price Indices**

Although the CPI receives the most attention, there are two other price indices that are also important. The producer price index is an index of the prices of goods that producers purchased. That is, it is the cost of a bundle of goods that the "typical" producer buys. Among other items, it includes the prices of lumber, paper, metals and metal products.

Another important price index is the implicit GDP deflator. This price index includes in its bundle all of the goods produced in the economy. It is therefore a broader index of prices than the CPI. Although the paths of the CPI and the GDP deflator may differ in any given period of time, the two indices tell a similar story. Since the deflator is a broader index, it is often preferred to the CPI.

The GDP deflator is produced as a by-product of the calculation of real GDP. The method used by the Commerce Department to calculate real GDP and the deflator recently changed.
Until the end of 1995, the Commerce Department calculated real GDP using base year prices in a way different than we described earlier. To see how the Commerce Department figured real GDP, consider the data in Table 3.1.

<table>
<thead>
<tr>
<th>Good</th>
<th>Prices</th>
<th>Quantities</th>
<th>Prices</th>
<th>Quantities</th>
</tr>
</thead>
<tbody>
<tr>
<td>sunglasses</td>
<td>$10</td>
<td>1000</td>
<td>$12</td>
<td>950</td>
</tr>
<tr>
<td>cotton shirts</td>
<td>$22</td>
<td>810</td>
<td>$24</td>
<td>870</td>
</tr>
<tr>
<td>liters of Sprite</td>
<td>$1.30</td>
<td>33,000</td>
<td>$1.40</td>
<td>36,000</td>
</tr>
</tbody>
</table>

If these are the only three goods in the economy, then the nominal GDPs in the two years are

\[
GDP_1 = 70,720 \quad \quad GDP_2 = 82,680
\]

Suppose we let year 1 be the base year, then to calculate real GDP according to the old Department of Commerce method we use year 1 prices and year 2 quantities to get

\[
\text{real } GDP_2 = (10)(950) + (22)(870) + (1.30)(36,000) = 75,440 \text{ in year 1 dollars.}
\]

This is the value of second period output when it is evaluated with first period prices.

Now, we have a number for real GDP in year 2 and a number for nominal GDP in year 2, so we can find the price level from the relationship \( \text{real } GDP_2 = GDP_2/P_2 \). It is

\[
P_2 = 82,680/75,440 = 1.096
\]

We multiply this number by 100, just as we did in the earlier standardization procedure, to get the implicit GDP deflator, 109.6.
The implicit deflator is the cost of a bundle of goods, so it has the same general interpretation as the CPI. However, the bundle not only includes consumption goods, but also investment goods, the goods that the government buys, and exports and imports. In addition, the bundle or weights change each period because the quantities used to calculate GDP and real GDP vary each year.

Sharp price declines and large quantity increases in computers spelled the end for this approach. To see why, suppose a new technology made the price of shirts fall to $10 in year 2. Nevertheless, the old method would use the $22 price to calculate the real GDP. This leads to an overestimate of GDP, shirts have too large of a contribution, and this bias, in turn, causes GDP growth to be "too high". If price declines are rare or small or both, then this type of bias doesn't pose a significant problem. But, the price declines in computers were large and persistent, and were accompanied by large increases in quantities.

To address these problems the Commerce Department decided to use an averaging method that is called chaining. To calculate real GDP growth, the Commerce Department now makes two growth calculations. The first growth rate uses year 1 prices to calculate real GDP in both years and is given by

\[ \text{real GDP growth(yr1$)} = \frac{75,440 - 70,720}{70,720} \]

\[ = 0.067 \text{ or } 6.7\%. \]

We next use year 2 prices to calculate levels of real GDP in both periods and its growth rate.

The levels are

\[ \text{real GDP}_2 \text{ (yr2$)} = (12)(950) + (24)(780) + (1.40)(36,000) = 82,680, \]

\[ \text{real GDP}_1 \text{ (yr2$)} = (12)(1,000) + (24)(810) + (1.40)(33,000) = 77,640, \]

and the growth rate is
real GDP growth(yr2$) = \frac{[82,680 - 77,640]}{77,640}

= .065 or 6.5%.

The chain-weighted growth rate that is reported by the Commerce Department is the average of the above two:

real chain-weighted GDP growth = \frac{[\text{real GDP growth(yr2$)} + \text{real GDP growth(yr1$)}]}{2}

= \frac{.067 + .065}{2} = .066 or 6.6%.

This gives the growth rate in real GDP from year 1 to year 2. To find the growth rate from year 2 to year 3, we just move everything up a notch. Growth would be calculated in year 2 dollars and in year 3 dollars and then the average would be chained growth.

Chaining does not give us the level of real GDP or the implicit price deflator. To find the level of real GDP, we use the growth rates. Suppose we take year 0 to be the base year and GDP in year 0 was $66,000. Also, suppose that real GDP growth from year 0 to year 1 was calculated on the "chained" basis to be .043 or 4.3%. The level of year 1 real GDP in year 0 dollars is

real GDP_1(yr0$) = GDP_0 + (.043)GDP_0 = 68,838

To get the level of real GDP in year 2 you apply the same idea but begin with year 1 real GDP and use the growth rate from year 1 to year 2. The level of year 2 real GDP in year 0 dollars is

real GDP_2 (yr0$) = 68,838 + (.066)(68,838) = 73,381.

We now have the level of real GDP and nominal GDP for years 1 and 2, and we can now find the implicit GDP deflator using the same relationship that we used earlier. For year 2 the deflator is
GDP deflator$_2 = (82,680/73,381)100 = 112.7.$

Chaining does not change our general interpretation of a price index as a weighted average of prices or the cost of a bundle of goods. Instead, the new method is an attempt to adjust the weights or bundle to give us a better estimate of the price level and its rate of change.

Summary

In this chapter we have motivated and defined price indices. Price indices are used to calculate inflation rates and to move from nominal variables to real variables. They will thus serve an important function in our study of the macroeconomy. Price indices are also important to the government budget and to millions of people whose wages and benefits are tied to the cost of living.

REVIEW QUESTIONS

1) Consider the following bundle of goods:

100  loaves of bread
75   quarts of milk
1/100 21" Panasonic color TV.

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<tbody>
<tr>
<td>$p_{bread}$</td>
<td>$1.00</td>
<td>$1.10</td>
<td>$1.11</td>
<td>$1.15</td>
<td>$1.27</td>
</tr>
<tr>
<td>$p_{milk}$</td>
<td>$1.50</td>
<td>$1.50</td>
<td>$1.65</td>
<td>$1.60</td>
<td>$1.76</td>
</tr>
<tr>
<td>$p_{TV}$</td>
<td>$300</td>
<td>$330</td>
<td>$330</td>
<td>$305</td>
<td>$336</td>
</tr>
</tbody>
</table>
a) calculate the price index for each year

\[ P_{87} = \]  

\[ P_{88} = \]  

\[ P_{89} = \]  

\[ P_{90} = \]  

\[ P_{91} = \]  

b) Must all individual prices rise for the price index to rise?

c) If individual prices change, must the price index change?

2) a) Suppose nominal GDP was 5,400,000,000 in 1990 and 5,750,000,000 in 1991. Calculate real GDP in both years and its growth rate. Use the price index that you calculated in the previous problem to move from nominal GDP to real GDP.

b) Suppose the quality of the TV set improved significantly from 90 to 91 so that the 90 model sold for only $290 in 1991. How would this affect your calculation of real GDP.

3) Let 1988 be the base year and recalculate the standardized price index for each year.

\[ P_{87}^s = \]  

\[ P_{88}^s = \]  

\[ P_{89}^s = \]  

\[ P_{90}^s = \]  

\[ P_{91}^s = \]
4) Calculate the inflation rate over each period. We denote the inflation rate by the Greek letter \( \pi \) (pi). For example, \( \pi_{88} \) is the inflation rate from 1987 to 1988, and is given in decimal form by \( \pi_{88} = \frac{P_{88} - P_{87}}{P_{87}} \). Report the rates in both decimal and percentage form. Check to see if your answer changes when you use the standardized price index in your calculations.

\[
\pi_{88} = \frac{P_{88} - P_{87}}{P_{87}}
\]

\[
\pi_{89} = \frac{P_{89} - P_{88}}{P_{88}}
\]

\[
\pi_{90} = \frac{P_{90} - P_{89}}{P_{89}}
\]

\[
\pi_{91} = \frac{P_{91} - P_{90}}{P_{90}}
\]