4 Measuring Prices and Inflation

As we have seen in the last two chapters, a measure of the general price level is needed to convert nominal quantities to real quantities and to estimate the rate of inflation. We begin this chapter with the question, how can information about millions of prices in the economy be reduced into a simpler, more manageable index? We begin by looking at the main types of price indices. How are they calculated? What are the advantages and disadvantages of each type? We conclude with a discussion of the price indices most commonly used in the formulation and execution of economic policy.

In Chapter 2, we used a **PRICE INDEX**, the GDP (implicit price) deflator, as the preferred measure of the general level of prices or the value of money. The GDP deflator is not the only price index. In this chapter we shall learn about a variety of price indices and how they are constructed.

The GDP deflator in Chapter 2 served two purposes. First, we typically care about *real* rather than *nominal* quantities: real GDP, real consumption, real investment, real government expenditure. In Chapters 2 and 3 we saw that real GDP and its components are not observed directly. Rather, the national-income accountants must first measure market or nominal GDP in current dollars and then use a price index to convert it into real or constant dollars. Second, we sometimes care about how fast prices are changing. The growth rate of a price index, the rate of inflation, provides a measure.

The construction of price indices is obviously important to the national-income accountant. A mistake in constructing the GDP deflator resulting in an overstatement of the rate of inflation by the very small amount of 0.1 percentage points would reduce the estimate of real GDP in 2004 by about $10 billion. Such errors can be costly to the government. For example, the government uses the consumer price index (CPI; see section 4.2.2) to adjust Social Security and government pensions for inflation. In 2004, each tenth of a percentage point overestimate of the CPI rate of inflation would have added about $500 million to the cost of Social Security. In 1996, the Boskin Commission estimated that the CPI rate of inflation was overstated by 1.1 percentage points. That would translate into $5.5 billion in 2004 – a costly mistake. And such mistakes compound and accumulate year by year.

We are also often interested in the rate of inflation in its own right. One goal of monetary policy is to keep the rate of inflation low but not negative – as we saw in Chapter 2, deflation (falling prices) is at least as undesirable as inflation. Zero inflation might, then, appear to be an optimal target for policy. But according to which index? Inflation rates are typically lower when measured using the GDP deflator than when using the CPI. If the GDP deflator were the better index, then achieving a zero rate of CPI inflation would imply deflation in fact. It is important to get the price index right or, at the least, to understand the differences among various price indices.

We begin with the general principles behind the construction of price indices and conclude with a description of the main indices used by economists, national-income accountants, and policymakers.

4.1 Constructing Price Indices

Why can the price of a single good (such as the can of Coca-Cola in Chapter 2) not serve as an accurate representation of all market prices? It would be perfect, provided that every price in the economy moved proportionately at all times,. Alas, they do not.

Although for over half a century most prices in the United States have risen, they have done so at different rates, and the prices of some goods, such as televisions, have actually fallen. What we need is an average measure of prices. But a simple average (adding the prices of, say, 1,000,000 goods and dividing by 1,000,000) would not be very satisfactory. The price of matches hardly matters to us, while the price of cars matters a great deal. A satisfactory measure needs to take account of the relative importance of different goods.

We can illustrate different approaches to estimating the **GENERAL PRICE LEVEL** with a simple, artificial example. The "couch-potato" economy produces only two goods – tortilla chips and beer. (The television and the couch can be considered to be natural resources.) Table 4.1 shows the prices and quantities of each for three years.

4.1.1 The Laspeyres (or base-weighted) Index

How much have prices risen, say, between 2003 and 2004? The price of tortilla chips has doubled, while the price of beer rose by 5/3. One approach to estimating the average is to weight these changes by how important each good is in total expenditure in 2003. Nominal GDP in 2003 is \$5.50 (= 5 tortilla chips × \$0.50/bag + 4 beers × \$0.75/can). Total expenditure on tortilla chips is \$2.50 or 45.5 percent of nominal GDP (= \$2.50/\$5.50 = 0.455). Total expenditure on beer is 54.5 percent of GDP. The **BASE PERIOD** is *the period for which expenditure shares are calculated* – here 2003.

Using the expenditure shares in the base period as weights, the increase in general prices is measured by the **PRICE FACTOR**, defined as *the ratio of price levels* (= p_{2004}/p_{2003}) and calculated as

Table 4.1. The Couch-Potato Economy

		Tortilla Chips (bags)	Beer (cans)
2003	**Price**	$0.50	$0.75
	Quantity	5	4
2004	**Price**	$1.00	$1.25
	Quantity	4	5
2005	**Price**	$1.25	$1.40
	Quantity	3	6

$$pf = 0.455 \times 2 + 0.545 \times 5/3 = 1.818.$$

The price factor shows that prices in general have risen faster than the price of beer, but slower than the price of tortilla chips.

The price factor can be used just as we used the relative increase in the price of Coke to deflate 2004 GDP and to express it in 2003 dollars. Nominal GDP in 2004 is \$10.25. What is 2004 GDP in constant 2003 dollars?

$$\$_{2003}Y_{2004} = \$_{2004}Y_{2004} \div pf = \$_{2004}10.25 \div 1.818 = \$_{2003}5.64.$$

Real GDP has increased by 2.5 percent (= (5.64 – 5.50)/5.50).

To construct a price index, we start with a **REFERENCE PERIOD** in which the index is set to some arbitrary value – typically, to 100. If 2003 is the reference period, then by definition $p_{2003} = 100$. Since prices have increased in general by a factor of 1.818, the index for 2004 must be higher by the same factor: $p_{2004} = pf \times p_{2003} = 1.818 \times 100 = 181.8$. Using 2003 as the base year (that is, using the expenditure shares of 2003), we could compute the price factor that measures how much prices increased between 2003 and 2005 and use it to compute the price index for 2005 (see Problem 4.3).

An index that weights price increases by the expenditure shares in the base period is known as a **BASE-WEIGHTED** OR **LASPEYRES INDEX** after the German statistician Ernst Louis Etienne Laspeyres (1834-1913**)**, who invented it in the 19th century. The Laspeyres index is, perhaps, the most commonly used of all the many types of price indices. Such common indices as the consumer price index (CPI) and the producer price index (PPI) are

Laspeyres indices. (The *Guide*, section G.8.2, gives a general formula for computing a Laspeyres index.)

The base period (that is, the period for which the weights are computed) and the reference period (that is, the period in which nominal and real values coincide) are usually the same for a Laspeyres index, but they need not be. For example, we might have answered the question, what is the value of 2003 GDP in 2004 constant dollars?, using the same Laspeyres index to *inflate* the dollars of 2003:

$$\$_{2004}Y_{2003} = \$_{2003}Y_{2003} \times pf = \$_{2003}5.50 \times 1.818 = \$_{2004}10.00.$$

Similarly, the price index could be arbitrarily set to 100 in 2004. Then, $p_{2004} = 100$ and $p_{2003} = 100/pf = 100/1.818 = 55.0$. Although the reference year is now 2004, the base year is still 2003, since the price factor is based on the 2003 expenditure shares.

The data in Table 4.1 tell a typical economic story. Notice that in 2003 the price of beer relative to tortilla chips is \$0.75 per can of beer/\$0.50 per bag of chips = 1.5 cans of beer per bag of chips. The price of chips rose faster than the price of beer, so that by 2004, the relative price of beer had fallen to 1.25 cans per bag. Table 4.1 shows that people bought more beer and fewer chips, illustrating the general rule, the principle of **substitution**: *When the relative price of a good falls the quantity sold typically increases, while the quantity sold of the relatively more expensive good falls.* As a result, the Laspeyres index tends to overstate the average increase in prices. People tend to substitute those goods with slower than average increases in prices for those goods with faster than average increases. Typically, such substitution lowers the share in total expenditure of the goods with the faster increases in price. But since the weights of the Laspeyres index are fixed in the base period, neither the price factor nor the price index reflects the changing weights.

The overestimation of the rate of inflation because of fixed weights is called **SUBSTITUTION BIAS**. To mitigate substitution bias, the base period of a Laspeyres index must be updated from time to time. The weights for the CPI (a Laspeyres index) were updated historically about every ten years. Recently, the updating schedule has been accelerated, so that they are on average only about three years old. Even though the base period for the CPI has been updated several times, the reference period has remained 1982-84 for some time.

A base-weighted price index can also overstate price inflation if it fails to account properly for quality change. The average price of a house in the United States has gone up substantially over the past fifty years, but so has its quality. For example, the average floor space of new houses in the United States more than doubled from 983 square feet in 1950 to 2,265 square feet in 2000. A price index that uses the house price will find more inflation than one that uses the price per square foot of floor space. Similarly, a price index that measures prices of computers has not fallen as rapidly as the more relevant price of computing power – measured by such properties as the speed of the processor and the size of the memory – and contributes to overstating the rate of increase of prices in general.

Computers highlight another problem with base-weighted indices – **NEW PRODUCT BIAS**. In 2004 personal computers are an important element in general expenditure and carry a significant weight in the calculation of the general price level.

Yet, in 1970 there were no personal computers. Weights must be updated from time to time to account for new goods.

4.1.2 The Paasche (or Current-weighted) Index

One way of mitigating substitution bias is to update the weights. In 1874, Hermann Paasche (1851-1925), another German statistician, suggested replacing the backward-looking Laspeyres index with an index that used the current expenditure shares to weight different price changes. In Table 4.1, expenditure on tortilla chips in 2004 is 39 percent of GDP, and expenditure on beer is 61 percent of GDP. The price of tortilla chips in 2003 was ½ the price in 2004; the price of beer was 3/5. The price factor for the Laspeyres index expressed changes as the ratio of later prices to earlier prices. Since the **Paasche index** (or **current-weighted**) **index** looks forward, it expresses changes as the ratio of earlier prices to later prices. To put it on the same basis as the Laspeyres index, we must calculate the reciprocal of the weighted average:

$$pf = \frac{1}{0.39 \times 1/2 + 0.61 \times 3/5} = 1.783$$

(The *Guide*, section G.8.2, gives a general formula for computing a Paasche index.) Real GDP in 2003 expressed in constant 2004 dollars is

$$\$_{2004}Y_{2003} = \$_{2003}Y_{2003} \times pf = \$_{2004}5.50 \times 1.782 = \$_{2004}9.80.$$

If the price index is set to 100 in the reference year 2004, then p_{2004} = 100 and p_{2003} = p_{2004}/pf = 100/1.782 = 56.1.

Although the Paasche index mitigates the substitution bias of the Laspeyres index, it suffers from a bias of its own – **QUALITY CHANGE BIAS**. When the price of one good rises we often substitute into less desirable goods: hamburger replaces steak, Budweiser replaces Heineken, a Toyota replaces a Lexus. The Paasche index undercounts the loss in satisfaction because of such substitutions. As a current-weighted index, the Paasche index also suffers from a major inconvenience. It must be recomputed each period because, typically, the weights change each period. Each time a Paasche index is recomputed, the whole history of the index could be revised using the new weights. In practice, the reference period is kept constant, and the new weights apply only to the calculation of the current level of the index.

4.1.3 The Fisher-ideal Index

Is the rate of inflation in the couch-potato economy of Table 4.1 82 percent per year (according to the Laspeyres index) or only 78 percent (according to the Paasche index)? Whichever index we use, prices and quantities of chips and beer are the same. We are looking at the same underlying facts through different pairs of glasses. Is one pair better than the other? Unfortunately not. Each suffers from a different bias.

There is no *true* price index. Price indices summarize the changes of millions of prices in an single number. Some information must be lost in the process. Different things are lost according to the weights placed on individual changes. The Laspeyres index more or less defines the upper bound for the change in the general price level, and the Paasche index defines the lower bound. There are, in principle, an infinite number of reasonable weighting schemes that lie between these bounds – each defines a different index. The great American economist Irving Fisher (1867-1947) suggested a compromise between the Laspeyres and the Paasche indices that he called "ideal," because of its many desirable properties. The price factor for the **FISHER-IDEAL INDEX** (pf^F) is the geometric average of the Laspeyres (pf^L) and the Paasche (pf^P) indices:

(4.1) $$pf^F = \sqrt{pf^L \times pf^P}\ .$$

The price factor for the Fisher-ideal index for the couch-potato economy for 2004 is $pf^F_{2004} = \sqrt{1.818 \times 1.782} = 1.800$. The price factor can be used in the usual way. If 2003 is taken to be the reference year, then the Fisher-ideal price index is $p^F_{2004} = pf^F_{2004} \times p^F_{2003} = 1.800 \times 100 = 180.0$.

(The *Guide*, section G.8.2, gives a general formula for computing a Fisher-ideal index.)

4.1.4 THE CHAIN-WEIGHTED INDEX

Most of the price indices used in compiling the national accounts in the United States are a variant of the Fisher-ideal type called the **CHAIN-WEIGHTED INDEX**. The first step in constructing a chain-weighted index is to calculate the price factors for the Fisher-ideal index for successive pairs of periods for which the base of the Laspeyres index is updated each period.

For example, using the data in Table 4.1, we already know that the Fisher ideal index calculated for 2004, taking 2003 as the base of the underlying Laspeyres index, is $pf_{2004}^{F} = 1.800$. We also already know that, in 2004, 39 percent of expenditure went to tortilla chips and 61 percent to beer. Therefore, the Laspeyres price factor for 2005, taking 2004 as the base, is $pf_{2005}^{L} = 0.39 \times \frac{1.25}{1.00} + 0.61 \times \frac{1.40}{1.25} = 1.171$. The Paasche price factor $pf_{2005}^{P} = 1.157$ (the student should confirm this value as an exercise). The Fisher-ideal price factor is then $pf_{2005}^{F} = \sqrt{1.171 \times 1.157} = 1.164$.

The price factors are then combined in a chain in which last period's index is multiplied by this period's price factor to construct the complete series. Taking 2003 as the reference year:

$$p_{2003}^{C} = 100,$$

$$p_{2004}^{C} = p_{2003}^{C} \times pf_{2004}^{F} = 100 \times 1.800 = 180.0,$$

$$p_{2005}^{C} = p_{2004}^{C} \times pf_{2005}^{F} = 180.0 \times 1.164 = 209.5.$$

$$\ldots$$

4.1.5 Price Indices and Real GDP

Table 4.2 shows the Laspeyres, Paasche, and chain-weighted price indices for 2003-05 for the couch potato economy and uses them to calculate real GDP. (The student should

Table 4.2. Converting Nominal GDP to Real GDP in the Couch-Potato Economy

Year	Nominal GDP	Price Index			Real GDP in Constant Dollars Using								
					Laspeyres Index			Paasche Index			Chain-weighted		
		Laspeyres	Paasche	Chain-weighted	with reference year								
					2003	2004	2005	2003	2004	2005	2003	2004	2005
2003	$5.50	100.0	100.0	100.0	$5.50	$10.00	$11.71	$5.50	$9.80	$11.34	$5.50	$9.90	$11.52
2004	$10.25	181.8	178.2	180.0	$5.64	$10.25	$12.00	$5.75	$10.25	$11.86	$5.69	$10.25	$11.93
2005	$12.15	212.9	206.2	209.5	$5.71	$10.37	$12.15	$5.89	$10.50	$12.15	$5.80	$10.43	$12.15

Note: Data are based on Table 4.1.

check to see that any entries not based on calculations in the text are correct.) The table illustrates two rules:

- *First, for the same reference period, typically the Laspeyres index is greater than the chain-weighted index, which is greater than the Paasche index.*
- *Second, the higher the general price level, the lower real GDP, so that real GDP (except in the reference period) appears larger when estimated with a Paasche index than with a chain-weighted index, which in turn is larger than when estimated with a Laspeyres index.*

The first rule rule extends to inflation rates: the average rate of inflation between 2003 and 2005 measured by each index is: Laspeyres 45.9 percent > chain-weighted 44.7 percent > greater Paasche 43.6 percent. The second rule extends to the growth rate of real GDP: the average rate of real growth over the same period measured by each index is: Paasche 3.48 percent > chain-weighted 2.69 percent > Laspeyres 1.89 percent.

Although the numbers in the couch potato economy exaggerate the differences among the three indices compared to what is typically observed in the real world, they illustrate well the general pattern. It is important to recall that, despite different inflation and growth rates, there is only one economy seen through different glasses. The faster growth rate based on the Paasche index does not give people in the couch-potato economy any more beer or tortilla chips than the slower growth rate based on the Laspeyres index. The faster inflation rate based on the Laspeyres index does not impose any more costs on them than the slower inflation rate based on the Paasche index.

4.1.6 The Implicit Price Deflator

Most of the components of U.S. GDP are converted into constant dollars or deflated using chain-weighted indices. A few components still use a fixed-weight index such as the Laspeyres or Paasche indices. Official estimates of real GDP are constructed from the deflated components. The ratio of nominal GDP to the estimate of real GDP gives an overall measure of the general price level known as the GDP **IMPLICIT PRICE DEFLATOR**:

$$p^{Implict} = \frac{Nominal\ GDP}{Real\ GDP} \times 100 .$$

Multiplying by 100 ensures that $p^{Implicit} = 100$ in the reference year for real GDP. The GDP implicit price deflator does not necessarily correspond exactly to any of the many price indices used to construct real GDP. Instead, it summarizes the net effect of their interaction. Implicit price deflators may be constructed for consumption and other components of GDP as well.

In Chapter 2, we asked, how much bigger is the economy today than in 1960? It is now clear why that question is better answered using an appropriate price index than using the price of a can of Coca Cola. The implicit price deflator in 1960 was 22.3 and in 2001, 109.8. On this measure, prices have risen 4.92 times over 41 years. Table 4.3 is similar to Tables 2.1 and 4.2 except that it uses this ratio to make the conversions of nominal GDP to the constant dollars of 1960 and 2001. Where using the price of Coke as deflator indicated that GDP had risen about 7½ times, using the Bureau of Economic Analysis's implicit price deflator shows a rise of just shy of 5 times. What we believe is

Table 4.3
Converting Nominal GDP to Real GDP
Using the Implicit Price Deflator

			Real GDP in Constant Dollars of Reference Year	
Year	**Nominal GDP**	**Implicit Price Deflator (1996=100)**	**1960**	**2001**
1960	$527.4	22.3	$527.4	$2,596.8
2001	$10,082.2	109.8	$2,047.7	$10,082.2

Source: Bureau of Economic Analysis.

true about prices in general makes a big difference to what we believe about the size of the real economy.

4.2 Alternative Price Indices

Although the GDP deflator is used to convert nominal to real GDP, other price indices are generally used for other purposes. Monetary policymakers at the Federal Reserve (see Chapter 17) have recently preferred to use the **personal consumption expenditure (PCE) deflator** (i.e., the deflator defined as the ratio of nominal consumption to real consumption) to estimate inflation rates. One reason is that the GDP deflator reflects the prices of all of the components of GDP, yet significant parts of GDP (for example, investment or government expenditure) are not consumed directly by individual people, and the welfare of people is the main aim of policy. The two most commonly cited price indices are not reported in the national accounts. These are the **consumer price index** (**CPI**) and the **producer price index** (**PPI**). Both are constructed and published by U.S. Bureau of Labor Statistics (BLS).

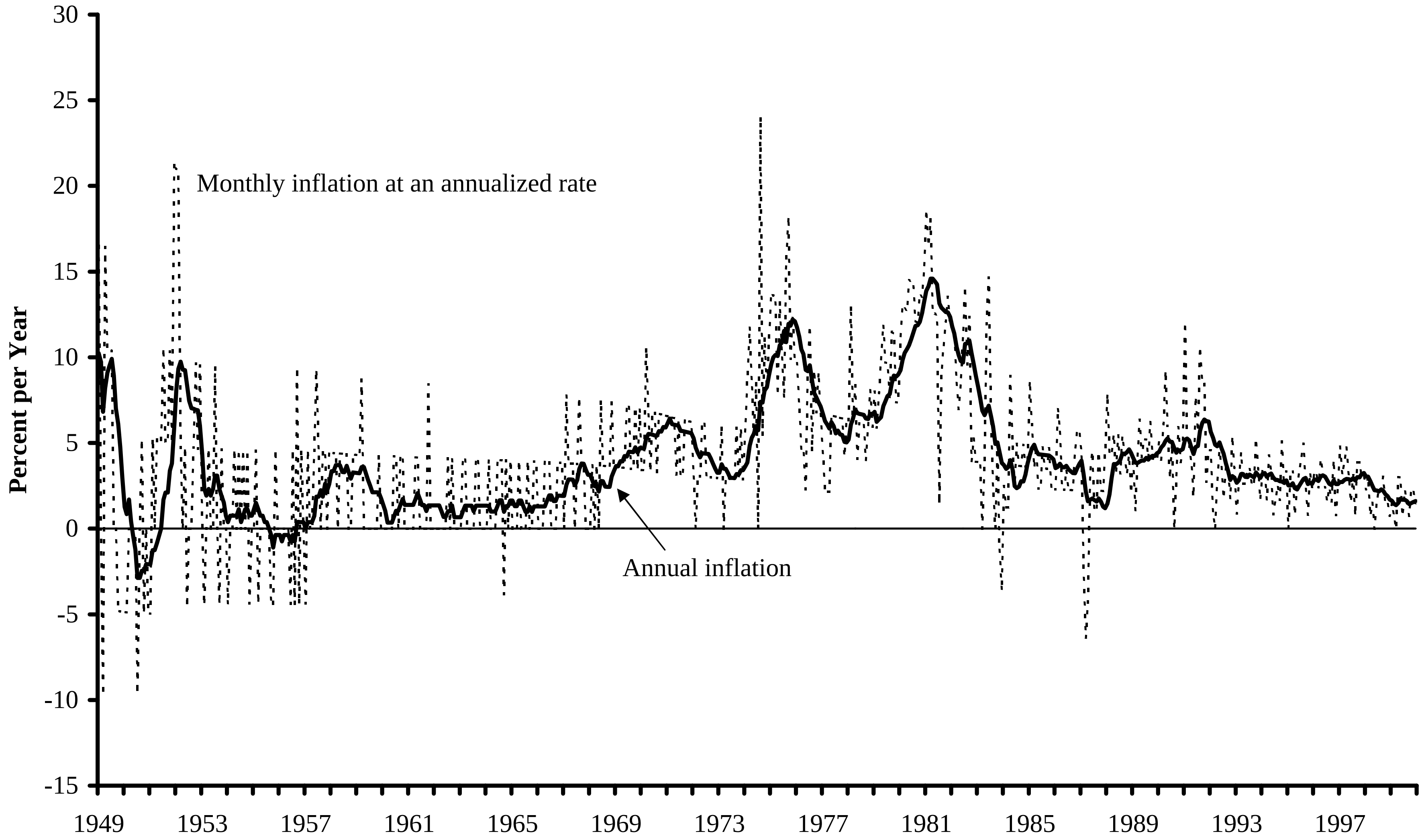
4.2.1 The Consumer Price Index (CPI)

The CPI is a **COST-OF-LIVING INDEX**. Essentially, it is a Laspeyres index, whose weights reflect the relative importance of different goods and services in the consumption bundle of typical consumers. The CPI is based on surveys of what consumers actually buy. In fact, the CPI is not a single index; there are many CPIs. Each is distinguished by the basket of goods that is used to construct it. The most frequently quoted CPI is **CPI-U**, the consumer price index for all items for all urban consumers. This index reflects the purchasing bundles of the approximately 87 percent of the population living in urban areas.

Over 350 other CPI series are computed. There are indices for over 200 particular types of goods (e.g., apples, airline fares, men's shirts, gasoline). These indices are combined into over 120 broader indices (e.g., food and beverages, housing, medical care, energy; men's and boys' apparel), which are, in turn, combined into eight major groups (food and beverages, housing, apparel, transportation, medical care, recreation, education, communications, and other goods and services). And there are still broader categories, such as durable goods, nondurable goods, and all items. In addition, separate CPIs are computed for major metropolitan areas, such as Los Angeles-Riverside-Orange County, California or the Northeast Urban Census Region. A CPI series for a narrower group of urban wage earners and clerical workers (about 32 percent of the population) is called **CPI-W**. And the BLS is experimenting with a special CPI that uses a bundle appropriate to elderly people. Many of the various CPI's are published in both seasonally adjusted and non-seasonally adjusted versions (see the *Guide*, section G.1.3). Currently, the reference period for the CPI is set so that the average value in 1982-1984 is 100.

Unlike the GDP price deflator, which is published quarterly and frequently revised, the CPI is published monthly and, once published, is not changed, even though the BLS makes frequent improvements to its methods of computing new data. This means that the CPI is the most timely and most frequently reported and cited measure of prices. Reports in the news media most often cite the monthly rate of inflation for CPI-U. Monthly CPI inflation is highly volatile (Figure 4.1). It is not uncommon for rapid

Figure 4.1
CPI Inflation (monthly and annual), 1948-1998



Source: Bureau of Labor Statistics, CPI-U.

growth one month to be followed by much slower growth the next. It is generally safer to look at annual rates of CPI inflation.

The CPI is the most widely cited of all price indices. It is particularly important because it is used to make cost-of-living adjustments, including those for Social Security recipients. The CPI has long been criticized for overstating the underlying rate of inflation. In the mid-1990s, the United States Congress commissioned a study of the CPI. The commission, headed by Stanford economists Michael Boskin, noted several sources of bias in CPI estimates. In addition to the substitution and quality change, and new product biases discussed in section 4.1, it identified two other sources of bias: *Outlet-substitution bias* results from a failure of the BLS to account for consumers shifting their purchases of the same goods to cheaper outlets, such as Wal-Mart. *Formula bias* occurred because of a technical problem in some BLS formulae, which affected historical CPI data although it had already been corrected by the time of the report. The Boskin commission estimated that the total bias averaged 1.1 percentage points (not counting 0.2 points for formula bias before 1996). It recommended a number of changes to the procedures of the BLS, including abandoning the Laspeyres formula, in favor of a so-called *superlative index*. A superlative index is similar in spirit to the Fisher-ideal index, although it relies on weighted-geometric, rather than arithmetic, averages to construct its root indices.

In the period since the Boskin report, the BLS has introduced many of its recommendations with respect to the treatment of new products, quality change, and outlet bias. The CPI remains essentially a Laspeyres index. It is not built up from individual prices, but from price indices for narrowly defined commodity groups. Some of these components are now superlative indices, while others remain Laspeyres indices. In 2002, the BLS also began publishing **C-CPI-U**, a chained CPI index based on the superlative formula. Unlike CPI-U, C-CPI-U is revised from time to time.

4.2.2 The Personal Consumption Expenditure Deflator

The PCE deflator (sometimes call the *PCE price index* or *PCEPI*) is the closest analogue to the CPI in the national accounts. In fact, the PCE deflator and the CPI use many of the same surveys as raw material. Yet, they differ in a number of ways. First, the PCE deflator takes a producer's-eye view. It tries to capture the prices of consumption goods produced in the domestic private sector, not the goods actually purchased by consumers. Among other things, it excludes foreign-produced goods. Second, it is a chain-weighted index, not a Laspeyres index. Third, it is revised as often as the national-accounts are revised. In contrast, once published, the CPI is essentially never revised. Finally, the PCE deflator is a quarterly rather than a monthly series. Table 4.4 summarizes the main differences between the PCE deflator and the CPI. Figure 4.2 compares annual rates of inflation measured by these two indices, as well as by the GDP deflator.

4.2.3 The Producer Price Index (PPI)

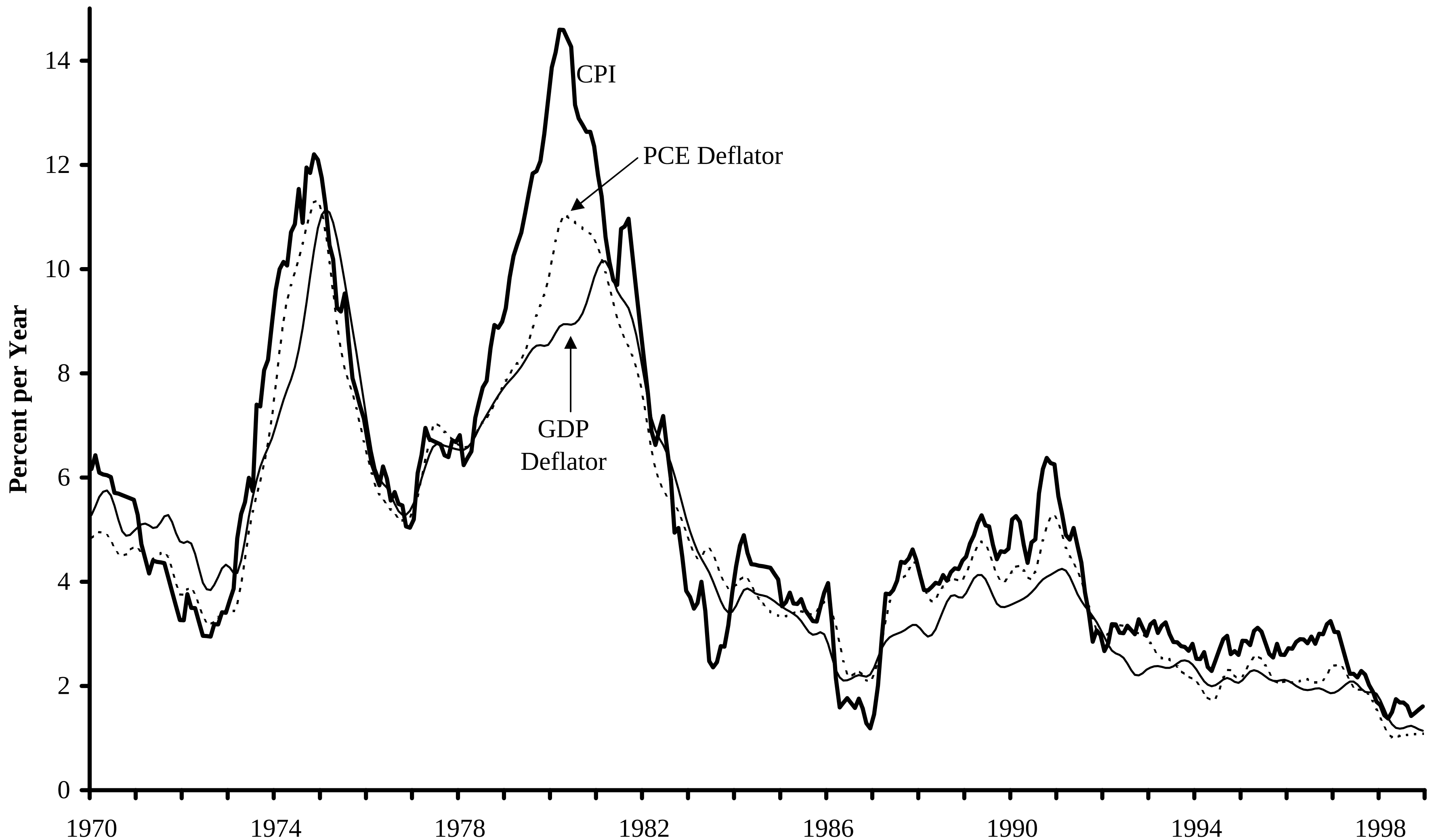
The PPI is the second most commonly cited price index in the United States. It is the oldest continuously computed price index in the United States, having been first published by the BLS under its original name, the *wholesale price index*, in 1902. Like the CPI, the PPI is not one index but a family of indices that aim to capture the prices at which manufacturers and other producers sell their output. Producer price indices for

Table 4.4
Summary of the Differences between the CPI and the PCE Deflator

Category	**Differences**
Formula	The CPI uses a fixed-weight Laspeyres formula, with weights determined by base-year expenditures. The PCE deflator uses a chain-weighted Fisher-Ideal formula.
Scope	The PCE deflator is broader in scope. The CPI covers out-of-pocket expenditures by urban consumers [CPI-U]. The PCE deflator also covers spending by rural consumers, nonprofit institutions that serve consumers, medical care and insurance funded by government and employers, and imputed financial services.
Weights	Weight differences reflect differences in: scope, item definition, and sources of expenditure data.
Prices	Although most of the detailed item prices in the PCE deflator are CPI indices, the PCE deflator relies on non-CPI price information for items not included in the CPI and items having substantially different coverage in the CPI and PCE deflator.
Treatment of Revisions	The CPI is essentially never revised, but the PCE deflator is continually revised.

Source: Adapted from Todd E. Clark, "A Comparison of the CPI and the PCE Price Index," *Federal Reserve Bank of Kansas City Economic Review*, vol. 84, no. 3, (3rd quarter), 1999, Table 1, p. 21.

Figure 4.2
The CPI and National-Accounting Measures of Inflation



Source: CPI-U, Bureau of Labor Statistics; GDP and PCE deflators, Bureau of Economic Analysis.

more than 10,000 manufacturing and mining products in over 500 industries are regularly published. In addition, there are over 1,000 indices for service-sector outputs, and 3,200 indices grouped by type of product or end use.

Producer price indices are also published in groups divided according to **stages of processing**. Think back to Figure 3.1 in Chapter 3, which showed the production and sale of the Frisbee from crude oil through final product at retail. The various steps of Frisbee production correspond well to the three stages of processing used for the PPI. Crude petroleum at the well is an example of *crude materials for further processing*. Other examples include grains, livestock, metal ores, raw cotton, and construction sand and gravel. The plastic used in the production of the Frisbee is an example of *intermediate materials, supplies, and components*. This category also includes such products as flour, cotton yarn, lumber, diesel fuel, paper boxes, computer chips, and fertilizers. The finished Frisbee ready to be sold at wholesale is an example of *finished goods*. The prices recorded in the PPI refer to those received by the manufacturer, not the retail merchant, so that the final stage of the production and marketing of the Frisbee, sale to the consumer, is captured by the CPI rather than by the PPI. The PPI for finished goods is the most commonly reported PPI index. The PPI is reported monthly. Currently, the base for the PPI is set so that the average value in 1982 is 100.

For the most part the PPI refers to intermediate, rather than final, goods, which are not part of GDP. There are some exceptions: occasionally crude goods are consumed directly and capital goods, which are considered final, are part of GDP. The stage-of-processing structure of the PPI is based on the idea that goods proceed in chains from crude to final. But, of course, the world is really more complicated. Some goods (say, tomatoes bought at a farmers' market) can move from the crude to the final consumer stage skipping all intermediate stages. Intermediate goods or final goods, for example containers or capital equipment, may be inputs to other intermediate or crude good production. These complications to one side, the stage-of-processing structure suggests that prices pass through as the outputs of one stage become the inputs for a later stage.

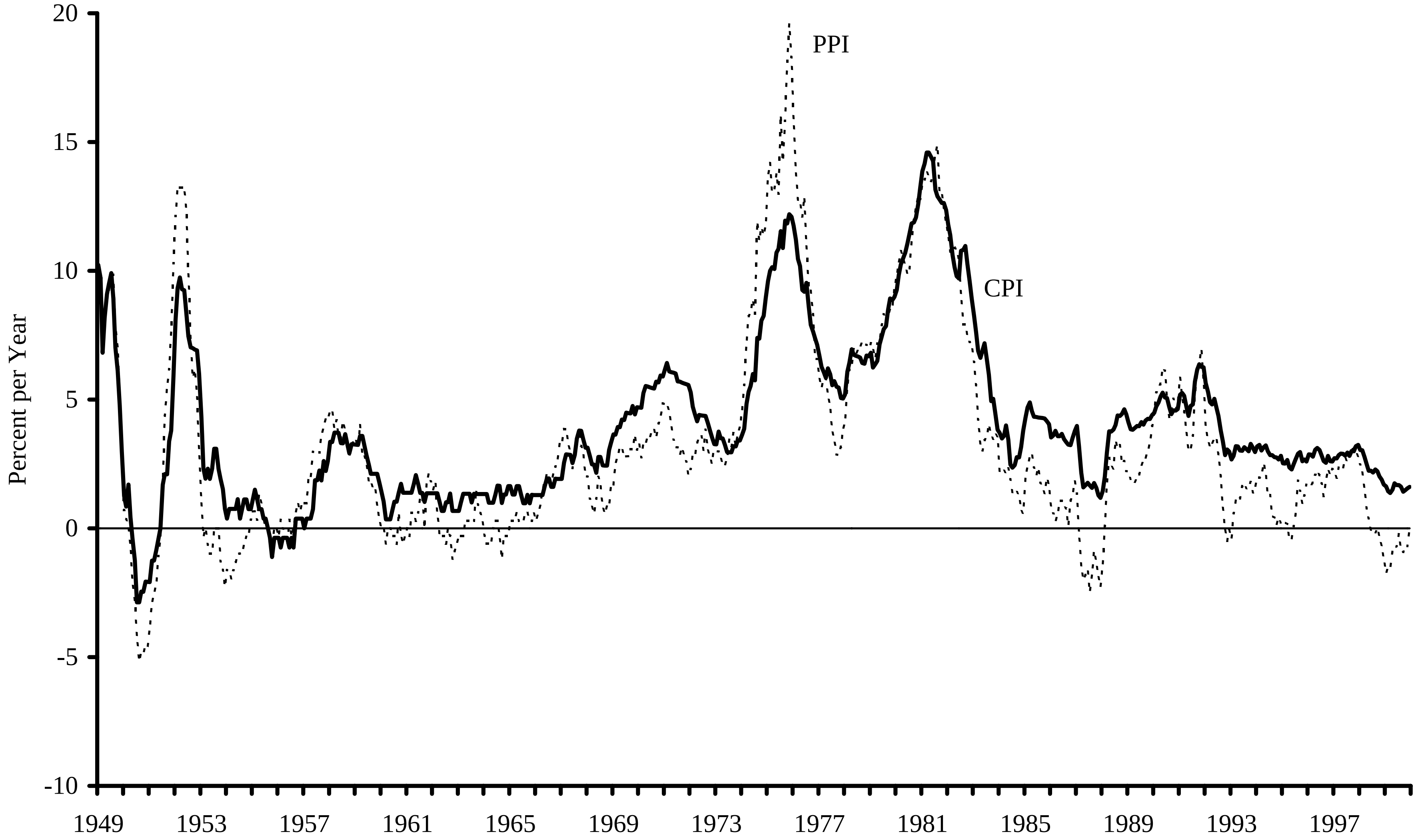
Much of the interest in the regular announcement of the PPI for finished goods derives from the idea that it is a harbinger of changes in the CPI. The linkage is loose. The PPI for final goods does not include services or imports, both of which are in the CPI, and does include capital equipment, which is not in the CPI. Figure 4.3 shows the relationship between inflation rates measured using the CPI-U and the PPI for finished goods. PPI inflation is somewhat more volatile than CPI inflation. Otherwise, they track each other quite well.

4.3 Core Inflation

4.3.1 The Core Rate of Inflation

Annualized monthly rates of CPI or PPI inflation tend to be highly volatile, which suggests that we might do better measuring inflation using true annual rates (current rate over twelve months previous). Even annual rates can be misleading, since the prices of some goods in the price index are more variable, not only month-to-month, but year-to-year as well. Food and energy prices are particularly variable. As we mentioned in Chapter 2, oil prices rose sharply in the decade after 1973, only to collapse in the mid-1980s. In 2004, they are set new record high levels. Food prices vary substantially with weather conditions (floods in the Midwest drive up the price of corn and corn-fed cattle;

Figure 4.3
PPI and CPI Inflation



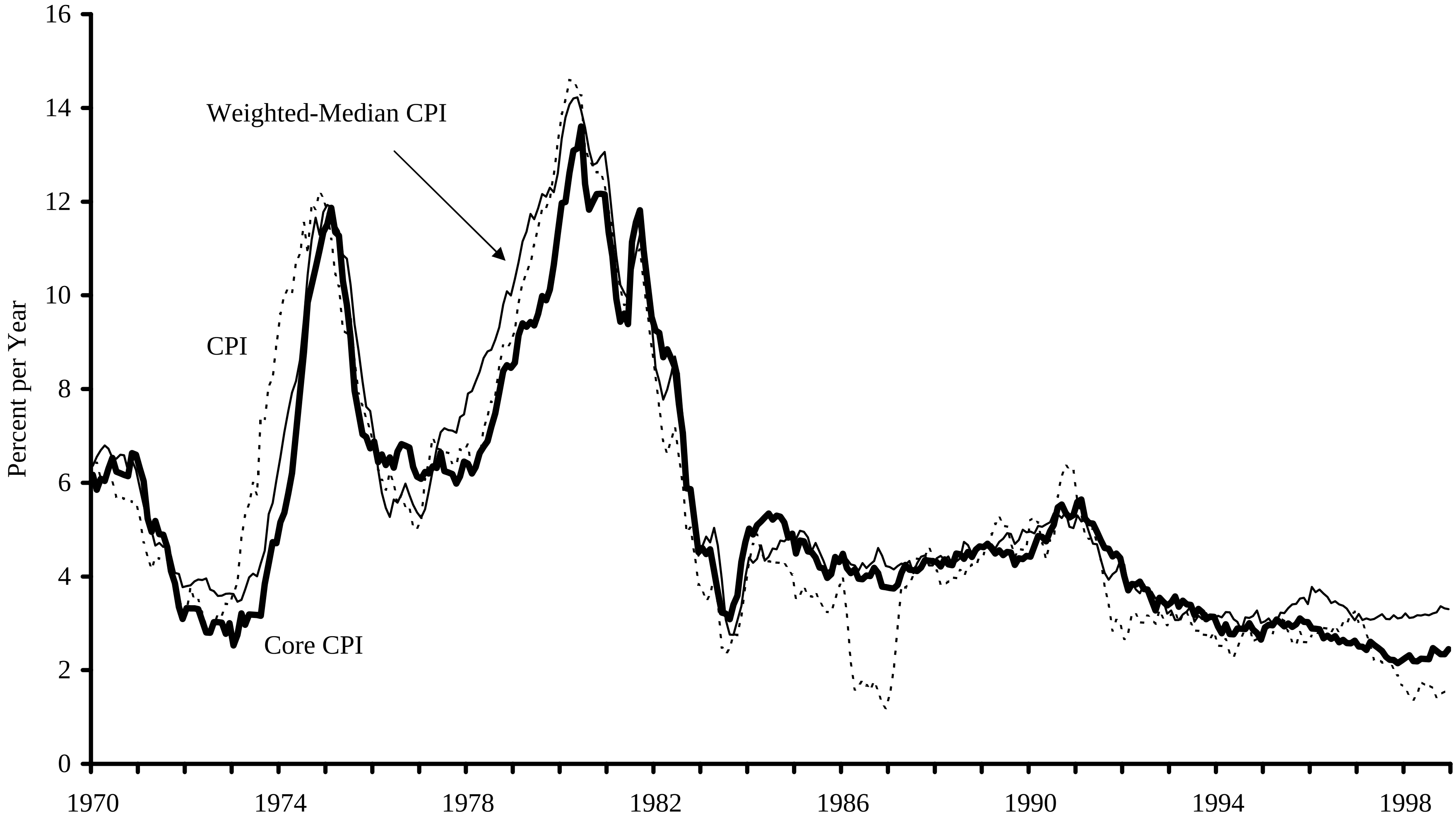
Notes: Annual rates of inflation. PPI for finished goods (not seasonally adjusted); CPI-U.
Source: Bureau of Labor Statistics.

drought in California drives up the price of vegetables) and with international demand (good crops in Russia drive down the price of U.S. wheat). Food and energy prices carry a substantial weight in the CPI, but may behave differently from other prices and may convey little information about future trends. Policymakers often look to the inflation rate calculated using the CPI or the PPI less food and energy prices. Referred to as the **CORE RATE OF INFLATION**, these indices may be a better indicator of the general course of prices.

The dashed line in Figure 4.4 shows the annual rate of CPI inflation, while the solid line shows the annual rate of core CPI inflation. Core CPI inflation is substantially smoother than CPI inflation. When the two lines diverge, the prices of food and energy relative to other goods must be changing. If such divergences were permanent, policymakers who concentrated on core inflation would miss substantial changes in the underlying cost of living for consumers and would be misled over time about the general path of prices. But Figure 4.4 shows that, although the divergences often last for several years, core inflation tracks the overall CPI well over the longer term.

It is important to understand that excluding food and energy prices from core inflation is not to claim that they do not constitute genuine inflation. When oil prices rise, the consumer's bill for gasoline and home-heating oil rises, the cost of living has gone up – sometimes painfully. For some purposes (say, for adjusting pensions), this is important. But monetary and fiscal policies that aim to stabilize the overall rate of inflation cannot focus on any one price. If large fluctuations in energy or food prices are nearly always reversed, they represent changes in prices relative to the general trend and convey little information about the general trends.

Figure 4.4
Core and Median Measures of CPI Inflation



Source: CPI-U and core CPI, Bureau of Labor Statistics; weighted-median CPI, Federal Reserve Bank of Cleveland.

4.3.2 THE WEIGHTED-MEDIAN CPI

Because food production depends on highly variable weather conditions around the world, it seems likely that the volatility of food prices is a permanent feature of the economy. But is this necessarily true of energy prices as well? Most of the volatility in oil prices is the result of the particularly unstable nature of the political relationships of major oil exporters over the past 30 or so years. This may or may not continue. And there is no reason to believe that other prices may not show similar episodes of volatility. The general rule is that, in trying to judge the central tendency of price movements, less weight should be given to changes in prices that are volatile. This may sometimes mean discounting changes in energy prices, but it may also sometimes mean discounting changes in the prices of other types of goods.

Working at the Federal Reserve Bank of Cleveland, economists Michael Bryan and Stephen Cecchetti devised a CPI measure, called the **weighted-median CPI,** that discounts volatile price changes without assuming automatically that these must be food and energy prices. To construct the weighted-median CPI, they calculate the percentage changes of all the prices in the CPI bundle and then find the value that divides the prices into groups so that as many changes are above the value as are below it. An unusually large increase in an energy price or any other price will not change the median CPI at all unless it jumps from the group below the median to the group above the median. Even then, since it is just one of many prices in that group, it will not change the median very much. Only if most prices increase will the median increase noticeably.

The lighter solid line in Figure 4.4 plots the weighted-median CPI. CPI-U, core CPI, and weighted-median CPI track each other fairly well. In the large run-ups in oil prices in the 1970s and early 1980s, and during the collapse in oil prices in 1986, there is a substantial deviation in the rate of inflation as measured by both the core and the median series compared to CPI-U. Median inflation is sometimes faster and sometimes slower than core inflation, reflecting the fact that food and energy prices are not always the most volatile prices.

Summary

1. Price indices are important for computing real quantities, for estimating inflation, and for making cost-of-living adjustments.
2. Price indices reduce large amounts of individual price information to a single number. There are many reasonable ways to do this and, so, many reasonable price indices.
3. The most common price index is the Laspeyres (base-weighted) index. It uses expenditure shares in a base period to form a weighted, arithmetic average of price changes.
4. The Laspeyres index suffers from substitution bias, as people typically reduce their expenditures on goods whose prices increase relatively faster. It also suffers from new product and quality change biases, since base expenditure shares cannot reflect goods or new versions of goods that have not available in the base period.
5. The Paasche (current-weighted) index uses current expenditure shares to form a weighted average of price changes. It mitigates the biases of the Laspeyres index, but

also suffers from a quality bias, as it underweights quality losses as people substitute into inferior versions of goods to avoid rising prices.

6. The Fisher-ideal index is the geometric average of the Laspeyres and the Paasche indices. It aims to strike a happy medium between their conflicting biases.
7. In practice, the Fisher-ideal index is implemented as a chain-weighted index in which the base periods for the Laspeyres and Paasche indices are a period apart and are advanced each new period.
8. Estimates of real GDP are derived from nominal GDP, each component being deflated by an appropriate chain-weighted index. The ratio of nominal to real GDP expressed as a price index is called the GDP implicit-price deflator. It measures the net effect of all the indices used to estimate real GDP.
9. The consumer price index (CPI) is the most commonly cited price index. It is essentially a Laspeyres index used to measure the cost of living for ordinary consumers. The CPI is economically important because many cost-of-living adjustments, including to Social Security payments, are based on it.
10. The personal consumption expenditure (PCE) deflator is the implicit price deflator for the consumption component of GDP. It uses much the same raw information as the CPI, but it is a chain-weighted index.
11. The producer price index (PPI) is the oldest U.S. price index. It measures prices for a large number of commodity groups and for various stages of processing from the point of view of the producer.

12. The core rate of inflation refers to CPI or PPI inflation ignoring food and energy prices. These prices tend to track other prices over time, but are often highly volatile, so that month-to-month changes give little information about general price movements.

Key Concepts

price index
general price level
base period
price factor
reference period
Laspeyres (base-weighted) index
substitution bias
new product bias
quality change bias
Paasche (current-weighted) index
Fisher-ideal index
chain-weighted index
implicit price deflator
cost-of-living index
core rate of inflation

Suggestions for Further Reading

Joseph Persky. "Retrospective: Price Indices and General Exchange Values," *Journal of Economic Perspectives*, vol. 12, no. 1 (Winter 1998), pp. 197-205.

Todd E. Clark. "A Comparison of the CPI and the PCE Price Index," *Federal Reserve Bank of Kansas City Economic Review*, vol. 84, no. 3, (3rd quarter), 1999, pp. 15-29.

Michael J. Boskin, *et al. Toward a More Accurate Measure of the Cost of Living.* Final Report to Senate Finance Committee from Advisory Commission to Study the Consumer Price Index, 4 December 1996.

Brian Motley. "Bias in the CPI: "Roughly Right or Precisely Wrong," *Federal Reserve Bank of San Francisco Economic Letter*, 97-12, 23 May 1997.

Bureau of Labor Statistics. *BLS Handbook of Methods*, chapter 14 ("Producer Prices") and chapter 17 ("Consumer Prices"). Available on the BLS website: http://www.bls.gov/opub/hom/home.htm

Problems

Data for this exercise are available on the course website under the link for Chapter 4 (**insert web link here**). Before starting these exercises, the student should review the relevant portions of the *Guide to Working with Economic Data*: sections G.4, G.6, G.8, and G.9.

Problem 4.1. The following information describes the "cop economy" in which the only two final goods are coffee and doughnuts.

	Coffee		Doughnuts	
Year	**Quantity (cups)**	**Prices (dollars)**	**Quantity (number)**	**Prices (dollars)**
2006	20	0.75	20	0.50
2007	30	1.00	18	0.75

(Round calculations to two decimal places.)

(a) Compute the Laspeyres, Paasche, and Fisher-ideal indices for each year taking 2006 as the reference year ($p_{2006} = 100$).

(b) Compute real GDP for each year in 2006 constant dollars using the chain-weighted index.

(c) Compute real GDP for each year in 2007 constant dollars using the chain-weighted index.

Problem 4.2. Consider an economy completely described by the following goods and prices:

		Wine (bottles)	**Hotel Accommodation** (nights)	**CDs** (disks)
2006	**price**	\$5	\$100	\$12
	quantity	50	5	10
2007	**price**	\$6	\$110	\$15
	quantity	48	6	7
2008	**price**	\$7	\$120	\$16
	quantity	45	7	8

(Round calculations to two decimal places.)

(a) Taking 2006 to be the reference year ($p_{2006} = 100$) in each case, compute the Laspeyres (base-weighted) and Paasche (current-weighted) indexes for each year.

(b) For each index compute the rates of inflation between 2006 and 2007 and 2007 and 2008. Compute the average rate of inflation (expressed at compound annual rate) between 2006 and 2008. Approximately how long will it take prices to grow 4-fold if this rate of increase were to continue steadily?

(c) Using each index compute real GDP for each year and average rate of real GDP growth (compound annual rate) from 2006 to 2008.

(d) With reference to your computations in (a)-(c), explain the differences between the two indices.

(e) Calculate the chain-weighted price index for each year and use it to compute real GDP. Explain the relationship of these calculations to those in (a)-(c).

Problem 4.3. Show in detail how the Paasche and chain-weighted indices for 2005 were computed in Table 4.2 and how real GDP was computed using the chain-weighted index for 2005 in the constant dollars of 2003, 2004, and 2005.

Problem 4.4. (This question draws on ideas from Chapter 3 as well as Chapter 4.) Elbonia is a country richly endowed with water and reeds, which are both free goods. It produces mud, *which is used exclusively for making bricks*. Bricks are baked in brick kilns and 10 percent of every batch of bricks must be used to keep the ovens in good repair. The Elbonians also produce funny reed hats. Here are the annual production figures and prices for Elbonia. Assume to begin with that Elbonia is a completely closed economy, completely owned by Elbonians.

		Mud (tons)	**Bricks (number)**	**Hats (number)**
2006	**quantity**	100	100,000	5,000
	price per unit (dollars)	810	1.00	20
2007	**quantity**	95	95,000	5,300
	price per unit (dollars)	891	1.10	21

(Round calculations to two decimal places.)

(a) Calculate the following for each year: nominal GDP, the Laspeyres (base-weighted index), the Paasche (current weighted index), the chain-index, real GDP using the chain index. (For all price indices take 2006 to be the reference year (p_{2006} = 100).

(b) Explain the difference between *Gross* Domestic Product and *Net* National Product. Calculate the net national product for Elbonia at current prices in each year.

(c) Assume that all other things are the same as in the table above except that Elbonia opens trade with Italy. What would happen to nominal GDP and net exports in 2007 if Elbonia doubled its mud production and exported the entire additional amount in exchange for 100,000 Italian tiles priced at 50¢/tile?

(d) What is Gross *National* Product in 2006? Now, assume that all other things are the same as in the table above, except that an American company buys ½ of the Elbonian hat-making industry in 2007. If the rate of profit is 10 percent of sales, what is gross national product in 2007?

Problem 4.5. The table gives actual expenditure shares and price indices for broad components of the CPI.

	Expenditure Shares 2002 (percent)	Price Indices 2002 (1982-84=100)	Expenditure Shares 2003 (percent)	Price Indices 2003 (1982-84=100)
Food and Beverages	15.583	177.8	15.384	184.1
Housing	40.854	181.1	42.089	185.1
Apparel	4.220	121.5	3.975	119.0
Transportation	17.293	154.2	16.881	154.7
Medical Care	5.961	291.3	6.074	302.1
Recreation[1]	5.943	106.5	5.872	107.7
Education and Communication[1]	5.798	109.3	5.948	110.9
Other Goods and Services	4.350	295.6	3.776	300.2

Notes: *1997=100 for these indices.

(a) Calculate the Laspeyres index for 2003, taking 2002 as the base and reference year.
(b) If the value of the CPI with 1982-84 as the reference period ($p_{82\text{-}84} = 100$) was 180.9 in 2002, what is its value in 2003 based on your answer to (a)?
(c) The CPI is also reported with 1967 as the reference year ($p_{82\text{-}84} = 100$). If the value of the CPI with 1967 as the reference year was 541.9 in 2002, what is its value in 2003 based on your answer to (a)?
(d) Calculate the Paasche and Fisher-ideal indices for 2003 (taking 2002 as the reference year). Do your answers conform to the patterns discussed in section 4.1? If not, how do they differ? What might explain any differences?

Problem 4.6. Explain the advantages and disadvantages of the Laspeyres, Paasche, and chain-weighted indices.

Problem 4.7. Here are some actual prices of good in past years, recorded in November of the indicated year: (i) Man's sport coat, $22.85 in 1960; (ii) Coffee (2 lbs.), 1.09 in 1965; (iii) Ford Sedan (Galaxie), $3,939 in 1972; (iv) Reclining Chair, $299 in 1981; Washing Machine, $349 in 1988. What are their prices in November 2005 constant dollars, using CPI-U as the price index?

Problem 4.8. Here are some actual prices of goods in the third quarter of 1998: (i) Vacuum Cleaner, $169; (ii) 10-piece Cookware Set, $299.99; (iii) Man's Sportshirt, $24.99; (iv) 24" Television, $219.99; (v) E-machine Computer, $604.00. What would their prices have been in 1980 and in 1948 constant dollars, using the GDP price deflator?

Problem 4.9. Here are some actual prices of past goods stated in 1992 constant dollars (using CPI-U): (i) One-bedroom Apartment (Sacramento, California), $906 in 1960; (ii) Men's Necktie, $8.90 in 1965; (iii) Reclining Chair, $300.51 in 1972; (iv) Coffee (2 lbs.), 4.53 in 1981; (v) Ford Sedan (Galaxie), $11,809 in 1988. What would their prices have been in November of their year of sale?

Problem 4.10. When two series have nearly the same constant mean, then it makes sense to directly compare their variances or standard deviations. The case of inflation is different. Figure 4.1 shows that both annual and monthly inflation are much higher in the 1970s and early 1980s than at earlier or later times. To calculate the variance or standard deviation would mainly pick up the variability relative to the mean for the sample as a whole. Most of this variability are movements that last over several years. Since both series share in these movements, the difference in the variance is likely to be rather small and to miss the point, which is to compare how variable one series is *relative* to the other. To better get at this question, subtract the annual series from the monthly series and compute the mean, the variance and standard deviation of the difference. Report your calculations in a table. If the series track each other well, the mean of the difference should be nearly zero. Is it? Visually, is the monthly or the annual series more variable? Is the variability in difference large or small according to your calculations? Compared to what?

Problem 4.11.

(a) Calculate the difference between the annual rates of CPI and core CPI inflation reported in Figure 4.4. Visually, which is more variable? Calculate and report the mean, the variance, and the standard deviation of this difference?

(b) Using the calculation of the standard deviation, we can get idea of how misleading CPI inflation might be for policymakers. Recall from the *Guide*, section G.5 that, if data are normally distributed, then about 62 percent of the time the data will be more than half a standard deviation above or below the mean; 32 percent of the time more than one standard deviation; and 5 percent of the time more than two standard deviations. Calculate the size of the difference (in percentage points) between CPI and core CPI at the 62, 32, and 5 percent reference points (i.e., how many percentage points of inflation correspond to ½, 1, and 2 standard deviations). Would you judge that CPI inflation is very misleading or not very misleading relative to core CPI inflation for policymakers? Why?

Problem 4.12. Reconsider the data in Problem 4.9 using the same procedures as in the last problem. Is there a strong case for using annual rates of inflation rather than monthly rates for judging economic policy?

Problem 4.13. The idea of categorizing producer prices by stages of processing is that crude prices pass on to intermediate prices, which in turn pass on to final producer prices. Compare the PPI at these three stages of processing using whatever graphics and calculations you deem appropriate. At which stage of processing are prices more variable? Is there any long-term trend for prices at one stage of processing to grow faster or slower than at other stages? Is there any evidence that prices at earlier stages predict prices at later stages?