

Chapter

8

Purchasing Power Parity and Real Exchange Rates

Jn a speech in October 2010, U.S. Treasury Secretary Timothy Geithner accused China of deliberately maintaining an exchange rate that undervalues the yuan relative to the dollar to help China's export industries. To discuss undervaluation, you obviously need a benchmark that provides the correct value of a currency. One popular benchmark model is **purchasing power parity (PPP)**.¹ PPP links exchange rates to the prices of goods in different countries, and this chapter explores these relations in depth.

Why should you study the theory of purchasing power parity? First, PPP provides a baseline forecast of future exchange rates that is usually considered whenever it is necessary to forecast future cash flows in different currencies, especially when inflation rates differ across these countries. Consequently, PPP plays a fundamental role in corporate decision making, such as the international location of manufacturing plants, and other international capital budgeting issues. Second, understanding the theory of purchasing power parity is important because deviations from PPP significantly affect the profitability of firms. For example, pricing products internationally, analyzing long-term international contracts, hedging the cash flows of an ongoing international operation, and evaluating the performance of foreign subsidiaries all require an analysis in terms of deviations from PPP. Third, PPP is particularly useful in assessing cost-of-living differences across countries. If you are going to work in a different country, and your salary is denominated in a foreign currency, you would like to know what standard of living you will experience.

As we will see when we look at the data, PPP does not hold very well in the short run. The deviations from the theory are sometimes so large that some economists dismiss the theory, at least as far as the determination of exchange rates is concerned. Nevertheless, for the world's major currencies, we will also see that PPP has some validity in the long run. It even works reasonably well over shorter horizons, whenever inflation dominates the economic environment.

Because purchasing power parity involves comparing the **purchasing power** of a money within a country to the purchasing power of that money when spent in a different country, we need to examine how to measure these purchasing powers. When economists convert from monetary magnitudes into units of purchasing power, they say they are converting from nominal units into real units. This chapter also introduces the real exchange rate. You will see that deviations from PPP can also be described as fluctuations in real exchange rates.

To understand these ideas, we first need to discuss price levels and price indexes.

¹Dornbusch (1988) notes that the earliest references to the subject are from 16th-century Spain and 17th-century England. Swedish economist Gustav Cassel (1916) is generally credited with coining the name for the theory.

8.1 PRICE LEVELS, PRICE INDEXES, AND THE PURCHASING POWER OF A CURRENCY

The General Idea of Purchasing Power

Economists usually measure the purchasing power of a country's currency in two steps:

1. First, economists calculate the monetary value, or **nominal price**, of a typical bundle of consumption goods in a country. We call this the price of the country's consumption bundle, and it represents the country's **price level**. Specifically, the price level is the weighted average of the nominal prices of the goods and services consumed in the economy. The weights of the goods and services usually represent the percentage shares of the goods and services in the consumption bundle. That is, if shoes constitute 1% of the typical consumer's budget, the price of shoes receives a weight of 0.01 in constructing the weighted average of all prices. When the price level of an economy is rising, **inflation** is occurring. Conversely, when the price level is falling, **deflation** is occurring.

2. Second, economists figure out what the purchasing power of the country's money is—that is, what a unit of currency will actually buy, given the price level in the country. To do this, they take the reciprocal, or inverse, of the price level. Taking the reciprocal of the price level gives the purchasing power of the currency. The purchasing power measures the amount of goods that can be purchased per unit of currency.

Calculating the Price Level

Rather than associate the price level with a country, for notational purposes, we associate the price level with the currency of a country. Hence, for the United States, we can write the price level as

$$P(t, \$) = \sum_{i=1}^N w_i P(t, i, \$)$$

where $P(t, i, \$)$ represents the dollar price of good i at time t , w_i represents the weight or consumption share of good i , and $P(t, \$)$ is the dollar price level, the weighted average of the dollar prices of the N different goods and services.

For example, the price level in the United States or Japan indicates how many dollars or yen it takes to purchase the consumption bundle of goods and services in either country. It might take something like \$15,000 to purchase the consumption bundle in the United States and ¥1,600,000 to purchase a similar bundle in Japan. This is why the price level is also known as the cost of living.

Calculating a Price Index

Unfortunately, governments usually do not provide information on consumer price levels. Instead of reporting data on price levels, governments usually provide information on price indexes. A **price index** is the ratio of a price level at one point in time to the price level in a designated base year. Typically, the ratio of the two price levels is multiplied by 100. That is, the dollar price index in year $t+k$ with year t as a base year is

$$PI(t+k, \$) = \left(\frac{P(t+k, \$)}{P(t, \$)} \right) \times 100 = \left(\frac{\sum_{i=1}^N w_i P(t+k, i, \$)}{\sum_{i=1}^N w_i P(t, i, \$)} \right) \times 100$$

Because price indexes are ratios of price levels at different points in time, they directly reflect the amount of inflation (that is, the percentage change in the average of all

Exhibit 8.1 Price Indexes for the G7 Countries, 1960–2010

Year	United States	Canada	France	Germany	Italy	Japan	United Kingdom
1960	27.6	24.6	17.2	39.4	9.8	21.2	13.2
1970	36.1	32.3	25.2	50.9	14.0	36.9	19.6
1980	76.5	69.7	63.3	82.6	51.0	87.2	70.7
1985	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1990	121.4	124.1	116.3	107.7	131.2	107.0	133.4
1995	141.7	139.2	129.9	126.2	168.6	113.5	158.4
2000	159.0	150.0	138.0	133.9	188.3	115.2	179.9
2005	179.4	167.8	151.8	144.9	212.0	112.4	202.1
2008	197.8	179.0	161.1	154.5	227.8	114.3	219.3
2009	197.1	179.5	161.2	155.0	229.5	112.7	224.0
2010	199.3	181.1	162.6	155.8	231.3	111.7	228.2

Note: Data are from the Organization for Economic Cooperation and Development's Main Economic Indicators.

nominal prices) between the base year (in the denominator of the ratio) and the current year (in the numerator of the ratio). If the price index today is 115, we know that prices are 15% higher than they were in the base year, and economists say the cost of living has increased by 15% because it takes 15% more money to purchase the consumption bundle.

Exhibit 8.1 provides some information on consumer price indexes for the G7 countries—the United States, Canada, France, Germany, Italy, Japan, and the United Kingdom—from 1960 to 2010. We can use these data to understand the historical inflationary experiences in these countries.

Example 8.1 Calculating an Annual Rate of Inflation

Notice that if the base year in a price index for year t , $PI(t)$, is the same as the base index for the next year, $PI(t+1)$, the ratio of the two price indexes measures 1 plus the rate of inflation between the 2 years because the two base-year price levels will cancel each other out:

$$\frac{PI(t+1)}{PI(t)} = \frac{P(t+1)}{P(t)} = [1 + \pi(t+1)]$$

$$\text{where } \pi(t+1) \equiv \frac{P(t+1) - P(t)}{P(t)}.$$

Now, let's use the data in Exhibit 8.1 to determine the British rate of inflation between 2008 and 2009. The values of the U.K. price indexes for 2008 and 2009 were 219.3 and 224.0, respectively. We find the percentage rate of inflation by subtracting 1 from the ratio of the price indexes and multiplying by 100:

$$\left(\frac{224.0}{219.3} - 1 \right) \times 100 = 2.1\%$$

Example 8.2 Calculating the Cumulative Rate of Inflation

How do we determine the total amount of inflation between 1985 and 2010 for the United States, and how can we calculate the average annual rate of inflation during that same period? First, because 1985 is the base year, we know that $1985 = 100$. Because the U.S. price index in 2010 was 199.3, we know that the average dollar prices of goods and services in 2010 were 99.3% higher than were the prices in 1985. Over the 25 years, prices increased at a compound annual rate of inflation of 2.79% because

$$\left(\frac{199.3}{100}\right)^{1/25} = 1.0279$$

Internal Purchasing Power

Now that we know how to measure a country's price level and inflation's impact on it, we can discuss the purchasing power of a dollar, first internally in the United States and then externally outside the United States. The units of the **internal purchasing power** of a dollar are the amount of goods and services that can be purchased with a dollar in the United States. That is, the amount of goods that corresponds to the purchasing power of 1 dollar is measured by taking the reciprocal of the U.S. price level. Because the units of the U.S. price level are dollars per U.S. consumption bundle, the units of purchasing power (the reciprocal of the price level) are U.S. consumption bundles per dollar. The internal purchasing power of a dollar at time t is $1/P(t, \$)$.

Example 8.3 Calculating the Purchasing Power of \$1,000,000

Suppose the price level in the United States is \$15,000 for the average consumption bundle. What is the purchasing power of \$1,000,000?

The purchasing power of 1 dollar is $(1/\$15,000)$, so the purchasing power of \$1,000,000 is

$$\frac{1}{\$15,000/\text{consumption bundle}} \times \$1,000,000 = 66.67 \text{ consumption bundles}$$

In other words, \$1,000,000 is enough to purchase 66.67 consumption bundles.

External Purchasing Power

The units of the **external purchasing power** of a dollar are the amount of goods and services outside the United States that can be purchased with a dollar, say, in the United Kingdom. Therefore, calculating the external purchasing power of a dollar in Britain involves two steps. First, it is necessary to purchase some amount of pounds with the dollar. Second, it is necessary to examine the purchasing power of those pounds in Britain.

One dollar buys $1/S(t, \$/\pounds)$ pounds if $S(t, \$/\pounds)$ represents the spot exchange rate of dollars per pound. The purchasing power of the pound may be measured by taking the reciprocal of the price level in Britain, $1/P(t, \pounds)$, which represents the number of consumption

bundles that can be bought per pound in Britain. Therefore, the external purchasing power of the dollar in Britain is

$$\frac{1}{S(t, \$/\pounds)} \times \frac{1}{P(t, \pounds)}$$

We check the units on the external purchasing power calculation:

$$\frac{\text{Pounds}}{\text{Dollar}} \times \frac{\text{U.K. consumption bundles}}{\text{Pound}} = \frac{\text{U.K. consumption bundles}}{\text{Dollar}}$$

as is required by the concept of the external purchasing power of a dollar in Britain.

Now that we can calculate the purchasing power of the dollar in two countries, we can examine what happens when we equate the two.

8.2 ABSOLUTE PURCHASING POWER PARITY

The Theory of Absolute Purchasing Power Parity

One version of PPP, called **absolute purchasing power parity**, states that the exchange rate will adjust to equalize the internal and external purchasing powers of a currency. The internal purchasing power is calculated by taking the reciprocal of the price level, and the external purchasing power is calculated by first exchanging the domestic money into the foreign money in the foreign exchange market and then calculating the purchasing power of that amount of foreign money in the foreign country. Hence, the prediction of absolute PPP for the dollar–pound exchange rate is found by equating the internal purchasing power of a dollar to the external purchasing power of a dollar:

$$\frac{1}{P(t, \$)} = \frac{1}{S^{\text{PPP}}(t, \$/\pounds)} \times \frac{1}{P(t, \pounds)} \quad (8.1)$$

where $S^{\text{PPP}}(t, \$/\pounds)$ signifies the dollar–pound exchange rate that satisfies the PPP relation. By solving Equation (8.1) for $S^{\text{PPP}}(t, \$/\pounds)$, we find

$$S^{\text{PPP}}(t, \$/\pounds) = \frac{P(t, \$)}{P(t, \pounds)} \quad (8.2)$$

You should think of absolute PPP as a theory that makes a prediction about what the exchange rate should be given the price levels in two countries. Equation (8.2) predicts that the dollar–pound exchange rate should be equal to the ratio of the price level in the United States to the price level in the United Kingdom. The key here is that differences in prices across countries should be reflected in the relative price of the currencies—that is, in the exchange rate. Later, we examine how well or poorly the theory works by comparing actual exchange rates to the predictions of PPP. First, let’s explore the foundations of the theory of absolute PPP.

Goods Market Arbitrage

Suppose the internal purchasing power of the dollar is less than its external purchasing power in a foreign country. What could you do to make a profit? If the dollar buys more goods abroad than it does at home, it ought to be possible to take some amount of dollars, buy goods abroad, ship the goods to the United States, and sell them for more dollars than your original dollar expenditure.

To demonstrate this arbitrage, consider the following example.

Example 8.4 A Goods Market Arbitrage

Suppose that the U.S. price level is \$15,000/consumption bundle and that the U.K. price level is £10,000/consumption bundle. Let the exchange rate be \$1.40/£. Rather than compute the purchasing power of 1 dollar, consider the internal and external purchasing powers of \$1 million. As we saw earlier, the internal purchasing power of \$1 million in the United States is

$$\$1,000,000 \times \frac{1}{\$15,000/\text{consumption bundle}} = 66.67 \text{ consumption bundles}$$

The external purchasing power of \$1 million in the United Kingdom is found in two steps. First, convert the \$1 million into pounds to get

$$\$1,000,000 \times \frac{1}{\$1.40/\text{£}} = \text{£}714,286$$

Then, find the purchasing power of £714,286 in the United Kingdom:

$$\text{£}714,286 \times \frac{1}{\text{£}10,000/\text{consumption bundle}} = 71.43 \text{ consumption bundles}$$

Because the external purchasing power of the dollar in the United Kingdom is higher than the internal purchasing power of the dollar in the United States, we can profit by buying goods in the United Kingdom and shipping them to the United States for resale. If we buy goods in the United Kingdom, we can purchase 71.43 consumption bundles with our \$1 million. If we sell the 71.43 consumption bundles in the United States at \$15,000/consumption bundle, we will receive

$$(71.43 \text{ consumption bundles}) \times (\$15,000/\text{consumption bundle}) = \$1,071,450.$$

Thus, by buying goods at low prices and selling goods at high prices, we have generated a 7.145% rate of return on our \$1 million investment.

Example 8.4 demonstrates another way of looking at PPP. If absolute PPP holds, the costs of the consumption bundles in different countries are equal when expressed in a common currency. When absolute PPP does not hold, there is a potential opportunity for goods market arbitrage. Such goods market arbitrage would, of course, be subject to somewhat larger transaction costs than the financial arbitrages we discussed in previous chapters. For example, there would be transaction costs associated with the physical shipment of goods between countries. Also, if you attempted to do this type of goods market arbitrage, you would obviously have to buy a particular commodity versus a consumption bundle.

8.3 THE LAW OF ONE PRICE

The Perfect Market Ideal

If markets are competitive, we should not be able to make a profit buying and reselling goods between countries. In fact, if there were no transaction costs, arbitrage would drive the price of any good quoted in a common currency to be the same around the world. The

law of one price says that the price of a good, when denominated in a particular currency, is the same wherever in the world the good is being sold. (PPP is thus an extension of the law of one price. Only instead of looking at a single good, PPP considers the prices of a bundle of goods.)

For example, in the absence of arbitrage possibilities, the dollar price of a barrel of oil should equal the dollar price of the British pound multiplied by the pound price of a barrel of oil:

$$\frac{\$}{\text{Barrel of oil}} = \frac{\$}{\pounds} \times \frac{\pounds}{\text{Barrel of oil}}$$

If the dollar price of a barrel of oil in New York differed from the exchange rate (\$/£) multiplied by the pound price of a barrel of oil in London, someone could buy oil at the low dollar price and sell oil at the high dollar price just as in Example 8.4. But, of course, actual markets have transaction costs.

Why Violations of the Law of One Price Occur

No good or service will literally always satisfy the law of one price. Nevertheless, obvious violations of the law of one price do not necessarily represent unexploited profit opportunities. Why might the prices of goods and services deviate from the law of one price?

Tariffs and Quotas

One obvious reason for violations of the law of one price is because countries impose different tariffs on imports, taxes and/or subsidies on exports, quotas on imports and exports, and other non-tariff barriers to trade. Governments often tax international shipments of goods at their borders to generate revenue, and, more likely, to protect their industries.²

For example, Malaysian tariffs on imported fully assembled cars range from 75% on cars with less than 1,800-cc engines to 105% on cars with greater than 3,000-cc engines. These tariffs protect the Malaysian national car companies, Proton and Perodua, from foreign competition and allow those automakers to enjoy a market share of over 50% in Malaysia.

If we measure prices of goods in different currencies with these taxes incorporated into the prices, there will be deviations from the law of one price. For example, with a 100% tariff on imported cars, we should expect the domestic price of imported cars to be twice the world price, where the world price is the exchange rate multiplied by the foreign currency price of the cars.

Average tariff rates in many developed countries are quite low, but they are generally much higher in emerging markets. For example, Canada's average rate is 6.5%, Japan's is 5.4%, and the U.S. average is 3.5%, whereas Brazil's is 31.4%, Mexico's is 36.1%, and India's is 49%. China is anomalous among emerging markets, with an average tariff of only 10%. Its tariffs are also quite uniform across product categories. Its highest average tariff is 27.4% on sugars and confectionery. In most other countries, there is great dispersion across product categories. For example, Canadian tariffs on clothing average 17.2%, whereas its average tariff on dairy products is 179.7%. Japan has average tariffs of 86.3% on cereals and preparations and 134.7% on dairy products. The average U.S. tariff is 11.4% on clothing and 20.8% on dairy products. Mexico's highest average tariff is 119.4% on sugars and confectionery, whereas India's highest rate is 168.9% on oilseeds, fats, and oils.

Transaction Costs That Prevent Trade

In theory, all goods and services can potentially be traded across countries, but when transaction costs in international markets are prohibitively large, goods become non-traded. The

²See <http://tariffdata.wto.org> for information on tariff rates in WTO member countries.

quintessential example of a non-traded good is a haircut. If the dollar price of the euro multiplied by the euro price of Italian haircuts is lower than the dollar price of haircuts in the United States, you might consider getting your hair cut by an Italian barber. But the transaction costs of doing so are simply prohibitive. The true economic cost of the Italian haircut must include the cost of the trip to Italy. Given that this cost is high, when you are at home, you get your hair cut locally, and when you are in a foreign country and need a haircut, you pay the foreign currency price of haircuts. This foreign currency price multiplied by the domestic currency price of foreign currency might be very different from the domestic currency price of your usual haircut.

Notice that a haircut is a service performed by an individual; it is not a commodity that can be shipped from place to place. Of course, if the law of one price for services is violated in one direction by a large enough magnitude for a sufficiently long time, suppliers of these services will migrate from one country to another. If giving haircuts provides a higher real income in the United States than it does in Italy, for example, barbers will move from Italy to the United States. But migration is a slow way to equalize wages across countries.

Thus, if wages are not equalized by international trade, we should expect some violations of the law of one price even for traded retail goods because the sale of a retail good in a particular country always involves a certain amount of service. The goods must be shipped to retail outlets, and the retailer must hire someone to sell the goods. Because these services cannot be exported or imported, there can be differences in the prices of retail goods that arise purely from the fact that the purchase of the goods involves the purchase of some non-traded services.

Speculation and Contracts

Another reason for deviations from the law of one price in the goods market is that it is often difficult to find a buyer for a particular good at a point in time. In addition, because it takes time to ship goods between countries, a speculative element is introduced into the goods market arbitrage transaction. You may think or expect that you will be able to sell the goods for a profit in a particular country after buying them in a different country, but only if you are able to contract with a buyer at a specified price when you initially purchase the goods will you be sure to earn an arbitrage profit. If no contractual relationship is possible, there is a potential risk that either the market price for the commodity in the country of sale or the exchange rate between the two currencies may change. In such a circumstance, you are speculating that you will make a profit, and the transaction is risky. It is no longer an arbitrage. Of course, many companies sign long-term contracts with suppliers, and one of the parties necessarily bears the foreign exchange risk. Fixed price contracts imply that retail prices will adjust slowly to changes in exchange rates, leading to deviations from the law of one price.

Non-Competitive Markets

Deviations from the law of one price also arise when goods are sold in non-competitive markets. Under pure competition, individual buyers and sellers of goods do not influence the prices of the goods. In the absence of pure competition, though, firms may be able to effectively segment markets in different countries. This allows firms to charge different prices in different countries, a practice that is called **pricing to market**. (Chapter 9 explores some formal models of pricing to market.) Segmenting markets is especially easy if the goods are marketed through dealerships established in foreign countries. For example, when the dollar was very strong in the mid-1980s, the dollar prices of European luxury cars in the United States were much higher than the dollar values of the foreign currencies multiplied by the foreign currency prices of the cars in the countries of production. In other words, you could travel abroad, convert your dollars to a foreign currency, and purchase a foreign car much more cheaply than you could purchase the same car in the United States.

Why can't you arbitrage this situation? The problem is that automobile manufacturers typically only sell one car to an individual foreign buyer who then has to take receipt of the car in the foreign country. Many individuals did take advantage of this opportunity to purchase cars cheaply and simultaneously enjoyed vacations in the foreign countries.

Given such an apparent arbitrage opportunity, ideally you would like to make some real money by purchasing more than just one car: You would like to call the BMW factory in Germany, buy enough cars to establish a dealership in the United States, ship the cars to the United States, and sell the cars for less than their current dollar prices at established BMW dealers. Unfortunately, BMW's managers will not be willing to sell you more than one car. The managers are happy with their current dealer network and with the profitability of their exports. If they wanted to sell more cars to Americans, they could open more dealerships or ship more cars to their existing U.S. dealers and charge lower dollar prices (versus selling cars to you in Germany so you could profit from the price difference).

Sticky Prices

The last reason that there may be observed deviations from the law of one price arises from the fact that the nominal, or money, prices of many goods are set by firms for various lengths of time. Unlike exchange rates and the prices of financial assets such as stocks and bonds, which change continuously, the nominal prices of many goods and services are not changed very often. Economists say the prices of such goods and services are "sticky."

One reason for **sticky prices** was noted by Okun (1981), who distinguished between auction goods and customer goods. Auction goods are traded on organized exchanges and are homogeneous commodities, such as wheat, soybeans, gold, and oil. Customer goods are heterogeneous products that are highly differentiated and require marketing through established customer relations. Examples of customer goods include items from refrigerators to automobiles.

Auction goods should be expected to satisfy the law of one price much more consistently than customer goods. One reason has to do with the menu costs related to customer goods. **Menu costs** refer to the costs that a firm incurs in changing its prices. The classic example is a restaurant that must print up a new menu whenever the manager wants to change prices. If inflation is low, the restaurant may leave its prices unchanged for several months or even years, replacing the menus only as they become too dirty to use. But if inflation is high, the restaurant will find it optimal to print new prices weekly or even daily. If inflation is extreme enough, the restaurant could even adjust prices hourly on a chalkboard. The frequent adjustment of prices due to inflation is costly to consumers, who have no idea from one time to the next how much a particular item will cost.

Menu costs are ubiquitous. They arise whenever the marketing of a good requires the producer or retailer of the good to provide price information to potential customers in advance of the sale of the good, as in customer goods. Whenever a good is sufficiently complex that buyers would like to be able to do comparison shopping, retailers find it in their interests to set prices in advance and to leave their prices fixed for some period of time. Hence, changes in the exchange rate create deviations from the law of one price with regard to customer goods because firms do not continuously adjust the prices of their goods.

How Wide Is the Border?

Because of tariffs, non-competitive markets, sticky prices, and the other sources of deviations we just discussed, the prices of comparable goods differ across cities within a country as well as across countries. Broda and Weinstein (2008) use barcode data—that is, Universal Product Codes (UPCs)—to examine differences in prices of identical goods across cities, both within the United States and across the border in Canada for 2001 to 2004. UPCs provide

a unique identifier for hundreds of thousands of different goods, and Broda and Weinstein can therefore be sure that they are comparing the exact same goods. Their first finding is that the composition of consumption varies systematically with distance and across borders. The share of common goods is 28% between New York and Philadelphia, whereas it is only 18% between New York and Los Angeles. In comparisons between U.S. and Canadian cities, the commonality in consumption bundles falls to 7.5%. Their second finding is that prices of the same good vary substantially across cities. The typical difference, measured as the standard deviation of log price differences, is 22.3% between U.S. cities and 18.7% between Canadian cities. When comparing prices across countries, the typical difference rises to 26.7%. Thus, borders matter, but perhaps less than others had thought.

Early research by Engel and Rogers (1996) examines the failure of the law of one price using U.S. and Canadian data for 23 North American cities and 14 disaggregated commodities, such as men's and boy's apparel, footwear, medical care, and other goods. Their statistical analysis indicates that a substantial amount of the variation in the relative prices of similar goods across cities is attributable to the distance between the cities. However, Engel and Rogers conclude that crossing a border between countries adds as much variability to the relative prices of similar goods as does adding 2,500 miles to the distance between two cities within the same country. Clearly, if Engel and Rogers are correct, borders between countries, and in particular, the change in currencies that occurs with crossing the border, matter a great deal. Broda and Weinstein (2008) take issue with this finding, arguing that the Engel and Rogers study, although it uses disaggregated commodities, still suffers from an aggregation bias. When Broda and Weinstein use individual prices and the Engel and Rogers methodology, they find that crossing the border adds between 36 and 106 miles to the distance between cities. When they aggregate their individual prices into price indexes, they find results similar to Engel and Rogers.

One problem with the study by Broda and Weinstein (2008) is that its data come from an ACNielsen household survey so that the majority of the goods they examine are in the grocery, drug, and mass merchandise sectors. Thus, it is unclear how robust the results are to the major differentiated products like machine tools, refrigerators, and automobiles. A study of prices of televisions across European countries by Imbs et al. (2010) does find that identical televisions sell for different prices across the eurozone countries.

In the same way the deviations we just discussed affect the law of one price, they likewise affect PPP. In the following *Point–Counterpoint*, our friends Ante, Freedy, and Suttle discuss the theory of PPP and opportunities (or the lack thereof) related to the law of one price.

POINT–COUNTERPOINT

Making Money on Deviations from the Law of One Price

Ante, Freedy, and Suttle are savoring a beautiful spring day in Toronto, Canada, in the summer of 2010. They stop into a Sears store to buy Ante a pair of jeans because he caught his pants on a nail and ripped them beyond repair. Freedy says, “Hey, Ante, you like dark stone-washed Levi’s 501s, right? Here’s a pair for CAD74.99. That’s not too bad, is it?” Ante responds, “You imbecile! I can buy those in the United States for USD36.99 at our Sears store. With an exchange rate of CAD1.05/USD, I shouldn’t be paying more than CAD38.84. I told you the law of one price is a bunch of crap.”

Freedy is a bit taken aback. He states, “Maybe these jeans are special. They’re marked ‘Red Tab,’ which must mean they are higher quality denim than the usual ones you buy. That could account for the price difference.” Ante is again critical. “No, no, no. The Red Tab is Levi’s way of assuring the customer that those jeans are real Levi’s. They manufacture

a certain percentage with the Red Tab to protect their trademark. The quality of the jeans is no different.”

Ante continues, “Hey, if the jeans really are the same, and if there is a 93% difference between the CAD price of the U.S. jeans and the CAD price of the Canadian jeans, why don’t we get a truck, go around to Sears stores in the U.S., buy jeans, drive back to Canada, and sell the jeans here. If we sold 10,000 pairs of jeans, we’d make CAD361,500. That would be a pretty nifty profit.”

Freedy thinks for a minute and says, “Do you ever pay attention in class? Remember PPP and the law of one price. We would not make a profit. Renting the truck would cost money, it would take time to get the jeans, and nobody would buy them from you on the street. They wouldn’t believe that the jeans weren’t stolen. Fundamentally, goods market arbitrage ensures that there are no abnormal profits.”

Ante retorts, “PPP is a useless theory. Goods markets aren’t at all like asset markets. Goods markets are totally inefficient, so exchange rates really bear no relationship to goods prices because you can’t arbitrage in the goods market.”

Freedy shouts back, “Oh yeah? Well, I think PPP is pretty elegant economics, and people wouldn’t have talked about it for nearly 100 years if it didn’t work quite well.”

Ante responds, “Elegant schmelegant! What’s the point of learning something that just doesn’t work?”

Suttle, although somewhat mesmerized by two young women trying on jeans in the women’s department, responds slowly to the escalating argument. “Look guys, you are both right and both wrong. Freedy, you’re right: The PPP theory is good basic economics. But it isn’t the whole story. There is some validity to Ante’s point, too: Arbitrage in the goods market is a lot more costly than arbitrage in asset markets.”

To make the point, he pulls out his iPhone to check some prices on the Web. “Look here. At Amazon.com, the list price of Levi’s 501’s is USD48.00, but they are on sale for USD34.99. Let’s check the Levi’s Web site. There, the same 501’s list for USD46.00, but they are on sale for USD37.00. So, even in the United States and on the Web where it took a minute to check the prices, we still see price differences. Also, remember that although the exchange rate is now CAD1.05/USD, it wasn’t too long ago that it was CAD1.30/USD. At that exchange rate and with a list price of USD48.00, the Canadian dollar price that satisfies the law of one price would be CAD62.40. That’s still below CAD74.99, but we’re getting closer.”

Suttle continues, “What Ante is proposing is exactly how goods arbitrage makes PPP work in the long run. If Sears sets its Canadian dollar price too high, someone will set up a business to exploit the price differential, which moves us closer to the law of one price because that person will undercut Sears’ price to attract customers. Of course, as Freedy argued, setting up such a business is costly, and if Sears Canada starts losing sales, they can drop their price. Notice also that Sears Canada only sells a couple of Levi’s styles. So, maybe they know that the price is high, and they’re just waiting for someone like Ante who absolutely needs a new pair of jeans and can’t wait for delivery from a Web site.”

Ante smiles and says, “Well, maybe we should set up the business anyway! But one thing I do remember from our international finance class is that changes in exchange rates cause big changes in relative prices across countries. I guess a big move in the exchange rate while we are setting up our business could get us into serious trouble. I’m not sure I want the foreign exchange risk.”

Suttle nods, “Yes, you’re right about that. Changes in exchange rates can create big changes in relative prices, and people respond to such changes by shifting their consumption patterns. Managers try to find different suppliers, and they may even relocate production facilities to cheaper countries. All this takes some time. Maybe if we look at the data, we’ll get an idea for how well or poorly the PPP theory works in the short run and the long run.”

8.4 DESCRIBING DEVIATIONS FROM PPP

Overvaluations and Undervaluations of Currencies

Before we look at actual exchange rates and PPP predictions, we first need to discuss some additional terminology. A currency is said to be **overvalued** if its external purchasing power is greater than its internal purchasing power. An **undervalued** currency's external purchasing power is less than its internal purchasing power. Because purchasing power parity makes one prediction for the actual exchange rate between two currencies, if currency A is overvalued relative to currency B, currency B must be undervalued relative to currency A.

An easy way to remember which currency is overvalued and which currency is undervalued is to add the phrase “on foreign exchange markets” to the statement. For example, the dollar is “overvalued on foreign exchange markets” if the dollar's external purchasing power is greater than its internal purchasing power.³

Example 8.5 Overvaluation of the Dollar Implies Undervaluation of the Pound

In this example, we check our ability to manipulate internal and external purchasing powers by verifying that if the dollar is overvalued relative to the pound, as in Example 8.4, the pound must be undervalued relative to the dollar.

Recall that the dollar price level is \$15,000/consumption bundle, the pound price level is £10,000/consumption bundle, and the exchange rate is \$1.40/£. The statement that the dollar is overvalued relative to the pound implies that the external purchasing power of the dollar is greater than its internal purchasing power. As in Example 8.4, we calculate the external purchasing power of \$1 million in the United Kingdom as

$$\begin{aligned} \$1,000,000 \times \frac{1}{\$1.40/\text{£}} \times \frac{1}{\text{£}10,000/\text{consumption bundle}} \\ = 71.43 \text{ consumption bundles} \end{aligned}$$

This is larger than the internal purchasing power of \$1 million in the United States, which is

$$\$1,000,000 \times \frac{1}{\$15,000/\text{consumption bundle}} = 66.67 \text{ consumption bundles}$$

Thus, the dollar is overvalued on the foreign exchange market. Now, let's look at the pound. Is the pound over- or undervalued on the foreign exchange market? The internal purchasing power of £1,000,000 is

$$\text{£}1,000,000 \times \frac{1}{\text{£}10,000/\text{consumption bundle}} = 100 \text{ consumption bundles}$$

but the external purchasing power of the pound in the United States is

$$\begin{aligned} \text{£}1,000,000 \times \frac{\$1.40}{\text{£}} \times \frac{1}{\$15,000/\text{consumption bundle}} \\ = 93.33 \text{ consumption bundles} \end{aligned}$$

³The terms *overvalued* and *undervalued* are also employed in discussions of the relationship of a particular exchange rate to other theories of exchange rate determination. An overvalued currency must weaken on the foreign exchange markets to return to the prediction of the theory, and an undervalued currency must strengthen.

Because the internal purchasing power of the pound is greater than its external purchasing power, the pound is undervalued on the foreign exchange market. Hence, the statement that the dollar is overvalued relative to the pound is equivalent to the statement that the pound is undervalued relative to the dollar.

Predictions Based on Overvaluations and Undervaluations

The logic of overvaluations and undervaluations of currencies leads to predictions of currency depreciation or appreciation. If a currency is overvalued on foreign exchange markets, it must weaken, or suffer depreciation, on the foreign exchange markets if the exchange rate is to return to the prediction of PPP. This weakening, or depreciation, of the currency lowers its external purchasing power and returns the external purchasing power of the currency to its internal purchasing power. Conversely, a currency that is undervalued on foreign exchange markets must strengthen, or experience an appreciation, on foreign exchange markets if its external purchasing power is to increase to equal its internal purchasing power. Of course, apart from currency appreciations and depreciations, differences in the rates of inflation can also reestablish the PPP relationship.

Example 8.6 Using PPP Deviations to Predict Currency Appreciations

If the yen is undervalued relative to the euro, what prediction would you make regarding the movement of the exchange rate (in yen per euro) if you think a correction back to PPP is imminent? If the yen is undervalued (on foreign exchange markets) relative to the euro, the external purchasing power of the yen in Europe is less than the yen's internal purchasing power in Japan. This can be corrected by an appreciation, or strengthening, of the yen relative to the euro, which causes the exchange rate measured in yen per euro to fall.

The MacPPP Standard

Shortly, we will examine data on absolute PPP using conventional consumer price indexes (CPIs). One criticism of using CPI data is that the consumption bundles of the different countries are not the same. Fortunately, *The Economist* calculates implied PPP exchange rates for a large number of countries, using a bundle of goods that is the same around the world—namely, a McDonald's Big Mac sandwich.

There are several advantages to using the Big Mac as an index of prices. First, McDonald's strives to make the sandwich the same way in all its outlets. Just as with the consumer price level, there are particular weights that McDonald's places on each item in the Big Mac, and these weights are the same across countries. Specifically, the commodity bundle is “two all-beef patties, special sauce, lettuce, cheese, pickles, and onions on a sesame seed bun.” Second, McDonald's uses local suppliers for the goods entering the index, which reduces the role of international transportation costs.

Each spring since 1986, *The Economist* has had its correspondents sample the prices of Big Macs in local currencies in a large number of countries. Implied PPP exchange rates for various currencies relative to the dollar are calculated by taking the ratio of the local currency price of the Big Mac to its average dollar price in four U.S. cities.

Although the Big Mac PPP standard, called **MacPPP**, may seem somewhat silly in light of the fact that one cannot transport fresh Big Macs across countries, the deviations of actual exchange rates from the implied PPP values are actually about the same size as those that

arise using more conventional consumer price indexes. Also, the degree of overvaluation or undervaluation of particular currencies has been used by *The Economist* to make a few interesting predictions that have had some accuracy, as you will see.

Exhibit 8.2 gives MacPPP values for 2010 from *The Economist*. The first column shows the prices of Big Macs in the local currencies of the countries in which they are sold. For example, the average price of a Big Mac in the United States was \$3.58, whereas it cost ¥333.40 in Japan. The second column gives the dollar price of a Big Mac in the different countries calculated as the local currency price of a Big Mac divided by the exchange rate of local currency per dollar. This is the price that an American traveling in that country might calculate.

Because the yen-dollar exchange rate was ¥94.18/\$, the dollar cost of a Big Mac in Japan was

$$\frac{(\text{¥}333.40/\text{Big Mac})}{(\text{¥}94.18/\text{\$})} = \$3.54/\text{Big Mac}$$

The most expensive Big Mac for a person paying in U.S. dollars was in Norway, where it cost \$6.87. The cheapest Big Mac for a dollar purchaser was in China, where it cost only \$1.83.

The Implied MacPPP Rates

The third column of Exhibit 8.2 gives implied PPP exchange rates of the currency versus the dollar. This is the ratio of the local currency price of the Big Mac to the dollar price of the

Exhibit 8.2 MacPPP in 2010

		Big Mac Prices		Exchange Rates		% Under (-)/Over (+) Valuation against the Dollar
		Local Currency	Dollars	PPP	Actual	
United States ^a	dollar	3.58	3.58	1.00	1.00	
Australia	dollar	4.30	4.30	1.20	1.08	11%
Britain ^b	pound	2.27	3.48	1.58	1.53	-3%
Canada	dollar	4.10	4.06	1.14	1.01	13%
China	yuan	12.51	1.83	3.49	6.84	-49%
Egypt	pound	13.26	2.37	3.70	5.59	-34%
Euro area ^c	euro	3.48	4.62	1.03	1.33	29%
Hungary	forint	754.37	3.75	210.72	201.17	5%
Indonesia	rupiah	20,559.06	2.28	5,742.75	9,017.13	-36%
Japan	yen	333.40	3.54	93.13	94.18	-1%
Malaysia	ringgit	6.76	2.12	1.89	3.19	-41%
Mexico	peso	31.32	2.56	8.75	12.24	-28%
Norway	kroner	42.94	6.87	11.99	6.25	92%
Poland	zloty	8.42	2.86	2.35	2.95	-20%
Russia	ruble	69.78	2.39	19.49	29.19	-33%
Saudi Arabia	riyal	10.03	2.67	2.80	3.76	-25%
South Africa	rand	17.96	2.44	5.02	7.36	-32%
South Korea	won	3,330.75	3.00	930.38	1,110.25	-16%
Switzerland	franc	6.64	6.16	1.86	1.08	72%
Taiwan	dollar	73.97	2.36	20.66	31.35	-34%
Thailand	baht	70.12	2.16	19.59	32.46	-40%
Turkey	lire	5.51	3.71	1.54	1.49	4%
U.A.E.	dirham	10.98	2.99	3.07	3.67	-16%

^aAverage of New York, Chicago, San Francisco, and Atlanta.

^bExchange rate: dollars per pound.

^cWeighted average of member countries. Exchange rate: dollars per euro.

Note: Data are from *The Economist*, online edition, May 17, 2010, and author's calculations.

Big Mac in the United States, except for Britain and the euro area, in which case the implied PPP is expressed in dollars per pound and dollars per euro, respectively. The fourth column provides the actual exchange rate measured in local currency per dollar, except for the British pound and the euro, which are again expressed as dollars per pound and dollars per euro. For Big Macs to satisfy the law of one price, implied PPP exchange rates in the third column should equal the actual exchange rates in the fourth column. The fact that they do not indicates that the local currencies are either overvalued or undervalued relative to the dollar.

Overvaluations and Undervaluations

The fifth column presents the overvaluation or undervaluation of the local currency in percentage points defined as the percentage appreciation or depreciation of the dollar required to return the actual exchange rate to the implied PPP value. For example, the Canadian dollar is 13% overvalued because with the actual exchange rate at CAD1.01/\$, a 13% appreciation of the dollar versus the CAD would be required to increase the exchange rate to the implied PPP value of CAD1.14/\$. Similarly, the Swiss franc is 72% overvalued because with an actual exchange rate at CHF1.08/\$, a 72% appreciation of the U.S. dollar relative to the Swiss franc would be required to increase the exchange rate to the implied PPP value of CHF1.86/\$.

The average of the emerging market valuations relative to the dollar is -25% , indicating that the average emerging market currency is 25% undervalued versus the dollar. These undervaluations are consistent with the fact that Big Macs also contain some labor, which is less expensive in emerging markets than in the United States. If we take the ratio of the local currency price of the Big Mac in Thailand to the price in Malaysia, we find the PPP prediction of the Thai baht price of the Malaysian ringgit, which is THB10.37/MYR. The actual exchange rate is THB10.18/MYR, implying that the ringgit is only 2% undervalued relative to the baht.

Predicting British Heartburn

At this point, you might be feeling that PPP often does not work well. Before you decide that the theory is totally bunk, it is important to realize that *The Economist* made surprisingly accurate predictions using its MacPPP standard.

For example, in April 1991, *The Economist* noted that the implied PPP of the Deutsche mark relative to the British pound was DEM2.58/£. However, the central parity of the two currencies in the European Exchange Rate Mechanism (ERM) was DEM2.95/£ when Britain entered the ERM in October 1990. Given this difference of more than 14% between the implied PPP and the central parity, *The Economist* noted that the pound was overvalued, and the Deutsche mark was undervalued. *The Economist* also suggested that the British Treasury would eventually get “severe heartburn” if it tried to defend the actual exchange rate rather than devalue the pound within the ERM.

The logic of the argument is as follows: As we discussed in Chapter 5, the ERM required countries to buy their currencies with foreign currencies if the currency weakened by a certain amount relative to the central parity. The maximum deviation of the pound from its central parity with the DEM was DEM2.78/£ (6% below the central parity), which is substantially above the MacPPP value. Thus, if the pound began to weaken in the ERM to correct its overvaluation, the British Treasury would be forced to buy pounds with Deutsche marks. Given the limited amount of DEM that the Bank of England had in its international reserves, the market could force a devaluation of the pound by borrowing pounds and lending Deutsche marks. Investors would expect to profit from the devaluation because the pounds they would borrow would be easy to repay with the appreciated Deutsche marks they would own. The only way this would not occur would be if pound-denominated interest rates were increased sufficiently by the Bank of England to make it unattractive to borrow pounds and attractive for investors to hold pound-denominated assets.

Indeed, in September 1992, British authorities were essentially forced to withdraw from the ERM. From September 15 to September 16, the exchange rate fell from DEM2.7912/£

to DEM2.7500/£, and the authorities chose to abandon the ERM rather than increase pound interest rates and sell additional international reserves. After they abandoned the ERM and allowed the exchange rate to float, the pound weakened further and by September 28, it stood at DEM2.51/£. Before abandoning the ERM, it is estimated that the Bank of England lost over \$12 billion of international reserves trying to defend the pound. Because these are resources that could have been used to pay for British government spending, not only did the British Treasury get a bad case of heartburn, so did British taxpayers.

The Econometric Evidence

More formal statistical studies by economists also support the usefulness of MacPPP. Cumby (1996) finds that deviations from MacPPP are temporary. After allowing for a constant deviation, he estimates that one-half of the deviation from parity disappears in 1 year. Cumby's evidence also indicates that both the exchange rate and the prices of the burgers are adjusting to eliminate the deviation. The prediction is that a 10% undervalued currency tends to appreciate over the next year by 3.5%. Clements and Lan (2010) confirm that exchange rate forecasts using MacPPP have value, especially at 2- or 3-year horizons.

Parsley and Wei (2007) study the components of the Big Mac and infer that local labor costs account for 45.6% of its price. Section 8.6 addresses how such non-traded goods can affect PPP calculations. Parsley and Wei also find a very high correlation between PPPs calculated with Big Mac prices and those from CPI data, to which we now turn.

8.5 EXCHANGE RATES AND ABSOLUTE PPPs USING CPI DATA

Interpreting the Charts

One disadvantage of the MacPPP analysis is its comparatively short time span because *The Economist* only started calculating MacPPP in 1986. Exhibits 8.3 through 8.7 present data for actual exchange rates and the predictions of absolute PPP calculated from consumer price indexes for several of the world's major currencies. The solid line represents the actual exchange rate, and the dashed line is the implied exchange rate from the prediction of PPP.

Overvaluations and Undervaluations

In examining the deviations from PPP in Exhibits 8.3 through 8.7, it is important to remember how the exchange rate is quoted. For example, the pound and euro exchange rates are quoted directly as the amount of dollars it takes to purchase 1 pound or 1 euro, whereas the other exchange rates relative to the U.S. dollar are quoted indirectly as the amount of that currency that it takes to purchase 1 dollar. The PPP prediction for the dollar–pound exchange rate is therefore $P(t, \$)/P(t, £)$, whereas the PPP predictions for the indirect quotes relative to the dollar are the ratios of the foreign price levels to the U.S. price level. Hence, the dollar is undervalued when the actual exchange rate $S(t, \$/£)$ is above the PPP prediction, $P(t, \$)/P(t, £)$, because the dollar must strengthen relative to the pound if the undervaluation (on foreign exchange markets) is to be corrected. For the yen/dollar rate, the dollar is overvalued when the actual exchange rate, $S(t, ¥/\$)$, is above the PPP prediction, $P(t, ¥)/P(t, \$)$, because the dollar must weaken relative to the yen if the overvaluation of the dollar (on foreign exchange markets) is to be corrected by a movement in the exchange rate.

Fixing When PPP Held

The data in Exhibits 8.3 through 8.7 begin in January 1973 and end in January 2010. Because the prices of goods are obtained as consumer price indexes rather than price levels, it is necessary to

take a stand on when the actual exchange rate satisfied the PPP relationship in order for the units of the ratio of the prices to correspond to the units of the exchange rate. The data are plotted such that absolute PPP is assumed to have held on average during the decade of the 1980s.

Analyzing the Data

How well or poorly does the theory of absolute PPP work? Clearly, there are large and persistent deviations of actual exchange rates from the predictions of PPP.

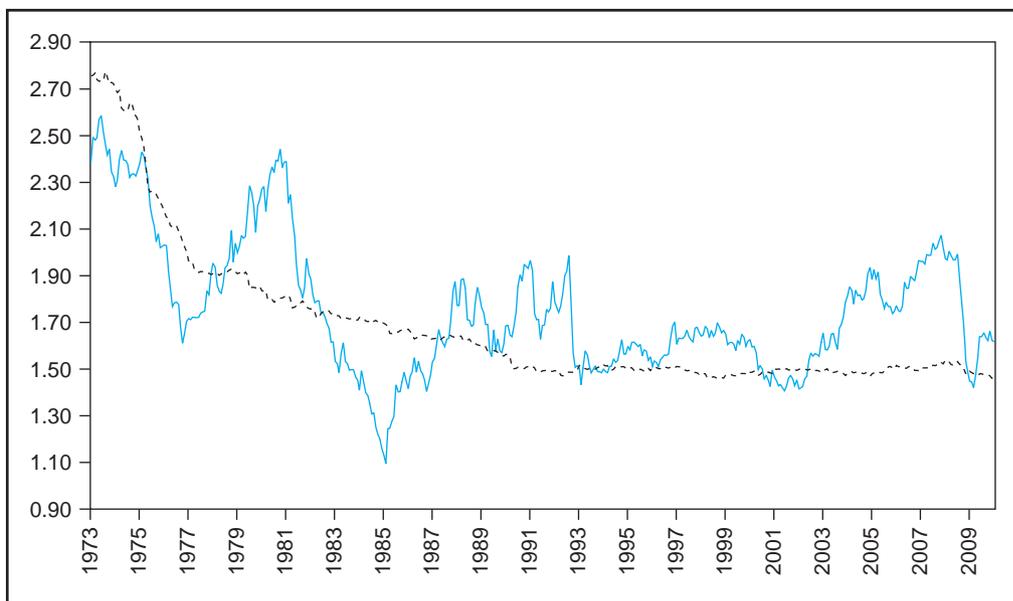
Dollar–Pound

The data for the \$/£ rate in Exhibit 8.3 indicate that the pound was 30.2% overvalued in October 1980, but by February 1985, it was 43.8% undervalued.⁴ Because the ratio of the price levels in the two countries changed only slightly over this period, almost all of the change is due to the movement of the exchange rate from \$2.40/£ to \$1.10/£. Once the dollar peaked in strength in 1985, though, it began to depreciate, and by October 1990, the pound was again more than 25% overvalued relative to the dollar. Just prior to the beginning of the financial crisis in November 2007, the pound was 30.5% overvalued, and at the end of the sample in January 2010, the pound was 9.6% overvalued.

Dollar–Euro

Exhibit 8.4 presents the dollar–euro data, where the exchange rate data prior to 1999 use the dollar–Deutsche mark exchange rate. The extreme overvaluation of the dollar relative to the PPP prediction that peaks in 1985 is repeated here. In February 1985, the dollar was

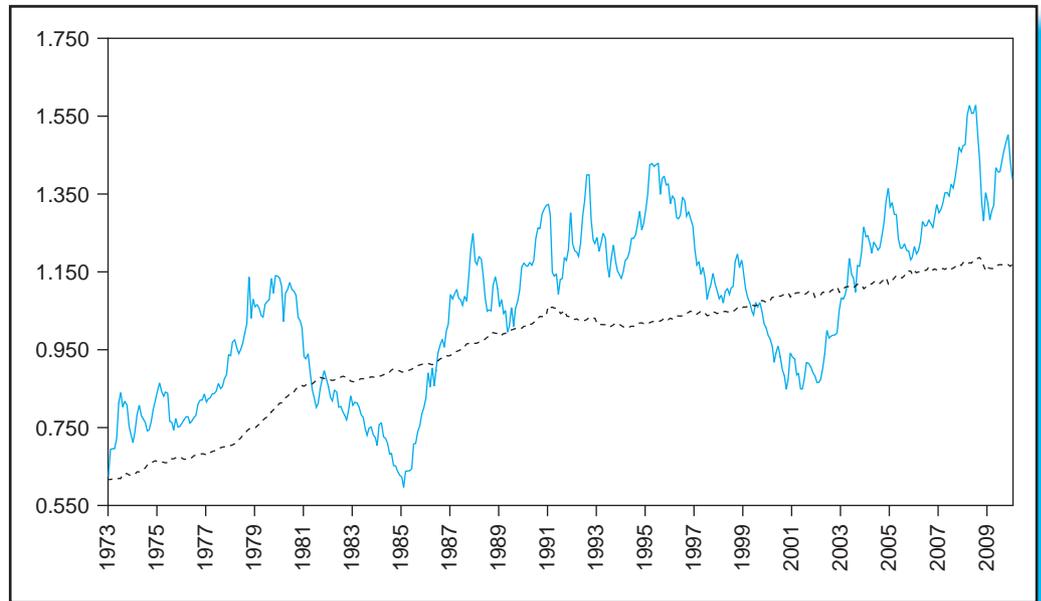
Exhibit 8.3 Actual USD/GBP and PPP Exchange Rates



Notes: The solid line is the actual exchange rate, and the dashed line is the PPP rate. Data are from the International Monetary Fund's International Financial Statistics.

⁴The percentage overvaluation or undervaluation of the denominator currency is computed as the percentage change in the exchange rate that is required to return to the PPP value. For example, if the actual exchange rate is \$1.50/£, and the PPP exchange rate is \$1.80/£, the pound is 20% undervalued because the appreciation of the pound required to go from the actual exchange rate to the PPP exchange rate is $[(\$1.80/\text{£})/(\$1.50/\text{£}) - 1] = 20\%$.

Exhibit 8.4 Actual USD/EUR and PPP Exchange Rates



Notes: The solid line is the actual exchange rate, and the dashed line is the PPP rate. Data are from the International Monetary Fund's International Financial Statistics.

overvalued by 40.7% because this is the amount the dollar would have had to weaken if the actual exchange rate were to adjust to its PPP value. This is precisely what happened over the course of the next 2 years.

For the $\$/\text{€}$ rate, the implied PPP value in January 1973 was $\$0.62/\text{€}$, and in January 2010, it was $\$1.17/\text{€}$. This is a cumulative weakening of the dollar relative to the Deutsche mark and then the euro of 88.7%, or 1.7% per year.⁵ This increase in the PPP exchange rate indicates that U.S. inflation was on average 1.7% per year higher than German inflation during this 37-year period. Notice that the exchange rate satisfied PPP at the start of the euro in 1999. Subsequently, the dollar strengthened substantially relative to the euro, and in October 2000, the euro was 25.9% undervalued relative to the prediction of PPP. The euro then began to strengthen, and its overvaluation peaked in July 2008, prior to the peak of the financial crisis.

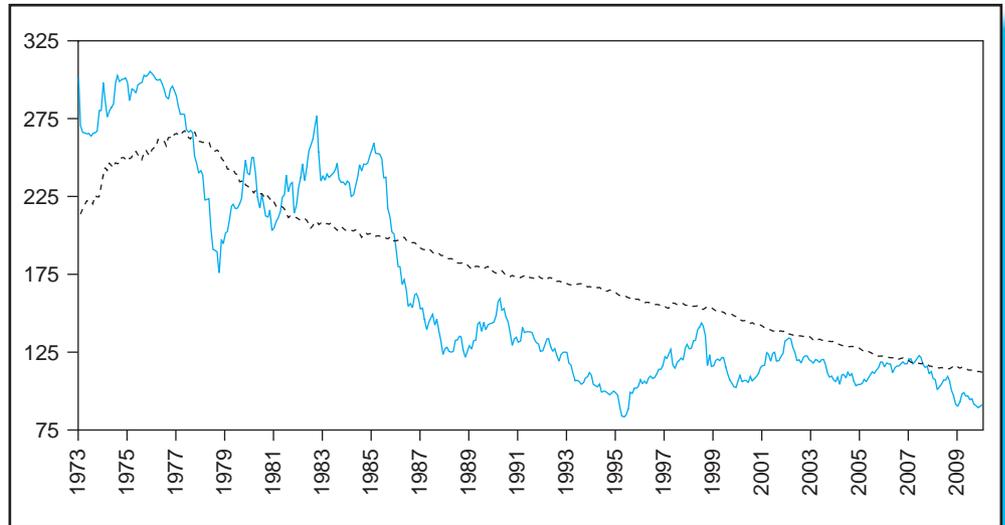
Yen-Dollar

The data for the yen-dollar exchange rates in Exhibit 8.5 differ somewhat from the previous ones. First, notice that the PPP line is upward sloping from 1973 to 1977, and then it is downward sloping thereafter. Because the PPP line corresponds to $P(t, \text{¥})/P(t, \$)$, the positive slope indicates that Japanese inflation was higher than U.S. inflation during the first part of the sample, whereas the negative slope of the ratio of the price levels indicates that Japanese inflation was lower than U.S. inflation during the second part of the sample.

The data on the $\text{¥}/\text{\$}$ rate indicate that the dollar was undervalued in October 1978 by 39%, with the implied PPP rate at $\text{¥}253/\text{\$}$ and the actual rate at $\text{¥}182/\text{\$}$. By February 1985, the dollar was 26.4% overvalued. Once the dollar peaked in strength in 1985, though, it began to depreciate relative to the yen. At the end of the sample in January 2010, at a PPP

⁵To find the annualized rate of appreciation of the euro, we solve for a in the following equation. $(\$0.62/\text{€})(1+a)^{37} = \$1.17/\text{€}$ or $a = \{[(\$1.17/\text{€})/(\$0.62/\text{€})]^{1/37} - 1\} = 0.017$.

Exhibit 8.5 Actual JPY/USD and PPP Exchange Rates



Notes: The solid line is the actual exchange rate, and the dashed line is the PPP rate. Data are from the International Monetary Fund's International Financial Statistics.

value of ¥111.6/\$, the dollar was undervalued relative to the yen by 20% because the actual exchange rate was ¥91.11/\$. In other words, those converting dollars into yen for expenditures in Japan found that their purchasing power was quite a bit lower than they were used to in the United States.

Canadian Dollar–U.S. Dollar

Exhibit 8.6 presents data for countries that share a common border, and here PPP works slightly better. The data for the Canadian dollar versus the U.S. dollar indicate that the maximal deviation from PPP was a 29.4% overvaluation of the U.S. dollar relative to the Canadian dollar in February 2002.

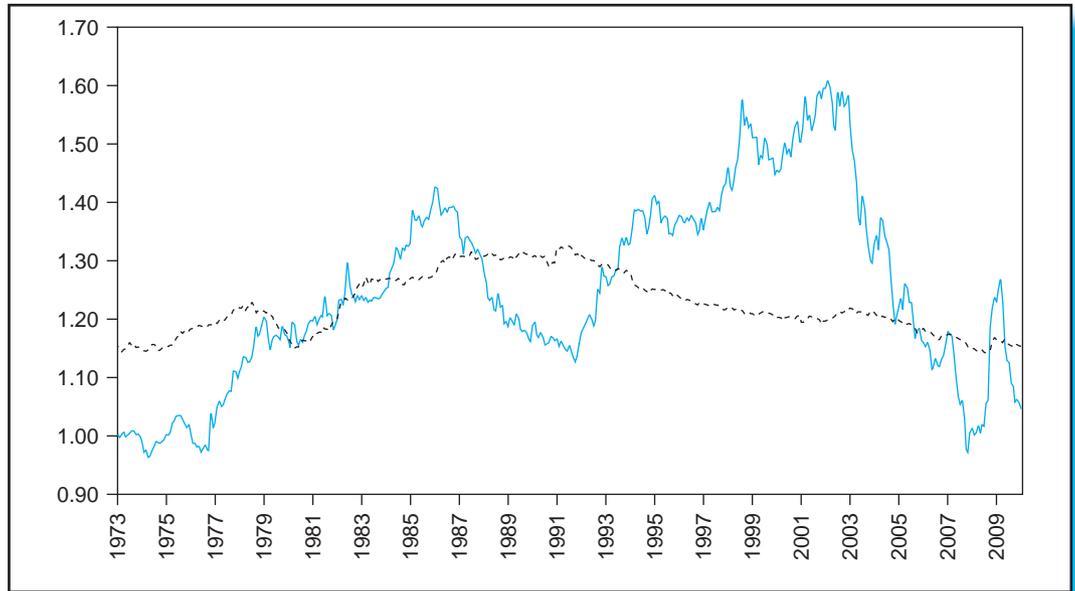
The overall flatness of the PPP line indicates that although U.S. and Canadian inflation rates were not identical period by period, they averaged essentially the same value over the sample period. Thus, the nominal weakening of the Canadian dollar during the 1990s led directly to a deviation from PPP, but by June 2004, the Canadian dollar had strengthened to restore PPP. The subsequent strengthening of the Canadian dollar returned the currencies to parity, which implies a 10% undervaluation of the U.S. dollar.

Mexican Peso–U.S. Dollar

All the exchange rates that have been discussed so far are for major developed countries. The last exchange rate we'll look at is the Mexican peso relative to the dollar, in Exhibit 8.7, where the exchange rates are in new pesos per dollar. Notice the periods of long stability when Mexico pegged the peso to the dollar, and the collapses of the fixed rates when devaluations occurred.

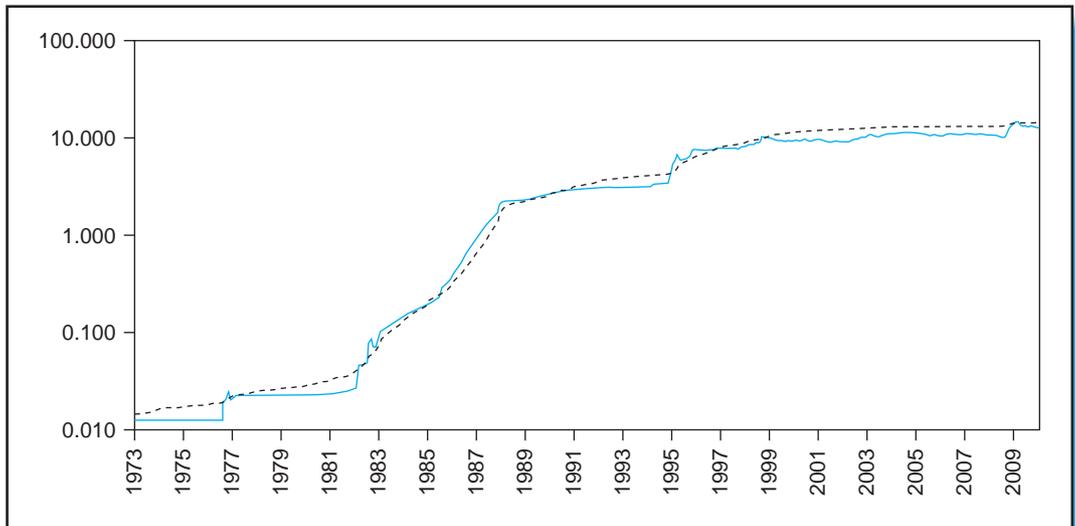
Note that the vertical scale is now a logarithmic one, in which the same vertical increment measures the same multiplicative increase or percentage rate of change. We need to use this graphical technique in order to see the early years of the period because the exchange rate (measured in current units) went from MXN0.0125/\$ in 1973 to MXN14.58/\$ in 2010. This is an increase of 116,640% over the 37 years, or 21% per year. The fact that the dollar was overvalued by only 8% relative to the peso after this enormous movement in the exchange rate is a

Exhibit 8.6 Actual CAD/USD and PPP Exchange Rates



Notes: The solid line is the actual exchange rate, and the dashed line is the PPP rate. Data are from the International Monetary Fund's International Financial Statistics.

Exhibit 8.7 Actual MXN/USD and PPP Exchange Rates



Notes: The solid line is the actual exchange rate, and the dashed line is the PPP rate. Data are from the International Monetary Fund's International Financial Statistics.

testimony to the long-run validity of PPP. The overvaluations of the peso prior to the 1976 and 1982 devaluations are also clearly present in the data. The data indicate that the peso was overvalued by 41% in August 1976, which is the maximum for the sample, and by 40% in January 1982 prior to the devaluations, whereupon it was subsequently undervalued by 13% in 1976 and 39% in 1982 after the devaluations. In November 1994, the data indicate that the peso was 21.3% overvalued when the market forced the devaluation known as the Mexican Peso Crisis.

8.6 EXPLAINING THE FAILURE OF ABSOLUTE PPP

Exhibits 8.6 through 8.7 show that there are large, persistent deviations of actual exchange rates from the predictions of absolute PPP. Because PPP is ultimately based on the law of one price, we know that anything that causes deviations from it can also cause deviations from PPP. As we saw, the factors causing deviations from the law of one price are quite numerous, including tariffs, quotas, and transaction costs. But there are other factors that cause deviations from absolute PPP.

Changes in Relative Prices

Changes in the relative prices of goods can cause deviations from PPP if price indices do not have the same weights across countries. To see this, suppose all goods are traded and assume that the prices of all goods satisfy the law of one price. Now, assume that tastes differ across countries so that expenditure shares on goods differ and let the price levels reflect the differences in consumption bundles. Typically, the residents of a country consume a larger share of the goods and services produced in that country than of imported goods and services. Consequently, the price indexes of each country will have a larger weight on goods produced at home and a smaller weight on imported goods. Changes in the relative prices will then lead to deviations from PPP.

A Burgers-and-Sushi World

Consider a simple example of the problem of changes in relative prices. Suppose there are only two countries, the United States and Japan, and to keep things really simple, assume that people consume only two goods, hamburgers and sushi. Let the United States produce only hamburgers, with a dollar price of \$10, and let Japan produce only sushi, with a yen price of ¥5,000. Assume the exchange rate is ¥100/\$. The U.S. price level will put a weight of 60% on the dollar price of hamburgers because U.S. consumers prefer hamburgers to sushi and a weight of 40% on the dollar price of sushi (the yen price of sushi divided by the yen-dollar exchange rate). Thus, the U.S. price level will be

$$P(t, \$) = 0.60 \times \$10 + 0.40 \times \frac{\text{¥}5,000}{\text{¥}100/\$} = \$26$$

Now, suppose the Japanese price level places a weight of 35% on the yen price of hamburgers (the dollar price of hamburgers multiplied by the yen-dollar exchange rate) because Japanese prefer sushi and a weight of 65% on the yen price of the sushi. Thus, the Japanese price level will be

$$P(t, \text{¥}) = 0.35 \times (\text{¥}100/\$) \times \$10 + 0.65 \times \text{¥}5,000 = \text{¥}3,600$$

The ratio of the price level in Japan to the price level in the United States is

$$\frac{P(t, \text{¥})}{P(t, \$)} = \frac{\text{¥}3,600}{\$26} = \text{¥}138.5/\$$$

Thus, even though the law of one price is satisfied in each country, the dollar appears to be 38.5% undervalued on the foreign exchange market. The problem is the difference in consumption shares. You should convince yourself that if the consumption shares were the same in both countries and if the law of one price held, then PPP would be satisfied.

It is now straightforward to understand how a change in relative prices can cause a change in the deviation between the exchange rate and measured PPP even though all goods are traded and all prices satisfy the law of one price. Suppose that there is a shift in demand away from U.S. hamburgers and toward Japanese sushi. With no changes in the supplies of the two goods, the relative price of sushi must rise both in the United States and in Japan. The

increase in the relative price can be accomplished by an appreciation of the yen relative to the dollar, with no change in the dollar price of hamburgers and no change in the yen price of sushi. Suppose the yen appreciates to ¥90/\$. With unchanged dollar prices of hamburgers and yen prices of sushi, the appreciation of the yen decreases the yen price of hamburgers in Japan and increases the dollar price of sushi, thereby making sushi relatively more expensive in both Japan and the United States. The U.S. price level will now be

$$P(t, \$) = 0.60 \times \$10 + 0.40 \times \frac{\text{¥}5,000}{\text{¥}90/\$} = \$28.22$$

and the Japanese price level will now be

$$P(t, \text{¥}) = 0.35 \times (\text{¥}90/\$) \times \$10 + 0.65 \times \text{¥}5,000 = \text{¥}3,565$$

The ratio of the price level in Japan to the price level in the United States is

$$\frac{P(t, \text{¥})}{P(t, \$)} = \frac{\text{¥}3,565}{\$28.22} = \text{¥}126.33/\$$$

Thus, even though the law of one price continues to be satisfied in each country, the dollar now appears to be 40.4% undervalued on the foreign exchange market because $(126.33 - 90)/90 = 0.404$. The shift in demand toward Japanese goods and away from U.S. goods causes the apparent undervaluation of the dollar to increase, but there is no opportunity for a goods market arbitrage.

Non-Traded Goods

Similar problems with absolute PPP arise when there are changes in the relative prices of traded and non-traded goods. Earlier in the chapter, we noted that when transaction costs are prohibitive, goods become non-traded. Because these goods are also included in the consumption bundles of individuals in the different countries, the prices of non-traded goods affect the price levels of the countries. Changes in the relative prices of traded and non-traded goods in two countries will cause deviations from absolute PPP that do not represent arbitrage opportunities.

Housing

Housing and other types of real estate are particularly important non-traded goods. If the price of housing in a country rises, with the price of other goods held constant, the relative price of housing rises, and the internal purchasing power of the country's money falls. Nevertheless, there need be no effect on the exchange rate. Consequently, after an increase in the relative price of housing in a country, the currency of that country will appear more overvalued (or less undervalued) on foreign exchange markets than before the increase in housing prices.

Technological Change

Why would the relative prices of non-traded goods rise compared to traded goods? Differential rates of technological change, which are also called productivity improvements, provide one answer. As the personal computer industry has aptly demonstrated over the past 25 years, improvements in technology in a competitive market force the prices of PCs to fall rapidly over time. The same is true of goods in other markets. If technology increases faster in traded goods industries than in non-traded goods industries, which is reasonable to expect if non-traded goods are services, we would expect that the relative price of non-traded goods would rise over time. This effect, known as the Harrod-Balassa-Samuelson effect, can impart a systematic bias in PPP calculations.⁶

⁶Harrod (1933), Balassa (1964), and Samuelson (1964) demonstrated that differential rates of technological change could produce systematic deviations from PPP. Canzoneri et al. (1999) and Lothian and Taylor (2008) provide empirical support for the idea.

PPP Deviations and the Balance of Payments

Our last explanation for deviations from absolute PPP is that they arise as equilibrium changes in the relative prices of goods across countries in a process that involves the balance of payments. The balance of payments of a country represents the aggregate amounts of goods and services that are bought and sold between the residents of a country and the rest of the world. We studied the accounting aspects of the balance of payments in Chapter 4. In Chapter 10, we formally discuss the relationship between deviations from PPP and the balance of payments. Here, we merely note that when a currency is overvalued relative to a PPP calculation, the external purchasing power of that currency increases, which shifts the nation's expenditures from domestic to foreign goods. This weakens the competitive position of domestic firms relative to foreign firms.

8.7 COMPARING INCOMES ACROSS COUNTRIES

Before we leave the subject of absolute PPP, we want to examine one particularly important use of PPP data: comparing nominal incomes across countries. Let's consider an extended example to make things easier.

Comparing Incomes in New York and Tokyo

The Salary Offers

Suppose you are considering working in New York for Citigroup and have been offered \$100,000 per year. Goldman Sachs has also offered you a job working in Japan for the next 2 years at ¥15,000,000 per year. Suppose you are indifferent between living in New York and living in Tokyo. Either sounds okay to you. The question then becomes, which job makes you better off financially—working in New York or Tokyo?

A Naïve Calculation

You might be tempted to make the decision by simply comparing the dollar value of the yen salary offer to the dollar salary of your New York offer by converting the yen salary into dollars at the current exchange rate. If the current exchange rate is ¥100/\$, the ¥15,000,000 is worth \$150,000. If you used this approach, you would accept the job offer to work in Japan.

Incorporating Purchasing Power

By now, you should realize that this is a naïve calculation because if you must live and work in Japan, you will not purchase goods with \$150,000. You will spend your yen salary to purchase goods and services that are sold in Japan and priced in yen, just as you would spend your dollar salary in New York to buy goods and services that are priced in dollars. To do a proper salary comparison, you must determine the command over goods and services that you will have based on the purchasing powers of the nominal salaries in each country. If you knew the price level in the United States, $P(t, \$)$, you could divide your \$100,000 salary offer by the price level to determine its command over goods and services. Similarly, if you knew the price level in Japan, $P(t, ¥)$, you could divide your ¥15,000,000 salary by the Japanese price level to determine its command over goods and services in Japan. From a financial viewpoint, you would be indifferent between working in New York and working in Japan if the purchasing powers of your two salaries were the same—that is, if

$$\frac{(\$100,000 \text{ salary})}{P(t, \$)} = \frac{(\text{¥}15,000,000 \text{ salary})}{P(t, ¥)}$$

Working with the PPP Rate

What if the prices levels are not available, but the PPP exchange rate is available? Multiplying on both sides of the previous equation by the price level in Japan gives

$$(\$100,000 \text{ salary}) \times \frac{P(t, \text{¥})}{P(t, \$)} = \text{¥}15,000,000 \text{ salary}$$

This equation states that you would be indifferent between the two jobs if your dollar salary multiplied by the PPP exchange rate, $[P(t, \text{¥})/P(t, \$)]$, equals your yen salary offer. Suppose the PPP exchange rate is ¥160/\$. To achieve the same purchasing power in Japan as you would have in the United States, you need a salary of

$$(\text{¥}160/\$) \times \$100,000 = \text{¥}16,000,000$$

But your offer is only ¥15,000,000.

Alternatively, if you divide your yen salary offer by the PPP exchange rate of yen per dollar, you get a dollar equivalent of your yen salary. Then, when you determine your command over goods and services by mentally dividing the dollar equivalent salary by the dollar price level, the resulting units are consumption bundles in Japan. The implied dollar salary is

$$\frac{\text{¥}15,000,000}{\text{¥}160/\$} = \$93,750$$

This calculation states that the purchasing power you would have in Japan from a ¥15,000,000 salary is equivalent to the purchasing power that you would have in the United States from a \$93,750 salary. As you can see, if the PPP exchange rate were ¥160/\$, you should turn down the offer to work in Japan or demand a higher yen salary.⁷

Given the occasional large percentage differences between actual exchange rates and implied PPP exchange rates that we saw in Exhibits 8.3 through 8.7, converting a foreign currency–denominated salary into dollars using an actual exchange rate versus a PPP exchange rate will sometimes produce quite substantively different results. The numerical example in this section demonstrates that if the dollar is undervalued relative to the foreign currency, the dollar-equivalent salary of a foreign currency offer is lower when you use the PPP exchange rate rather than the actual exchange rate.

Conversely, whenever the dollar is overvalued relative to a foreign currency, converting a foreign currency salary into dollars with the actual exchange rate will result in a smaller dollar salary than if the PPP exchange rate were used. However, although your salary in dollars will seem low, the dollar prices of goods and services purchased in the country will also seem quite low relative to comparable items in the United States. In such cases, dividing by the implied PPP exchange rate again provides a better estimate of the standard of living that you will face in the country, were you to be stationed there and paid in the foreign currency. This is particularly important if you are considering job offers in emerging market countries, whose currencies often appear to be undervalued relative to the dollar.

Comparing GDPs Using PPP Exchange Rates

Exhibit 8.8 presents a comparison of gross domestic product (GDP) per capita for the Organization for Economic Cooperation and Development (OECD) countries in 2008, measured in U.S. dollars, using a 3-year average of current exchange rates in the first column and PPP exchange rates in the second column.

⁷Ong and Mitchell (2000) use this approach with MacPPP rates to compare academic salaries across countries.

Exhibit 8.8 GDP per Capita for OECD Countries in 2008 Using Exchange Rates and PPP Values

OECD Country	In U.S. Dollars, Based on Market Exchange Rates	In U.S. Dollars, Based on PPP Exchange Rates
Australia	48,569	39,056
Austria	49,527	37,858
Belgium	47,151	35,288
Canada	44,995	39,014
Czech Republic	20,719	24,631
Denmark	62,054	36,808
Finland	50,775	35,809
France	44,450	33,098
Germany	44,519	35,432
Greece	31,174	28,896
Hungary	15,363	19,732
Iceland	52,610	36,994
Ireland	59,944	41,493
Italy	38,384	31,195
Japan	38,456	34,132
Korea	19,115	27,658
Luxembourg	117,967	84,713
Mexico	10,194	14,517
Netherlands	53,094	41,063
New Zealand	30,142	27,444
Norway	94,572	58,599
Poland	13,861	17,294
Portugal	22,951	23,283
Slovak Republic	17,537	22,141
Spain	34,971	31,455
Sweden	51,709	36,790
Switzerland	64,885	42,783
Turkey	10,275	13,959
United Kingdom	42,378	35,620
United States	47,186	47,186

Source: Data are from the Organization for Economic Cooperation and Development's statistical database.

The last row indicates that the United States produced final goods and services in 2008 that were worth \$47,186 per person. When the currency of a country is stronger in foreign exchange markets than its PPP exchange rate, as in the case of the Japanese yen, the dollar value of the country's GDP per capita when measured by current exchange rates is larger than when measured by PPP exchange rates. Notice that the dollar value of Japan's GDP falls from \$38,456 per capita in the first column to \$34,132 in the second column. The fact that the euro strengthened considerably relative to the dollar between 2004 and 2008 and was overvalued relative to PPP leads the European countries to have higher incomes measured at actual exchange rates rather than in PPP. Conversely, because non-traded goods are relatively inexpensive in emerging markets, their PPP exchange rates typically imply that their currencies are stronger versus the dollar than the actual exchange rates imply. Thus, the dollar value of the country's GDP per capita when measured by PPP exchange rates is larger than when measured by actual exchange rates.

The discussion in this section about comparing incomes across countries strongly suggests that the PPP exchange rates are the appropriate ones to use when comparing standards of living across countries.

8.8 RELATIVE PURCHASING POWER PARITY

Section 8.6 discusses reasons why absolute PPP generally will not hold. In addition, Exhibits 8.3 through 8.7 demonstrate that currencies are often substantially undervalued and overvalued relative to the predictions of absolute PPP calculated using CPI data. Another form of PPP, called **relative purchasing power parity**, takes market imperfections into account, and it acknowledges that because of these imperfections, a consumption bundle will not necessarily have the same value from country to country. However, according to the theory of relative PPP, exchange rates adjust in response to differences in inflation rates across countries to leave the differences in purchasing power unchanged over time. If the percentage change in the exchange rate just offsets the differential rates of inflation, economists say that relative PPP is satisfied. To help you better understand these concepts, let's begin with a numerical example.

Example 8.7 The Warranted Change in the Exchange Rate

Suppose, as in Example 8.4, that the price level in the United States is initially \$15,000/ U.S. consumption bundle, the price level in the United Kingdom is initially £10,000/ U.K. consumption bundle, and the exchange rate is \$1.40/£. We determined that absolute PPP is violated. The pound is undervalued on foreign exchange markets because the implied PPP exchange rate of

$$\frac{\$15,000}{£10,000} = \$1.50/£$$

is not equal to the actual exchange rate. The pound would have to strengthen relative to the dollar by 7.14% to correct its undervaluation because

$$\frac{\$1.50/£}{\$1.40/£} = 1.0714$$

Now, suppose that during the following year, the rate of U.S. inflation is 3%, and the rate of U.K. inflation is 10%. From the definition of *inflation*, we know that the new price level in the United States is 3% higher:

$$\$15,000 \times 1.03 = \$15,450$$

and the new price level in the United Kingdom is 10% higher:

$$£10,000 \times 1.10 = £11,000$$

Hence, the new implied PPP exchange rate is

$$\frac{\$15,450}{£11,000} = \$1.4045/£$$

If the pound remains 7.14% undervalued on the foreign exchange market, as it was before, the pound must weaken relative to the dollar for relative PPP to be satisfied. The new exchange rate should equal

$$S(t+1, \$/£) = \frac{\$1.4045/£}{1.0714} = \$1.3109/£$$

This keeps the ratio of the PPP exchange rate to the actual exchange rate at 1.0714, as before. The pound depreciates relative to the dollar by 6.36% because the actual exchange rate moves to \$1.3109/£ from \$1.40/£, and

$$\frac{\$1.3109/\text{£}}{\$1.40/\text{£}} = 0.9364 = 1 - 0.0636$$

Notice also that 0.9364 is the ratio of 1 plus the U.S. rate of inflation divided by 1 plus the U.K. rate of inflation because

$$\frac{1.03}{1.10} = 0.9364$$

Intuitively, the pound is losing purchasing power over goods and services due to U.K. inflation of 10% per year, and the dollar is losing purchasing power over goods and services due to U.S. inflation of 3% per year. A 6.36% depreciation of the pound relative to the dollar is therefore required to make the loss of the pound's external purchasing power equal to the loss of its internal purchasing power.

A General Expression for Relative PPP

The example in the preceding section demonstrates that relative PPP requires that 1 plus the rate of appreciation of the pound relative to the dollar should equal 1 plus the rate of inflation in the United States divided by 1 plus the rate of inflation in the United Kingdom.

The Logic of Relative PPP

Relative PPP is derived from the following economic reasoning: Inflation lowers the purchasing power of money. If the amount of inflation in the foreign country differs from the inflation rate in the domestic country, a change in the nominal exchange rate to compensate for the differential rates of inflation is warranted so that the loss of internal purchasing power due to domestic inflation equals the loss of external purchasing power due to foreign inflation and the change in the exchange rate. If the change in the exchange rate satisfies this warranted change, relative PPP is satisfied.⁸

A Symbolic Representation of Relative PPP

In general symbolic terms, let $s(t+1, \text{DC}/\text{FC})$ denote the percentage rate of change of the domestic currency (denoted DC) per unit of foreign currency (denoted FC) from time t to $t+1$, and let $\pi(t+1, \text{DC})$ and $\pi(t+1, \text{FC})$ represent the corresponding rates of domestic and foreign inflation, respectively; then relative PPP requires that

$$1 + s(t+1, \text{DC}/\text{FC}) = \frac{1 + \pi(t+1, \text{DC})}{1 + \pi(t+1, \text{FC})} \quad (8.3)$$

⁸It was this formulation of the theory that Cassel (1918) called *purchasing power parity*. Cassel was writing about the reestablishment of exchange rates after World War I because foreign exchange markets had closed during the war. Prior to the war, the countries of the world were on the gold standard, and their exchange rates were fixed. Cassel wrote:

The general inflation which has taken place during the war has lowered this purchasing power in all countries, though in a different degree, and the rate of exchange should accordingly be expected to deviate from their old parities in proportion to the inflation of each country. At every moment the real parity is represented by this quotient between the purchasing power of the money in one country and the other. I propose to call this parity "*purchasing power parity*" (p. 413).

If we subtract 1 from each side of Equation (8.3) and place terms over a common denominator, we get

$$s(t+1, \text{DC/FC}) = \frac{\pi(t+1, \text{DC}) - \pi(t+1, \text{FC})}{1 + \pi(t+1, \text{FC})} \quad (8.4)$$

Equation (8.4) states that the rate of appreciation of the foreign currency relative to the domestic currency is equal to the difference between the domestic rate of inflation and the foreign rate of inflation divided by 1 plus the foreign rate of inflation.

Because $[1 + \pi(t+1, \text{FC})]$ is often close to 1 if the foreign inflation rate is low, some presentations of relative PPP ignore this term in the denominator of Equation (8.4) and state that relative PPP requires equality between the rate of appreciation of the foreign currency relative to domestic currency and the difference between the domestic and foreign inflation rates. Equation (8.4) indicates that this statement is an approximation, albeit a pretty good one if the foreign inflation rate is small.

Of course, because the graphs in Exhibit 8.3 indicate that deviations from absolute PPP change over time, relative PPP also does not hold in the data. The rate of change of the exchange rate does not equal the inflation differential between two currencies.

Relative PPP with Continuously Compounded Rates of Change (Advanced)

The discussion of relative PPP suggests ignoring the denominator of Equation (8.4) as a reasonable approximation. We encountered a similar approximation in the discussion of interest rate parity in Chapter 6. There, we noted that if we measure the forward premium on the foreign currency and the domestic and foreign interest rates in continuously compounded terms, it is exactly correct to state that interest rate parity requires equality between the forward premium on the foreign currency and the interest differential between the domestic and foreign interest rates. Analogously, if we measure the rate of appreciation of the foreign currency relative to the domestic currency and the domestic and foreign inflation rates as continuously compounded rates of change, relative PPP requires equality between the rate of appreciation of the foreign currency and the difference between the domestic and foreign rates of inflation. We demonstrate this equality by using the dollar–pound exchange rate and the respective rates of inflation.

If there are obstacles to international trade that prevent absolute PPP from holding, we can introduce a factor k such that the internal purchasing power of the money equals k times the external purchasing power of the money:

$$\frac{1}{P(t, \$)} = k \times \frac{1}{S(t, \$/\pounds)} \times \frac{1}{P(t, \pounds)} \quad (8.5)$$

where $S(t, \$/\pounds)$ denotes the actual exchange rate and not the implied PPP value. By rearranging Equation (8.5), we have

$$\frac{S(t, \$/\pounds) \times P(t, \pounds)}{P(t, \$)} = k \quad (8.6)$$

If the amount of overvaluation or undervaluation of the dollar relative to the pound is the same at time $t+1$, we have

$$\frac{S(t+1, \$/\pounds) \times P(t+1, \pounds)}{P(t+1, \$)} = k \quad (8.7)$$

Hence, the ratio of Equation (8.6) to Equation (8.7) is

$$\frac{S(t+1, \$/\pounds)}{S(t, \$/\pounds)} \times \frac{P(t+1, \pounds)/P(t, \pounds)}{P(t+1, \$)/P(t, \$)} = 1 \quad (8.8)$$

Now, if $s(t+1, \$/\pounds)$ denotes the continuously compounded rate of change of the dollar–pound exchange rate over the time interval from t to $t+1$, then $[S(t+1, \$/\pounds)/S(t, \$/\pounds)] = \exp[s(t+1, \$/\pounds)]$. Similarly, let $\pi(t+1, \pounds)$ and $\pi(t+1, \$)$ now denote the continuously compounded rates of inflation over the time interval from t to $t+1$ in the pound and dollar prices of goods, respectively. Then, $P(t+1, \pounds)/P(t, \pounds) = \exp[\pi(t+1, \pounds)]$, and $P(t+1, \$)/P(t, \$) = \exp[\pi(t+1, \$)]$. Substituting these exponential expressions into Equation (8.8) gives

$$\frac{\exp[s(t+1, \$/\pounds)] \times \exp[\pi(t+1, \pounds)]}{\exp[\pi(t+1, \$)]} = 1 \quad (8.9)$$

If we apply the rules for taking natural logarithms from the appendix to Chapter 2 to Equation (8.9), we find

$$s(t+1, \$/\pounds) + \pi(t+1, \pounds) - \pi(t+1, \$) = 0$$

or, rearranging terms, we find

$$s(t+1, \$/\pounds) = \pi(t+1, \$) - \pi(t+1, \pounds) \quad (8.10)$$

Equation (8.10) expresses relative PPP in its continuously compounded version. The rate of appreciation of the pound versus the dollar equals the rate of dollar inflation minus the rate of pound inflation when all the rates of change are continuously compounded.

8.9 THE REAL EXCHANGE RATE

While discussions of purchasing power parity have been around since the early twentieth century, the concept of the **real exchange rate** is much newer, as it entered the jargon of international finance in the late 1970s. Nonetheless, the real exchange rate is important because it influences the competitiveness of firms, which is explored in Chapter 9. Here, we introduce the concept of the real exchange rate.

The Definition of the Real Exchange Rate

The real exchange rate, say, of the dollar relative to the euro, will be denoted $RS(t, \$/\text{€})$. It is defined to be the nominal exchange rate multiplied by the ratio of the price levels:

$$RS(t, \$/\text{€}) = \frac{S(t, \$/\text{€}) \times P(t, \text{€})}{P(t, \$)} \quad (8.11)$$

Notice that the real exchange rate would be 1 if absolute PPP held because the nominal exchange rate, $S(t, \$/\text{€})$, would equal the ratio of the two price levels, $P(t, \$)/P(t, \text{€})$. Similarly, if absolute PPP is violated, the real exchange rate is not equal to 1. Also, the real exchange rate is constant if relative PPP holds, as we see in the next example.

Because the real exchange rate is not equal to 1 in Example 8.8, absolute PPP does not hold. But because relative PPP holds in Example 8.8, the deviations from absolute PPP are constant in percentage terms. This keeps the real exchange rate constant. If deviations from absolute PPP vary over time, relative PPP does not hold, and the real exchange rate fluctuates.

Example 8.8 A Constant Real Exchange Rate

Suppose that the U.S. price level is initially \$15,000/U.S. consumption bundle and the price level in Europe is initially €11,000/European consumption bundle. With the nominal exchange rate equal to \$1.30/€, the real exchange rate equals

$$RS(t, \$/\epsilon) = \frac{\$1.30/\epsilon \times \epsilon 11,000}{\$15,000} = 0.9533$$

Suppose that over the next year, there is 4% inflation in the United States, there is 8% inflation in Europe, and the nominal exchange rate changes so that relative PPP is satisfied. Then, as Equation (8.3) indicates, the new nominal exchange rate is

$$S(t, \$/\epsilon) = \frac{\$1.30/\epsilon \times 1.04}{1.08} = \$1.2519/\epsilon$$

The euro weakens by 3.7%. With 4% U.S. inflation, the new U.S. price level is \$15,600 = \$15,000 × 1.04, and with 8% European inflation, the new European price level is €11,880 = €11,000 × 1.08. The new real exchange rate is the same as it was before, because

$$RS(t+1, \$/\epsilon) = \frac{\$1.2519/\epsilon \times \epsilon 11,880}{\$15,600} = 0.9533$$

Essentially, the real exchange rate describes deviations from absolute PPP, and changes in the real exchange rate represent deviations from relative PPP.

Real Appreciations and Real Depreciations

Of course, when the concept of the real exchange rate took hold, people naturally began to refer to **real appreciations** and **real depreciations** of different currencies. The concepts of real appreciations and real depreciations are useful because they help us describe real exchange risk, the topic of Chapter 9.

In Chapter 2, we defined the percentage rate of change in the nominal exchange rate of the dollar relative to the pound by $s(t+1, \$/\pounds) = [S(t+1, \$/\pounds) - S(t, \$/\pounds)]/S(t, \$/\pounds)$. If the percentage change in $S(t, \$/\pounds)$ was positive, we called it a nominal appreciation of the pound. We also defined a nominal appreciation of the pound by $a(t+1, \$/\pounds) = s(t+1, \$/\pounds)$, when $s(t+1, \$/\pounds) > 0$. Similarly, we defined a nominal depreciation of the pound by $d(t+1, \$/\pounds) = -s(t+1, \$/\pounds)$, if $s(t+1, \$/\pounds) < 0$. For example, if the percentage change in the dollar–pound exchange rate was –5%, we said that the pound depreciated by 5%.

The Percentage Change in the Real Exchange Rate

We can define the percentage rate of change in the real exchange rate by

$$rs(t+1, \$/\pounds) = \frac{RS(t+1, \$/\pounds) - RS(t, \$/\pounds)}{RS(t, \$/\pounds)} \quad (8.12)$$

If the right-hand side of Equation (8.12) is positive, we have a real appreciation of the pound:

$$ra(t+1, \$/\pounds) = rs(t+1, \$/\pounds), \text{ if } rs(t+1, \$/\pounds) > 0$$

and if the real exchange rate falls, we have a real depreciation of the pound:

$$rd(t+1, \$/\pounds) = -rs(t+1, \$/\pounds), \text{ if } rs(t+1, \$/\pounds) < 0$$

Because the ratio of the new real exchange rate to the old real exchange rate equals 1 plus the rate of change of the real exchange rate, we have

$$[1 + rs(t+1, \$/\pounds)] = \frac{RS(t+1, \$/\pounds)}{RS(t, \$/\pounds)} \quad (8.13)$$

To understand what leads to real appreciations and depreciations, we must substitute the definition of the real exchange rate from Equation (8.11) into Equation (8.13):

$$[1 + rs(t+1, \$/\pounds)] = \frac{[S(t+1, \$/\pounds) \times P(t+1, \pounds)]/P(t+1, \$)}{[S(t, \$/\pounds) \times P(t, \pounds)]/P(t, \$)} \quad (8.14)$$

Now, we group the exchange rate terms, the pound price-level terms, and the dollar price-level terms together to get the following:

$$[1 + rs(t+1, \$/\pounds)] = \frac{[S(t+1, \$/\pounds)/S(t, \$/\pounds)] \times [P(t+1, \pounds)/P(t, \pounds)]}{[P(t+1, \$)/P(t, \$)]}$$

After substituting the definitions of the ratios of variables at time $t+1$ to those at time t , we find

$$[1 + rs(t+1, \$/\pounds)] = \frac{[1 + s(t+1, \$/\pounds)] \times [1 + \pi(t+1, \pounds)]}{[1 + \pi(t+1, \$)]} \quad (8.15)$$

The left-hand side of Equation (8.15) is 1 plus the percentage rate of change of the real dollar–pound exchange rate. The right-hand side equals 1 plus the percentage rate of change of the nominal dollar–pound exchange rate multiplied by 1 plus the U.K. rate of inflation, $\pi(t+1, \pounds)$, divided by 1 plus the U.S. rate of inflation, $\pi(t+1, \$)$.

What Leads to Real Appreciations or Depreciations

Because the real exchange rate is composed of three variables that can all move simultaneously, many combinations of changes lead to a real appreciation of the pound. The three basic movements are as follows:

1. An increase in the nominal exchange rate ($\$/\pounds$), that is a nominal appreciation of the pound, holding the dollar prices and pound prices of goods constant.
2. An increase in the pound prices of goods, holding the exchange rate and the dollar prices of goods constant.
3. A decrease in the dollar prices of U.S. goods, holding the exchange rate and the pound prices of goods constant.

Because relative PPP implies a constant real exchange rate, we know that $rs(t+1, \$/\pounds) = 0$ in this case. We can therefore use this information to solve Equation (8.15) to find that the required percentage change in the nominal exchange rate that just keeps the real exchange rate constant is

$$[1 + s(t+1, \$/\pounds)] = \frac{[1 + \pi(t+1, \$)]}{[1 + \pi(t+1, \pounds)]} \quad (8.16)$$

Equation (8.16) provides the warranted percentage rate of change of the dollar–pound exchange rate that leaves the real exchange rate unchanged. If the nominal appreciation is larger than the amount that is warranted by the right-hand side of Equation (8.16), there is a real appreciation of the pound. Conversely, if the actual rate of appreciation of the pound relative to the dollar falls short of the warranted amount on the right-hand side of Equation (8.16), there is a real depreciation of the pound.

Example 8.9 A Variable Real Exchange Rate

When the real exchange rate was constant in Example 8.8, the annual U.S. rate of inflation was 4%, the annual European rate of inflation was 8%, and the dollar–euro exchange rate offset the inflation differential, with the euro depreciating by 3.7%. Suppose that the euro actually depreciates in nominal terms by 2% relative to the dollar during the year of these inflations. Is this nominal depreciation of the euro associated with a real depreciation of the euro or a real appreciation?

From Equation (8.16), we know that the warranted rate of depreciation of the euro relative to the dollar is 3.7% because

$$\frac{[1 + \pi(t+1, \$)]}{[1 + \pi(t+1, \text{€})]} = \frac{1.04}{1.08} = 0.963 = 1 - 0.037$$

Because the nominal rate of depreciation of the euro relative to the dollar is only 2%, there has been a real appreciation of the euro. The new real exchange rate is now greater than it was before. With the new nominal exchange rate of

$$(\$1.30/\text{€}) \times (1 - 0.02) = \$1.2740/\text{€}$$

the new real exchange rate is

$$RS(t+1, \$/\text{€}) = \frac{\$1.2740/\text{€} \times \text{€}11,880}{\$15,600} = 0.9702$$

The old real exchange rate was 0.9533. There is a real appreciation of the euro, and there is a real depreciation of the dollar, even though the dollar appreciated relative to the euro in nominal terms. The nominal dollar value of the euro just did not fall enough when compared to the respective rates of inflation of the two currencies. Because the euro only weakened by 2% instead of the 3.7% that was warranted by the inflation differential, the euro actually strengthened in real terms.

Notice from Equation (8.15) that real appreciations and real depreciations can occur even if the nominal exchange rate does not change. If the exchange rate is fixed between two currencies, but the prices of goods measured in these currencies rise at different rates because of differences in inflation, the high-inflation country will experience a real appreciation of its currency, and the low-inflation country will experience a real depreciation.

Trade-Weighted Real Exchange Rates

To this point, we have considered only bilateral real exchange rates. Many governments calculate a **trade-weighted real exchange rate**. The numerator of a trade-weighted real exchange rate contains the sum of the nominal exchange rates for different currencies multiplied by the price levels of different countries weighted by the proportion of trade conducted with that country. A trade-weighted real exchange rate makes good economic sense because a given currency rarely strengthens or weakens relative to all foreign currencies by the same amount, and real exchange rates are critical determinants of international trade. For example, if we are interested in describing the extent to which a depreciation of the domestic currency would affect a country's trade balance, we must know how much trade the country is doing with other nations and how much the depreciation is increasing the relative prices of the goods of those countries.

8.10 SUMMARY

This chapter explores the theory known as purchasing power parity and a related concept, the real exchange rate. The main points in the chapter are as follows:

1. Absolute PPP states that the nominal exchange rate adjusts to equate the internal purchasing power of a nation's currency to the external purchasing power of that currency.
2. The internal purchasing power of a currency is the amount of goods and services that a unit of the currency can buy in the country that issues that money. The consumer price level of a country measures the amount of money that is necessary to purchase a typical bundle of consumption goods in that country. The internal purchasing power of a currency is consequently the reciprocal of the price level.
3. The external purchasing power of a currency is the amount of goods and services that a unit of the money can buy in a foreign country after converting from the domestic money into the foreign money.
4. Inflation (increases in a nation's price level) lowers the purchasing power of a country's currency. In contrast, deflation (decreases in a nation's price level) increases the purchasing power of a country's currency.
5. The law of one price means that the price of a commodity denominated in a particular currency is the same wherever in the world the good is being sold. If markets are competitive and there are no transaction costs or information costs, goods market arbitrage drives the price of the good quoted in a common currency to be the same around the world.
6. Violations of the law of one price are caused by transaction costs; barriers to trade such as tariffs, quotas, and government regulations; and non-competitive markets. When transaction costs or barriers to trade in international markets are prohibitive, goods become non-traded. For these goods, the law of one price won't hold.
7. A currency is said to be overvalued on foreign exchange markets if its external purchasing power is

greater than its internal purchasing power. A currency is undervalued on foreign exchange markets if its external purchasing power is less than its internal purchasing power. Overvalued currencies must weaken to return to the prediction of PPP, whereas undervalued currencies must strengthen to return to PPP.

8. Deviations from absolute PPP are large and persistent. For the major currencies, deviations from PPP of 35% or more are not uncommon, and such discrepancies between the market exchange rate and the PPP prediction often persist for 5 or more years. In the long run, however, the deviations tend to subside and reverse sign.
9. Equilibrium changes in relative prices, especially between the prices of traded and non-traded goods, explain some of the observed deviations from absolute PPP.
10. The theory of relative purchasing power acknowledges that a consumption bundle will not necessarily be the same from country to country. However, it holds that exchange rates will adjust in response to differential inflation rates occurring in countries.
11. The real exchange rate of a domestic currency relative to a foreign currency is defined to be the nominal exchange rate (in domestic currency per unit of foreign currency) multiplied by the ratio of the price levels in the two countries:

$$RS = \frac{S(DC/FC) \times P(FC)}{P(DC)}$$

12. If the percentage change in the nominal exchange rate (domestic currency per unit of foreign currency) exceeds the rate of change that is warranted by differential inflation rates between two countries (that is, the differential inflation rate that satisfies relative PPP), there is a real appreciation of the foreign currency and a real depreciation of the domestic currency.

QUESTIONS

1. What does the purchasing power of a money mean? How can it be measured?
2. Suppose the government releases information that causes people to expect that the purchasing power of a money in the future will be less than they previously had expected. What will happen to the exchange rate today? Why?
3. What is the difference between a price level and a price index?

4. What do economists mean by the law of one price? Why might the law of one price be violated?
5. What is the value of the exchange rate that satisfies absolute PPP?
6. If the actual exchange rate for the euro value of the British pound is less than the exchange rate that would satisfy absolute PPP, which of the currencies is overvalued and which is undervalued? Why?
7. What market forces prevent absolute PPP from holding in real economies? Which of these represent unexploited profit opportunities?
8. Why is it better to use a PPP exchange rate to compare incomes across countries than an actual exchange rate?
9. What is relative PPP, and why does it represent a weaker relationship between exchange rates and prices than absolute PPP?
10. What is the real exchange rate, and how are fluctuations in the real exchange rate related to deviations from absolute PPP?
11. If the nominal exchange rate between the Mexican peso and the U.S. dollar is fixed, and there is higher inflation in Mexico than in the United States, which currency experiences a real appreciation and which experiences a real depreciation? Why? What is likely to happen to the balance of trade between the two countries?

PROBLEMS

1. If the consumer price index for the United States rises from 350 at the end of a year to 365 at the end of the next year, how much inflation was there in the United States during that year?
2. As a wheat futures trader, you observe the following futures prices for the purchase and sale of wheat in 3 months: \$3.00 per bushel in Chicago and ¥320 per bushel in Tokyo. Delivery on the contracts is in Chicago and Tokyo, respectively. If the 3-month forward exchange rate is ¥102/\$, what is the magnitude of the transaction cost necessary to make this situation not represent an unexploited profit opportunity?
3. Suppose that the price level in Canada is CAD16,600, the price level in France is EUR11,750, and the spot exchange rate is CAD1.35/EUR.
 - a. What is the internal purchasing power of the Canadian dollar?
 - b. What is the internal purchasing power of the euro in France?
 - c. What is the implied exchange rate of CAD/EUR that satisfies absolute PPP?
 - d. Is the euro overvalued or undervalued relative to the Canadian dollar?
 - e. What amount of appreciation or depreciation of the euro would be required to return the actual exchange rate to its PPP value?
4. Suppose that the rate of inflation in Japan is 2% in 2011. If the rate of inflation in Germany is 5% during 2011, by how much would the yen strengthen relative to the euro if relative PPP is satisfied during 2011?
5. One of your colleagues at Deutsche Bank thinks that the dollar is severely undervalued relative to the yen. He has calculated that the PPP exchange rate is ¥140/\$, whereas the current exchange rate is ¥105/\$. Because interest rates are 3% p.a. lower in Japan than in the United States, he thinks that this is a good time to speculate by borrowing yen and lending dollars. What do you think?
6. Suppose that you are trying to decide between two job offers. One consulting firm offers you \$150,000 per year to work out of its New York office. A second consulting firm wants you to work out of its London office and offers you £100,000 per year. The current exchange rate is \$1.65/£. Which offer should you take, and why? Assume that the PPP exchange rate is \$1.40/£ and that you are indifferent between working in the two cities if the purchasing power of your salary is the same.
7. Suppose that in 2011, the Japanese rate of inflation is 2%, and the German rate of inflation is 5%. If the euro weakens relative to the yen by 10% during 2011, what would be the magnitude of the real depreciation of the euro relative to the yen?
8. Pick a particular brand of appliance, like a Bosch dishwasher with certain features, and use the Internet to compare its prices across countries. Be sure to have exactly the same style of appliance in each country. How different are the prices when expressed in a common currency?
9. Go to the International Monetary Fund's Web site at www.imf.org, find the Data and Statistics tab, locate World Economic Outlook (WEO) data, and download the "Implied PPP conversion rate" for the Indonesian rupiah and the Philippines peso versus the dollar. Calculate a rupiah per peso PPP rate and compare it to the actual exchange rate. Which currency is overvalued, and by how much?

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