

# Chapter

# 6

## Interest Rate Parity

In January 2011, Brazilian real-denominated Treasury bill rates exceeded 11%, whereas U.S. Treasury bill rates were less than 20 basis points. Why would U.S. investors accept such low returns when they could invest in Brazil? First and foremost, U.S. investors face transaction foreign exchange risk when investing in a Brazilian security. The Brazilian real might weaken, wiping out the interest gain. If investors hedge this risk, the relative return on Brazilian Treasury bills versus U.S. Treasury bills is driven by four variables: the Brazilian interest rate, the spot and forward exchange rates, and the U.S. interest rate. After hedging, perhaps the dollar return on the Brazilian Treasury bill looks much lower.

Interest rate parity describes a no-arbitrage relationship between spot and forward exchange rates and the two nominal interest rates associated with these currencies. The relationship is called **covered interest rate parity**. This chapter shows that interest rate parity implies that forward premiums and discounts in the foreign exchange market offset interest differentials to eliminate possible arbitrage that would arise from borrowing the low-interest-rate currency, lending the high-interest-rate currency, and covering the foreign exchange risk. Interest rate parity is a critical equilibrium relationship in international finance. However, it does not always hold perfectly, and we discuss why, which will bring us back to the Brazilian example above.

The availability of borrowing and lending opportunities in different currencies allows firms to hedge transaction foreign exchange risk with money market hedges. We demonstrate that when interest rate parity is satisfied, money market hedges are equivalent to the forward market hedges of transaction exchange risk that were presented in Chapter 3. Moreover, we can use interest rate parity to derive long-term forward exchange rates. Knowledge of long-term forward rates is useful in developing multiyear forecasts of future exchange rates, which are an important tool in the valuation of foreign projects.

### 6.1 THE THEORY OF COVERED INTEREST RATE PARITY

In international money markets, the interest rate differential between two currencies approximately equals the percentage spread between the currencies' forward and spot rates. If this is not the case, traders have an opportunity to earn arbitrage profits. In this section, we first derive intuition for this interest rate parity relationship using a number of examples, and then we derive it formally. We end the section by illustrating how an arbitrage would result when the parity relationship is violated. For students rusty on concepts related to interest rates, the box titled *The Time Value of Money* in this chapter provides a brief review.

## Example 6.1 Kim Deal's Investment Opportunities

Let's consider the situation of Kim Deal, a portfolio manager at BNP Paribas, a French bank. Kim is trying to decide how to invest €10 million, and she must choose between 1-year euro deposits and 1-year yen investments. In the latter case, she knows she must worry about transaction foreign exchange risk, but she also understands that she can use the appropriate forward contract to eliminate it.

Suppose Kim has the following data:

EUR interest rate:	3.5200% per annum (p.a.)
JPY interest rate:	0.5938% p.a.
Spot exchange rate:	¥146.0300/€
1-year forward exchange rate:	¥141.9021/€

Which of these investments should Kim choose to get the highest euro return?

To do the analysis, let's first calculate the euro return from investing in the euro-denominated asset. If Kim invests €10,000,000 at 3.52%, after 1 year, she will have

$$€10,000,000 \times 1.0352 = €10,352,000$$

Next, let's calculate the euro return if Kim invests her €10,000,000 in the yen-denominated asset. This analysis requires three steps:

**Step 1.** Convert the euro principal into yen principal in the spot foreign exchange market. The €10,000,000 buys

$$€10,000,000 \times (¥146.03/€) = ¥1,460,300,000$$

at the current spot exchange rate.

**Step 2.** Calculate yen-denominated interest plus principal. Kim can invest her yen principal at 0.5938% for 1 year. Hence, Kim knows that in 1 year, she will have a return of yen principal plus interest equal to

$$¥1,460,300,000 \times 1.005938 = ¥1,468,971,261$$

**Step 3.** Hedge the transaction exchange risk with a 1-year forward contract.

Kim knows that if she does nothing today to eliminate the transaction foreign exchange risk, she will sell the ¥1,468,971,261 at the future spot rate in 1 year to get back to euros, and she will bear the foreign exchange risk that the yen weakens relative to the euro. Kim also realizes that this unhedged investment does not have the same risk characteristics as the euro-denominated bank investment. The unhedged investment is subject to foreign exchange risk; the euro investment returns a sure amount of euros. As we saw in Chapter 3, the transaction foreign exchange risk can be eliminated by selling yen forward for euros. In this case, Kim would contract to sell ¥1,468,971,261 for euros at the 1-year forward rate of ¥141.9021/€. In 1 year, she would receive

$$¥1,468,971,261 / (¥141.9021/€) = €10,352,005$$

So, even though she has the opportunity to invest euros at 3.52% versus investing yen at 0.5938%, Kim is slightly better off making the yen-denominated investment and covering the foreign exchange risk. But the difference between the two euro returns is an additional €5 of interest on €10,000,000 after 1 year for the yen investment, and this is 5 thousandths of a basis point. We conclude that the two returns are essentially the same.

## The Intuition Behind Interest Rate Parity

Forward exchange rates allow investors to contract to buy and sell currencies in the future. Because the future value of one unit of currency depends on the interest rate for that currency, the forward exchange rate must be linked to the current spot exchange rate and to the nominal interest rates in the two currencies. Interest rate parity relates the spot and forward exchange rates and the nominal interest rates denominated in the two currencies. Instead of memorizing a formula that requires you to remember which way spot and forward rates are quoted, think of interest rate parity as the equality of the returns on comparable money market assets when the forward foreign exchange market is used to eliminate foreign exchange risk. With interest rate parity satisfied in Example 6.1, the two euro-denominated returns were equal.

Interest rate parity holds if markets are efficient and there are no government controls to prevent arbitrage. In the absence of these conditions, traders could make an extraordinary profit via **covered interest rate arbitrage**. Once again, the term *covered* means the investment is not exposed to transaction foreign exchange risk. The return Kim Deal obtained by investing in yen, for example, and “covering” the yen exchange rate risk is sometimes called the *covered yield*. The next example demonstrates how to exploit the covered yield if interest rate parity is not satisfied.

### Example 6.2 Kevin Anthony’s Arbitrage Opportunity

Suppose Kevin Anthony has \$10,000,000 to invest, and he faces the following data: USD interest rate, 8.0% p.a.; GBP interest rate, 12.0% p.a.; spot exchange rate, \$1.60/£; and 1-year forward exchange rate, \$1.53/£. Doing the calculations analogous to Example 6.1 indicates that if Kevin invests \$10,000,000 in the dollar asset at 8%, he will have

$$\$10,000,000 \times 1.08 = \$10,800,000$$

If Kevin converts his \$10,000,000 into pounds at the current spot exchange rate, he’ll get

$$\$10,000,000 / (\$1.60/\text{£}) = \text{£}6,250,000$$

which he can invest at 12% to get

$$\text{£}6,250,000 \times 1.12 = \text{£}7,000,000$$

of pound principal plus interest. Selling this amount forward gives a dollar return of

$$\text{£}7,000,000 \times (\$1.53/\text{£}) = \$10,710,000$$

So, even though Kevin has the opportunity to invest in pounds at 12% versus investing dollars at 8%, he is better off making the dollar-denominated investment. But would Kevin stop there?

Let’s allow Kevin to borrow or lend at the dollar interest rate of 8% and the pound interest rate of 12%. Now, instead of simply choosing to invest in dollars instead of pounds, Kevin can borrow pounds and invest in dollars. Does it make sense for him to do this?

For each £1,000,000 that Kevin borrows, in 1 year he will owe

$$\text{£}1,000,000 \times 1.12 = \text{£}1,120,000$$

Let's see how many pounds he will have after 1 year if he converts the pound principal to dollars in the spot market, invests the dollars at 8%, and covers the foreign exchange risk by selling the dollar interest plus principal in the forward market. Once again, this takes three steps:

**Step 1.** Convert from pounds to dollars at the spot rate of \$1.60/£:

$$£1,000,000 \times (\$1.60/£) = \$1,600,000$$

**Step 2.** Calculate dollar interest plus principal at 8%:

$$\$1,600,000 \times 1.08 = \$1,728,000$$

**Step 3.** Cover the foreign exchange risk by engaging in a forward contract to sell the dollar interest plus principal at \$1.53/£:

$$\$1,728,000 / (1.53/£) = £1,129,411.76$$

The covered interest arbitrage produces a riskless profit of

$$£1,129,411.76 - £1,120,000.00 = £9,411.76$$

for every £1,000,000 that is borrowed.

If interest rates and spot and forward exchange rates were actually as they are in Example 6.2, many banks and investors would borrow pounds, convert to dollars, invest the dollars, and sell the dollar interest plus principal in the forward market for pounds. This arbitrage activity would quickly eliminate the profit opportunity. The additional demand to borrow pounds would drive up the pound interest rate. The sale of pounds for dollars would lower the dollar–pound spot exchange rate. The lending of dollars would lower the dollar interest rate, and the forward purchase of pounds with dollars would raise the dollar–pound forward exchange rate. Each of these movements would reduce the arbitrage profits that are present at the current prices.

## The Time Value of Money

Interest rates provide market prices for buying and selling a given currency between different points in time. If you sell someone a dollar for 1 year (that is, you lend them \$1), they must pay you \$1 plus the 1-year dollar interest rate after 1 year. Similarly, if you buy pounds from someone today, promising payment in pounds in 1 year (that is, you borrow pounds), the price paid in 1 year for £1 today is £1 plus

the 1-year pound interest rate. Thus, interest rates provide prices for moving currencies between different time periods. Interest rates are therefore said to be the *time values* of monies.

The two fundamental concepts associated with the time value of money are **present value** and **future value**. The following are examples of each.

### Example 6.3 Lisa Dowling's Lottery Choices

Suppose Lisa Dowling has just won the London daily lottery and has been offered a choice of prizes. The lottery is willing to pay her either £100,000 today or £110,000 in 1 year. Suppose that London banks are paying 11% interest on deposits for the next year. Which offer should she accept and why?

First, we know that if Lisa deposits £100,000 in the bank today, she will receive an amount of pounds in 1 year, denoted  $FV$  (for future value), equal to

$$FV = £100,000 + 0.11 \times £100,000 = £100,000 \times 1.11 = £111,000$$

$$FV = \text{Return of Principal} + \text{Interest on Principal}$$

We say that £111,000 is the future value in 1 year of £100,000 today when the interest rate is 11% p.a. Because this is more than the lottery has promised her in 1 year, she should take the money today.

An alternative way to analyze Lisa's choice is to ask how much money she must set aside today if she wants to have £110,000 in 1 year. This approach calculates the present value ( $PV$ ) of the future cash flow promised by the lottery. We want to know the amount of pounds, denoted  $PV$ , that is equal to £110,000 in 1 year after Lisa earns interest on the  $PV$  pounds at 11% p.a. Algebraically, we have

$$PV \times 1.11 = £110,000$$

Solving for  $PV$  gives the present value of the future pounds:

$$PV = £110,000 / 1.11 = £99,099.10$$

$$PV = \frac{\text{Future Value}}{1 + \text{Interest Rate}}$$

Lisa's decision is still the same. She should take the £100,000 today. If she wants to have £110,000 in 1 year, she can deposit £99,099.10 in the bank, and she can spend the residual £900.90 today. When interest rates appear in the denominator of a present value relation, as in the formula here, they are called **discount rates**. Both present value analysis and future value analysis lead Lisa to the same solution. This is true in all problems involving the time value of cash flows, whether they are denominated in pounds, dollars, or yen. Because the interest rates denominated in different currencies are not the same, we must use an interest rate quoted on a particular currency to understand the time value of that currency.

## Deriving Interest Rate Parity

### A General Expression for Interest Rate Parity

Now let's consider the derivation of interest rate parity in algebraic terms. Our goal is to derive an expression that summarizes the relationship between the interest rates denominated in two different currencies and the spot and forward exchange rates between those currencies when there are no arbitrage opportunities in the money markets. The notation is as follows:

$i$  = the domestic currency interest rate appropriate for one period

$i^*$  = the foreign currency interest rate appropriate for one period

$S$  = the spot exchange rate (domestic currency per foreign currency)

$F$  = the one-period forward exchange rate (domestic currency per foreign currency)

Consider an investor who has one unit of domestic currency and two alternative investments at time  $t$ .

**Alternative 1:** Invest one unit of domestic currency. Get  $[1 + i]$  units of domestic currency (the return of the principal plus interest) after the investment period.

**Alternative 2:** Convert the one unit of domestic currency into foreign currency to get  $[1/S]$  units of foreign currency in today's spot market. Invest the  $[1/S]$  units of foreign currency to get  $[1/S] \times [1 + i^*]$  units of foreign currency (the return of the principal plus interest) after the investment period. Because the foreign currency principal plus interest that is returned in the future is known today, a contract can be made to sell the foreign currency in the forward market for domestic currency to produce  $[1/S] \times [1 + i] \times F$  units of domestic currency after the investment period.

Because Alternatives 1 and 2 are both made with one unit of domestic currency, and because both provide a certain return of domestic currency at the end of the investment period, the domestic currency returns must be equal. Hence, the equality of the two returns is

$$[1 + i] = [1/S] \times [1 + i^*] \times F \quad (6.1)$$

This is one way to represent interest rate parity.

### Interest Rate Parity and Forward Premiums and Discounts

By using a little algebra, we can express Equation (6.1) as a relationship between the interest differential between the two currencies and the forward premium or discount. First, divide both sides of Equation (6.1) by  $[1 + i^*]$ :

$$\frac{1 + i}{1 + i^*} = \frac{F}{S} \quad (6.2)$$

Then, subtract 1 from both sides of Equation (6.2) and apply a different common denominator on each side:

$$\frac{1 + i}{1 + i^*} - \frac{1 + i^*}{1 + i^*} = \frac{F}{S} - \frac{S}{S}$$

After simplifying, the result is an expression of interest rate parity that is valid when the exchange rates are expressed in direct terms as domestic currency per unit of foreign currency:

$$\frac{i - i^*}{1 + i^*} = \frac{F - S}{S} \quad (6.3)$$

Notice that the right-hand side of Equation (6.3) is the forward premium or discount on the foreign currency and that the numerator of the left-hand side is the interest differential between the domestic and foreign currencies. It is often said casually that interest rate parity requires equality between the interest rate differential and the forward premium or discount in the foreign exchange market. For simple interest rates, the expression of interest rate parity in Equation (6.3) demonstrates that this statement is an approximation because it ignores the term  $[1 + i^*]$  in the denominator on the left-hand side. But the approximation is reasonably good because this term is close to 1, especially if the maturity is short.

From our expression for interest rate parity, Equation (6.3), we learn that if the domestic currency interest rate is greater than the foreign currency interest rate, the foreign currency must be at a premium in the forward market. That is, the forward exchange rate (domestic currency per foreign currency) must be greater than the spot exchange rate. Analogously, if the domestic interest rate is less than the foreign interest rate, the foreign currency must sell at a discount in the forward market. Let's examine the intuition behind these results.

Notice from our original expression for the equality of the two investment opportunities in Equation (6.1) that when the foreign currency is at a premium (that is, the forward rate is above the spot rate), an individual buying foreign currency in the spot market and contracting

to sell it forward locks in a domestic currency capital gain. This capital gain contributes an additional return on the foreign investment. But when domestic interest rates are higher than foreign interest rates, a capital gain on the foreign currency is required to equate the two returns. Conversely, when the foreign currency interest rate is above the domestic currency interest rate, a domestic investor must suffer a capital loss when buying foreign currency in the spot market and selling it forward. Otherwise, foreign investments would be very attractive. The capital loss arises because the forward rate, expressed in domestic currency per foreign currency, is less than the spot rate. In this scenario, the domestic investor locks in a capital loss when buying foreign currency spot and contracting to sell it forward.

Let's revisit Kim Deal's situation and calculate the forward premium on the yen. This requires that we work with the reciprocals of the exchange rates quoted as yen per euro. The forward premium on the yen is therefore

$$\frac{F - S}{S} = \frac{\frac{1}{¥141.9021/€} - \frac{1}{¥146.03/€}}{\frac{1}{¥146.03/€}} = 2.91\%$$

By investing now in the yen and selling the yen proceeds forward after 1 year, Kim earns this premium. Of course, this premium compensates her for the lower interest rate that yen investments offer. Notice that the interest rate differential (Euro – Yen) is  $3.52\% - 0.5938\% = 2.93\%$ , which is approximately equal to the forward premium.

### Interest Rate Parity with Continuously Compounded Interest Rates (Advanced)

In Chapter 2, we introduced continuously compounded interest rates and natural logarithms. When interest rates are continuously compounded, interest rate parity has a particularly elegant representation. Now, let  $i$  and  $i^*$  represent the 1-year domestic currency and foreign currency interest rates quoted on a continuously compounded basis. Investing one unit of domestic currency provides  $\exp[i]$  units of domestic currency after 1 year. If we instead convert the one unit of domestic currency into foreign currency, invest the foreign currency, and cover the foreign exchange risk, we have a domestic currency return of  $[1/S] \exp[i^*] F$ . Now, equating the two domestic currency returns gives

$$\exp[i] = [1/S] \times \exp[i^*] \times F. \quad (6.4)$$

Taking natural logarithms of both sides of Equation (6.4) and rearranging terms, we have

$$i - i^* = \ln[F] - \ln[S]. \quad (6.5)$$

The left-hand side of Equation (6.5) is the interest differential between the continuously compounded interest rates, and the right-hand side is the forward premium, or discount, expressed in continuously compounded terms. Hence, interest rate parity is exactly characterized by the equality of the continuously compounded interest differential and the continuously compounded forward premium or discount.

### Covered Interest Arbitrage

In Example 6.2, the data violated the interest rate parity condition, and Kevin Anthony preferred the direct dollar investment because he achieved a higher dollar return than was available in the covered pound investment. In symbolic terms, we had

$$[1 + i(\$)] > [1/S] \times [1 + i(£)] \times F \quad (6.6)$$

where the dollar interest rate is  $i(\$)$ , the pound interest rate is  $i(\pounds)$ , and the units of the exchange rates are dollars per pound. In numbers, we had

$$1 + 0.08 > \frac{1}{\$1.60/\pounds} \times (1 + 0.12) \times (\$1.53/\pounds) = 1.071$$

Example 6.2 drew out the implication of Equation (6.6). Investors facing these interest rates and exchange rates would be able to profit by borrowing pounds, converting the pounds into dollars in the spot market, investing the dollars, and contracting in the forward market to cover the foreign exchange risk by selling the dollar amount of principal plus interest. To see this, multiply both sides of the inequality in Equation (6.6) by  $S$  and by  $[1/F]$  to get

$$S \times [1 + i(\$)] \times [1/F] > [1 + i(\pounds)]. \quad (6.7)$$

The right-hand side of the inequality in Equation (6.7) is the cost per pound to an investor who borrows pounds. For Kevin Anthony, this was £1.12. The left-hand side is the pound return per pound invested from converting the borrowed pound into dollars, investing the dollars, and contracting to sell dollar interest plus principal forward for pounds. For Kevin, the transaction would yield £1.1294. The inequality indicates that there is an arbitrage possibility at these interest rates and exchange rates, amounting to 0.94 pounds per £100 borrowed in Kevin's case.

Because the lending return is greater than the borrowing cost, a covered interest arbitrage opportunity would be available. Everyone would want to borrow an infinite amount of pounds, convert those pounds to dollars, invest the dollars, and sell the dollars forward for pounds. Clearly, such interest rates and exchange rates would not be in equilibrium.

### A Box Diagram

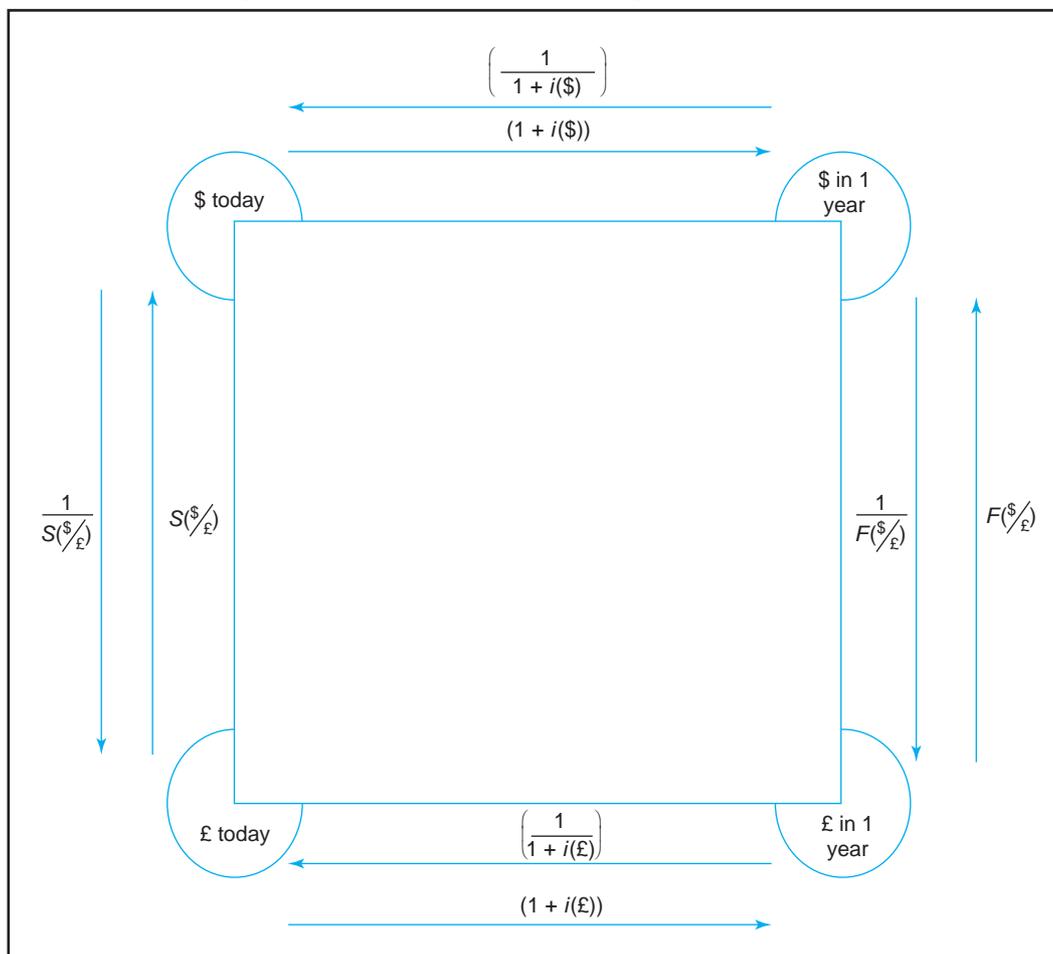
The idea of covered interest arbitrage can be represented in a box diagram that is similar to the diagrammatic representation of triangular arbitrage in Exhibit 2.7. Exhibit 6.1 presents a box diagram that represents covered interest arbitrage.

In Exhibit 6.1, each node represents either dollars or pounds today or dollars or pounds in 1 year. As in Exhibit 2.7, the arrows indicate the direction of movement from one node to another, and they are labeled with the associated revenue or price in terms of the currency at the final node as a result of delivering one unit of currency at the initial node. The interest rates provide the prices for moving monies between today and the future. The exchange rates provide the prices for moving from one currency to another currency either today for the spot rate or in the future period for the forward rate.

For example, if you are at the node representing pounds today and you move 1 pound to the future, the future pound revenue is  $[1 + i(\pounds)]$ . You invested 1 pound and earned interest. Similarly, if you place yourself at the dollar node in the future, and you move 1 dollar to the present, you receive  $\frac{1}{1 + i(\$)}$  dollars in the current period. Obtaining dollars today with payment of dollars in the future is equivalent to borrowing dollars today. You will owe interest plus principal on your loan. In order for the repayment to be \$1, you borrow only  $\frac{1}{1 + i(\$)}$  today. If you are at the node representing dollars today and move to pounds today, you receive  $\frac{1}{S(\$/\pounds)}$  pounds for 1 dollar, and if you are at the future pound node and move to the future dollar node, you get  $F(\$/\pounds)$  dollars for your 1 pound.

In the covered interest arbitrage of Example 6.2, we moved clockwise around the box, starting from the future pound node. We first bought current pounds (that is, we borrowed a fraction of a pound by promising to repay 1 pound in the future) and used the borrowed pounds to buy dollars today, yielding the dollar principal of  $\frac{S(\$/\pounds)}{1 + i(\pounds)}$ . We then sold our

**Exhibit 6.1** Diagram of Covered Interest Arbitrage



*Note:* The exchange rates and interest rates associated with each arrow indicate the funds obtained in the currency at the arrow's point from selling one unit of the currency at the arrow's tail. For example, at the \$ today node, selling 1 dollar for \$ in 1 year gives  $(1 + i(\$))$  dollars in 1 year.

current dollars for dollars in the future (by investing the dollars today), and we sold future dollars for future pounds by using a forward contract. This set of transactions made a profit.

If we start at the future pound node by selling 1 pound and move completely around the box in a clockwise direction, selling the amount of currency that we have at each node, our total revenue is found by multiplying the four prices of selling one unit together:

$$\begin{aligned} & (\text{Current } \pounds/\text{Future } \pounds) \times (\text{Current } \$/\text{Current } \pounds) \times (\text{Future } \$/\text{Current } \$) \\ & \times (\text{Future } \pounds/\text{Future } \$) = \left[ \frac{1}{1 + i(\pounds)} \right] \times [S(\$/\pounds)] \times [1 + i(\$)] \times \left[ \frac{1}{F(\$/\pounds)} \right] \quad (6.8) \end{aligned}$$

If interest rate parity is not satisfied, the right-hand side of Equation (6.8) gives us more than 1. (To see this, divide both sides of the inequality in Equation (6.7) by the value on its right-hand side.) We made a profit when we did the arbitrage because we were able to sell 1 pound in the future for more than 1 pound in the future. You should convince yourself that, with these prices, you could start at any node and move around the box in the clockwise direction to make a profit because the price of one unit starting at any node is always more than 1 with this particular violation of interest rate parity.

## 6.2 COVERED INTEREST RATE PARITY IN PRACTICE

Covered interest arbitrage not only requires transacting in the foreign exchange market, but also borrowing and lending. This is typically done in the *external currency market*, the inter-bank market most closely related to the foreign exchange market. To evaluate the possibility of arbitrage opportunities, we must take transaction costs into account. In addition to the bid–ask spreads in the foreign exchange markets, arbitrageurs also face transaction costs in the external currency market. The lending rate that banks charge their customers is above the rate that the banks are willing to pay on deposits. We now discuss how transaction costs affect covered interest rate parity.

### The External Currency Market

The **external currency market** is a bank market for deposits and loans that are denominated in currencies that are not the currency of the country in which the bank is operating. Its settlement procedures are identical to those of the foreign exchange market, and its interest rates flicker on the same computer screens.

The first of these deposits and loans were called eurodollars because they were dollar-denominated deposits at European banks. Although the external currency market was once limited to eurodollars, the idea quickly spread. Now, there are external currency markets for many currencies in financial centers around the world. A few of the examples include pound-denominated deposits and loans made by banks in Frankfurt, euro deposits and loans made by banks in Hong Kong or Tokyo, and yen deposits and loans made by banks in Paris or New York. Many market participants still use the terminology *euro-currency* for this market, but given its international nature and especially the emergence of the euro as a currency, *external currency market* now seems more appropriate.

One reason that the external currency market continues to grow is that the banks accepting the deposits and making the loans are subject to the regulations of the government of the country in which the bank is operating, not the government of the country that issues the money in which the deposits and loans are denominated. These regulations include how much banks must keep on reserve with their nation’s central bank (see Chapter 5). Because reserve requirements are often lower for foreign currency deposits than for domestic currency deposits, banks can lend out a larger part of these deposits. Thus, the foreign currency deposits are potentially more profitable.

The demand by domestic banks to meet the foreign competition from the external currency market has also resulted in some government authorities allowing external currency deposits that are internal to the country issuing the currency. In short, the domestic bank gets to act like a foreign bank in the domestic country. For example, U.S. financial regulations allow U.S.–chartered depository institutions to establish international banking facilities (IBFs) that accept dollar deposits from and make dollar loans to noncitizens of the United States. The IBF is not a separate physical or legal entity, but its asset and liability accounts are segregated from the rest of the bank’s. The IBF’s accounts are subject to different regulations and reserve requirements.

### Transaction Costs in the External Currency Market

In practice, the reduced regulatory burden and the strong competition in the external currency market have resulted in very small spreads between the interest rates at which banks are willing to pay for deposits and the interest rates that banks charge for loans. This has lowered transaction costs. Exhibit 6.2 provides borrowing and lending rates from the *Financial*

## Exhibit 6.2 Interest Rates in the External Currency Market

			Currency					
			USD	EUR	GBP	JPY	CAD	CHF
Maturity	1 Month	Bid	0.27	0.73	0.56	0.05	0.95	0.01
		Ask	0.57	0.88	0.76	0.30	1.05	0.30
	3 Month	Bid	0.33	0.96	0.73	0.30	1.05	0.29
		Ask	0.58	1.06	0.93	0.40	1.15	0.39
	6 Month	Bid	0.53	1.19	1.04	0.25	1.56	0.43
		Ask	0.83	1.31	1.24	0.46	1.88	0.55
	1 Year	Bid	0.91	1.35	1.46	0.46	1.80	0.56
		Ask	1.11	1.65	1.76	0.58	1.90	0.68

Note: Data are from the *Financial Times*, January 19, 2011.

*Times* for January 18, 2011. For example, at the 3-month maturity, banks are willing to make Canadian dollar (CAD) loans at 1.15% (ask rate) and accept CAD deposits at 1.05% (bid rate). These interest rates are quoted in percentage points per annum. The spread is therefore 10 basis points. To determine the appropriate interest rate for a 3-month basis, we must “de-annualize” the quoted interest rates by dividing by 100 (to convert from a percentage quotation to a decimal value) and then multiply by the fraction of a year over which the investment is made.

Most annualized external currency interest rates are based on a 360-day year, except for the pound sterling, which is quoted on a 365-day year. The interest received is the annualized interest rate multiplied by the ratio of actual days of deposit to the postulated number of days in a year. Thus, if the 3-month CAD deposit actually corresponds to 90 days, the de-annualized deposit interest rate is

$$1.05 \times (1/100) \times (90/360) = 0.002625$$

For the 3-month CAD borrowing rate, the de-annualized interest rate is

$$1.15 \times (1/100) \times (90/360) = 0.002875$$

Hence, for each CAD1,000,000 that you deposit, you would receive

$$\text{CAD}1,000,000 \times 1.002625 = \text{CAD}1,002,625$$

in principal and interest after 90 days, and for each CAD1,000,000 you borrow, you would owe

$$\text{CAD}1,000,000 \times 1.002875 = \text{CAD}1,002,875$$

in 90 days. If you borrowed first and then deposited, you would lose CAD250, or 0.0250%, of your principal in the two transactions, which is a bid–ask spread comparable to the ones in the foreign exchange market. Notice that this bid–ask spread is simply one-fourth of the quoted annualized spread of 0.10%.

These deposit and lending quotations are available in the interbank market on the same telecommunications networks as the spot and forward quotations discussed in Chapters 2 and 3. The minimum amount traded in the external currency markets is typically \$1 million. The maximum amount varies because lending banks limit the amount they lend to borrowing banks, depending on their default risk.

## How the External Currency Market Affects Other Capital Markets

External currency quotations in the interbank market form the basis for the interest rates at which investors and corporations can borrow and lend. An investor or a corporation that wants to participate in this market depositing funds typically earns less than the interbank rate. For example, in Exhibit 6.2, banks accept 3-month CAD deposits at 1.05% in the interbank market, but the deposit interest rate available to a corporate customer may be 10 basis points less, or 0.95%.

The lending rate that banks and other financial intermediaries charge investors and corporations is typically quoted as a fixed spread or margin over the external currency market interbank lending rate. The spreads depend on the borrower's creditworthiness. For example, in Exhibit 6.2, the 3-month CAD interbank lending rate is 1.15%. If a corporation's spread over the interbank rate is 0.50%, the corporation would borrow at  $1.65\% = 1.15\% + 0.50\%$ .

The most important interbank reference rates are calculated daily in London by the British Bankers' Association (BBA) for 10 currencies and 15 maturities ranging from overnight to 1 year. Each currency's interest rate is known as the **London Interbank Offer Rate (LIBOR)** for that currency. The BBA officially defines USD LIBOR as the "trimmed" arithmetic mean of 16 multinational banks' interbank offered rates; that is, only the eight middle rates are used in calculating the mean. These rates are sampled at approximately 11:00 A.M. London time.<sup>1</sup> Other currency LIBORs are calculated using the middle half of the rates quoted from eight, 12, or 16 banks. Borrowing agreements involving corporations and sovereign nations often specify that the interest rate on a loan is a fixed spread over LIBOR. The determination of the spread depends on the possibility that the borrower will default on the loan. We examine these issues in detail in Chapter 14. LIBOR also plays a large role in the swap market, which we discuss in Chapter 21.

## Covered Interest Arbitrage with Transaction Costs (Advanced)

In the presence of transaction costs in the foreign exchange and external currency markets, the absence of profitable covered interest arbitrage opportunities can be characterized by two inequalities. Arbitrage must be impossible either by borrowing the domestic currency and lending the foreign currency or by borrowing the foreign currency and lending the domestic currency. In each case, the transaction foreign exchange risk must be eliminated with the appropriate forward market transaction.

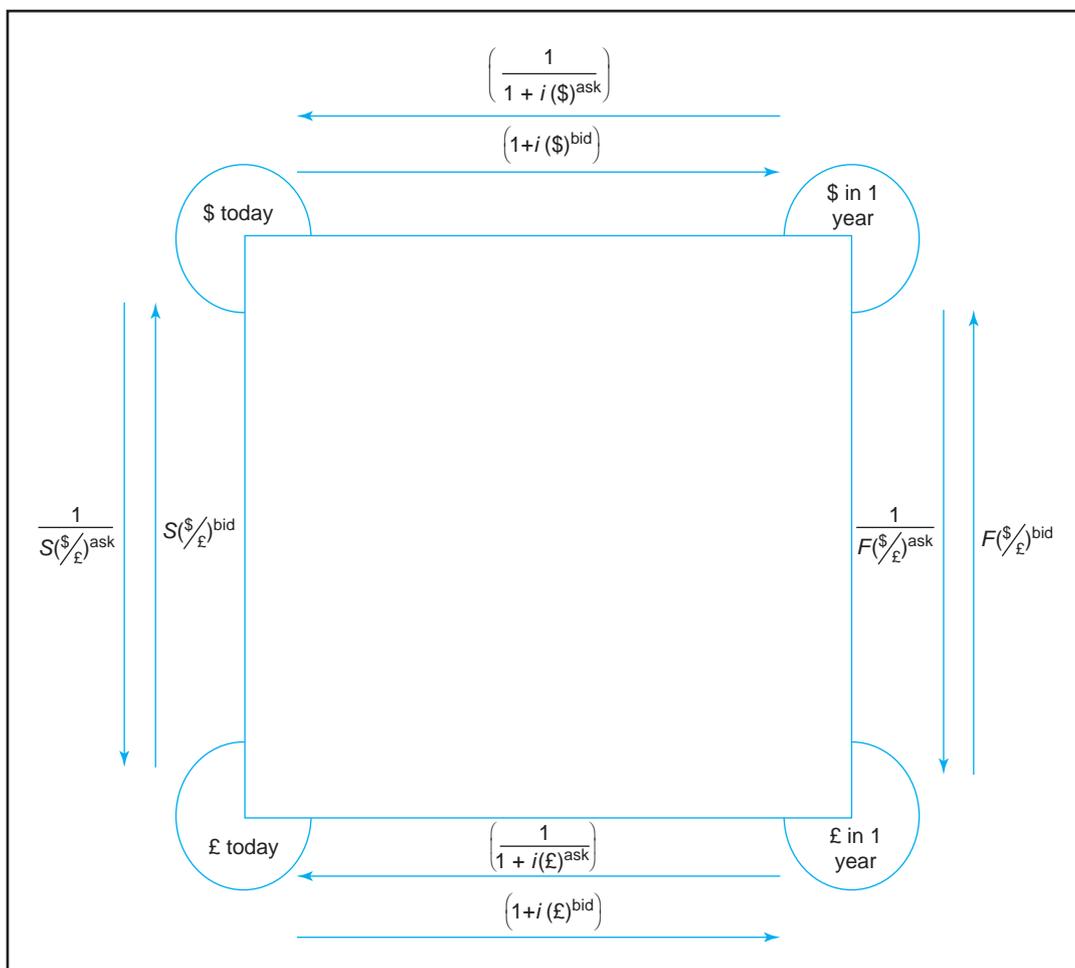
We can express these two inequalities symbolically by defining the dollar bid and ask interest rates,  $i(\$)^{\text{bid}}$  and  $i(\$)^{\text{ask}}$ ; the foreign currency bid and ask interest rates,  $i(\text{FC})^{\text{bid}}$  and  $i(\text{FC})^{\text{ask}}$ ; and the bid and ask spot and forward exchange rates of dollars per foreign currency,  $S^{\text{bid}}$ ,  $S^{\text{ask}}$ ,  $F^{\text{bid}}$ , and  $F^{\text{ask}}$ . The appropriate modifications to the box diagram in Exhibit 6.1, which used the pound as an example, are made in Exhibit 6.3.

Thus, if we go clockwise around the box in Exhibit 6.3, starting at £ in 1 year, we borrow pounds at  $i(\pounds)^{\text{ask}}$ ; we convert from pounds to dollars in the spot market at  $S^{\text{bid}}$ ; we lend the dollars at  $i(\$)^{\text{bid}}$ ; and we sell the dollars forward for pounds at  $F^{\text{ask}}$ . The failure of this attempt to do covered interest arbitrage out of pounds into dollars can be summarized by the fact that the revenue of selling 1 pound in the future is less than 1:

$$\frac{1}{[1 + i(\pounds)^{\text{ask}}]} \times [S^{\text{bid}}] \times [1 + i(\$)^{\text{bid}}] \times \frac{1}{F^{\text{ask}}} < 1 \quad (6.9)$$

<sup>1</sup>For more information on LIBOR, see the BBA Web site at [www.bbalibor.com](http://www.bbalibor.com). Other reference interest rates include EURIBOR (Euro Interbank Offered Rate), CIBOR (Copenhagen), MIBOR (Moscow), and SIBOR (Singapore).

### Exhibit 6.3 Covered Interest Rate Parity with Bid-Ask Rates



Note: The exchange rates and interest rates associated with each arrow indicate the funds obtained in the currency at the arrow's point from selling one unit of the currency at the arrow's tail. For example, at the \$ today node, selling 1 dollar for \$ in 1 year gives  $(1 + i(\$)^{\text{bid}})$  dollars in 1 year.

Alternatively, rearranging the terms in the inequality in Equation (6.9), we see that the pound borrowing cost is greater than the benefit of converting the pounds to dollars, lending the dollars, and selling the dollars forward for pounds:

$$[1 + i(\pounds)^{\text{ask}}] > S^{\text{bid}} \times [1 + i(\$)^{\text{bid}}] \times \frac{1}{F^{\text{ask}}} \quad (6.10)$$

The failure of an attempt to do covered interest arbitrage out of the dollar into the pound is summarized by going counterclockwise around the box in Exhibit 6.3. We start at the future dollar node and find out that the future revenue of selling 1 future dollar is less than 1:

$$\frac{1}{[1 + i(\$)^{\text{ask}}]} \times \frac{1}{S^{\text{ask}}} \times [1 + i(\pounds)^{\text{bid}}] \times F^{\text{bid}} < 1 \quad (6.11)$$

Alternatively, rearranging the terms in the inequality in Equation (6.11), we see that the dollar borrowing cost is greater than the benefit of converting the dollar to pounds, lending the pounds, and selling the pounds forward for dollars:

$$[1 + i(\$)^{\text{ask}}] > [1/S^{\text{ask}}] \times [1 + i(\pounds)^{\text{bid}}] \times F^{\text{bid}} \quad (6.12)$$

### Example 6.4 An Attempt at Arbitrage Using Dollars and Yen

We use the data from Exhibit 6.2 together with the spot and forward exchange rates that also appear in the *Financial Times* to examine how much would have been lost in attempting to arbitrage between, say, the U.S. dollar and the yen at the 1-year maturity. The relevant data are as follows:

	Bid	Ask
Spot exchange rates (¥ per \$):	82.67	82.71
Forward exchange rates (¥ per \$):	82.32	82.37
Dollar interest rates:	0.91	1.11
Yen interest rates:	0.46	0.58

To make the magnitudes interesting, let's first borrow \$10,000,000. If we convert this to yen, we do so at the bank's bid price for dollars:

$$\$10,000,000 \times \text{¥}82.67/\$ = \text{¥}826,700,000$$

This is our yen principal. We can invest this amount for 1 year at 0.46% p.a. Hence, in 1 year, we will have

$$\text{¥}826,700,000 \times 1.0046 = \text{¥}830,502,820$$

To eliminate the exchange risk, we can contract to sell this amount of yen for dollars at the forward rate. Because the bank charges us a high price to buy dollars, we transact at forward ask price of ¥82.37/\$. Hence, selling our yen principal plus interest for dollars yields

$$(\text{¥}830,502,820)/(\text{¥}82.37/\$) = \$10,082,589$$

Thus, if we borrow \$10,000,000 for 1 year at 1.11%, we would owe

$$\$10,000,000 \times 1.0111 = \$10,111,000$$

Notice that if we were to do these transactions, we would lose

$$\$10,111,000 - \$10,082,589 = \$28,411$$

Notice also that the loss is  $0.284\% = 28,411/10,000,000$  of the principal that we borrow.

Given that we lose money by attempting arbitrage by borrowing dollars, you should try to make money by doing a covered interest arbitrage that begins by borrowing yen. You will find that you would also lose money doing that. Hence, no profitable arbitrage exists in these data.

### Does Covered Interest Parity Hold?

Because the settlement procedures in the external currency markets are identical to the settlement procedures in the forward markets, and because transaction costs are small, banks

operating in this market should arbitrage away all deviations from covered interest rate parity. In fact, it is often the case that banks use interest rate parity to quote forward rates in outright forward transactions.

Prior to the financial crisis that began in 2007, documented violations of interest rate parity were exceedingly rare. Because prices move quickly within the day, careful analysis of the issue requires time-stamped data. Akram et al. (2008) assembled such data from Reuters for the pound, euro, and yen, all versus the dollar, for a short period from February 13 to September 30 of 2004. They detected multiple short-lived deviations from covered interest rate parity that provided possible arbitrage profits. Nevertheless, the deviations tended to persist only for a few minutes and represented a tiny fraction of all possible transactions. Hence, unless you are a trader in a bank, it is safe to assume that covered interest rate parity holds, at least in normal times.

The frequency, size, and duration of apparent arbitrage opportunities do increase with market volatility. This became very apparent during the 2007 to 2010 financial crisis, which we discuss in the box titled *Deviations from Interest Rate Parity During the Financial Crisis*.

## 6.3 WHY DEVIATIONS FROM INTEREST RATE PARITY MAY SEEM TO EXIST

If you observe foreign exchange prices and interest rates that appear to provide an arbitrage opportunity, you must make sure the arbitrage opportunity is real before plunging headlong into arbitrage trading. We now examine three reasons apparent arbitrage opportunities might not result in riskless profitable trades: default risk, exchange controls, and political risk.

### Default Risks

In all our derivations so far, we have ignored the possibility that one of the counterparties may fail to honor its contract. When this possibility is reflected in interest rates, we may find an apparent deviation from interest rate parity that does not represent a riskless arbitrage opportunity. Default risk or credit risk is the possibility that a borrower will not repay the lender the entire amount promised in a loan contract. Let's explore the implications of default risk in more detail.

Because there is always some risk that a bank will fail, depositors (lenders) must assess the possibility that they will not be repaid. To make a rational investment, the depositors must determine what possible events in the future could trigger a default, and they must ascertain what probabilities are associated with these events. For example, let  $p$  denote the probability that the borrowing bank will default, so  $(1 - p)$  is the probability that the borrowing bank will not default. Suppose that if the borrowing bank defaults, the depositing bank receives nothing. When the borrowing bank does not default, the depositing bank will receive  $(1 + i)$ , where  $i$  is the promised interest rate on the deposit of one unit of currency. Then the expected return to the depositing bank is

$$[(1 - p) \times (1 + i)] + (p \times 0) = (1 - p) \times (1 + i)$$

If depositors require a particular expected return in order to make a deposit, riskier banks (ones with larger values for  $p$ ) must offer higher deposit rates to increase the expected return on their deposits in order to compete effectively for funds. Therefore, observing different interest rates on bank deposits denominated in the same currency in the interbank market need not be evidence of market inefficiency. If we see a deviation from interest rate parity, we cannot be certain that we are observing a true profit opportunity without knowing more about the particular banks making the quotations.

There may also be some risk of default on the forward contracts (again, because some banks are risky), and this could also lead to deviations from interest rate parity that do not represent arbitrage opportunities. Banks must continually assess the risk of their counterparties, and a bank's risk managers put limits on the amount of trading that can be done with any particular counterparty.<sup>2</sup> Assessing credit risk became of paramount importance during the 2007 to 2010 crisis, as the box discusses in detail.

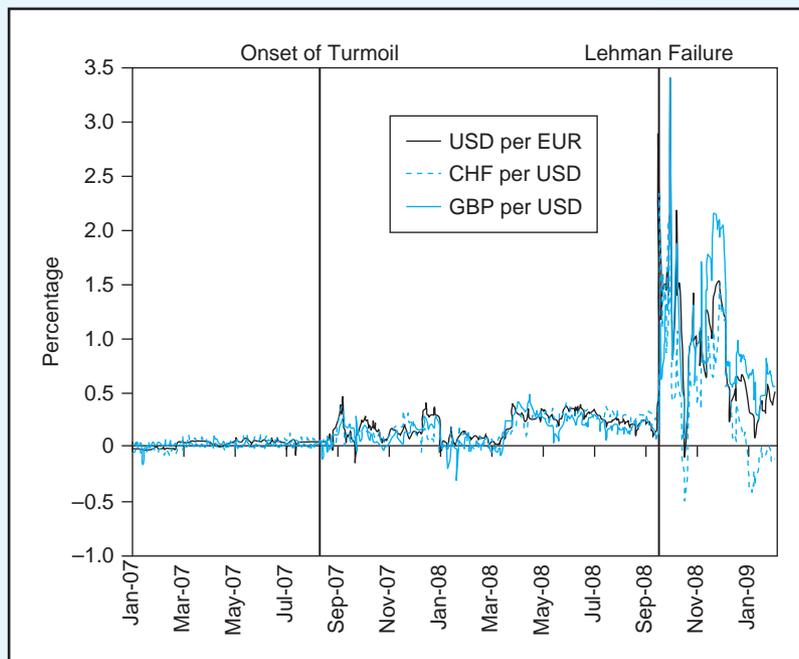
## Deviations from Interest Rate Parity During the Financial Crisis<sup>3</sup>

Exhibit 6.4, adapted from an article by Baba and Packer (2009b), shows deviations from covered interest parity between January 2007 and January 2009. Let's call them DEV; DEV is computed as

$$\text{DEV} = [1 + i(\text{FC})] \frac{F}{S} - [1 + i(\$)].$$

The three currencies considered are the euro, the pound, and the Swiss franc (quotes are in dollars per foreign currency), and the interest rates are 3-month euro-currency rates. Two important dates are indicated, the summer of 2007 when the first signs of trouble appeared (on August 9, 2007, BNP Paribas froze the assets of three of its investment funds, as

**Exhibit 6.4** Covered Interest Parity Deviations During the Financial Crisis



*Notes:* Reprinted from *Journal of Banking and Finance* 33, Naohiko Baba and Frank Packer, "Interpreting Deviations from Covered Interest Parity during the Financial Market Turmoil of 2007–2008," p. 195 (2009b), Copyright 2009 with permission from Elsevier. The covered interest rate parity deviations are defined in the text.

<sup>2</sup>Banks rely on information from firms that rate the creditworthiness of financial institutions and corporations; see Chapter 11 for additional discussion of these issues.

<sup>3</sup>Much has been written about this fascinating episode. We primarily relied on information in Baba and Packer (2009a, 2009b), Griffoli and Ranaldo (2010), and Coffey et al. (2009).

it failed to value the subprime mortgage-backed assets they were holding) and the failure of Lehman Brothers in September 2008. The graph clearly shows that the problems at several financial institutions in the United States, Europe, and elsewhere created apparent arbitrage opportunities in the foreign exchange market, which widened considerably after the Lehman failure. Apparently, borrowing dollars, converting them into any of the three currencies at the spot rate, investing them in those external currency markets, and then selling the known proceeds forward for dollars should have yielded juicy profits during this tumultuous period.

But were there truly arbitrage opportunities here? A first point is that the graph was created using only LIBORs and averages of bid and ask forward and spot rates. However, an arbitrageur would borrow dollars at the ask rate (correctly represented by LIBOR) but would lend at bid rates for the different currencies, not the LIBORs used in the calculations. The exchange rate quotes should also reflect transaction costs. As noted in Chapter 3, the crisis caused forex volatility to increase, which caused an increase in the transaction costs in the spot and especially the forward markets. The spreads between deposit and lending rates likewise increased substantially during the crisis. However, Griffoli and Rinaldo (2010) show that adjusting properly for transaction costs does not make the profit opportunities disappear.

Second, the creditworthiness of many financial institutions worsened as the crisis unfolded and deteriorated dramatically following the Lehman bankruptcy. Because different banks had very different exposures to “toxic” assets, LIBOR showed a lot of dispersion across banks, and many financial institutions had trouble obtaining funds in the money markets. However, the graph uses LIBOR for both the foreign currencies and the dollar. Because the different currency LIBOR bank panels use the same banks (for example, 14 of the 16 LIBOR panel banks in the dollar and euro panels are the same), the banks’ default risks should affect both the euro and the dollar interest rates. Hence, default risk is unlikely to explain the large differences we observe in the graph.

So, what caused the large deviations? The studies reveal that the mispricing came mostly from the forward rate; the forward dollar price of the euro was too high, making  $F$  in the computation of DEV too high. Although there is still debate about the exact reasons, the most plausible mechanism seems to be a combination of credit risk and the desire for dollar liquidity.

Most financial institutions have long-term assets funded by short-term liabilities, which they roll over in typically well-functioning money markets. When the

ramifications of the subprime crisis started to manifest themselves, many financial institutions, initially primarily in Europe, were stuck with long-term assets (mostly linked to American mortgages), which were hard to value and hard to sell. To pay off dollar loans that funded these dollar-denominated assets, the financial institutions needed either to borrow short-term dollars or engage in fire sales of the assets themselves. Because there was much uncertainty about the banks’ credit risk, the money markets started to freeze up, and several banks found it increasingly difficult to obtain dollar funding via the usual channels.

The foreign exchange market provides a potential solution: The bank borrows in another currency, say the euro, but uses the foreign exchange markets to transform the euro proceeds of the loan into the dollars it needs. Of course, it must pay off the euro loan, but it can do so by buying the euros forward with dollars. The cost of the operation is exactly  $[1 + i(\text{€})] \frac{F}{S}$ , the left term in DEV. Now, if everyone is trying to use the forward markets to do this, there may be upward pressure on the forward rate.

This is exactly what happened in the crisis. Many financial institutions were scrambling to find dollar funding. As a safe haven currency, the dollar was appreciating in the spot markets ( $S$  decreased), but the actions of many banks prevented the dollar from appreciating proportionally in the forward market ( $F$  did not decrease as much as it should have). The situation got much worse after Lehman failed. With many more financial institutions in trouble and money market funds that invested in commercial paper issued by Lehman Brothers losing money, the liquidity in the money markets almost completely dried up. A global dollar shortage followed, leading to the substantial interest rate parity deviations shown in Exhibit 6.4 after the Lehman bankruptcy.

What gives much credence to this interpretation of events is how central banks around the world managed to mitigate the crisis. As we discussed in Chapter 5, a central bank should be able to help banks in a liquidity crisis by acting as a lender of last resort. It can do so by lending to its banks, essentially creating money. But in this particular crisis, banks around the world needed dollars, not euros or pounds. This was recognized by the central bankers, and the Federal Reserve essentially provided global dollar liquidity by lending dollars to central banks in Europe, Latin America, and Asia. The study by Baba and Packer (2009b) shows that the Fed’s actions really helped reduce the deviations from covered interest rate parity, at least after the Lehman crisis.

Let's look at Exhibit 6.4 again from the perspective of an arbitrageur. The arbitrage profits from borrowing dollars and investing in these currencies while covering the currency risk would have been between 30 basis points and over 2% at the height of the crisis. Some canny investors may have taken advantage of this, but the fact that the deviations were so persistent shows that arbitrage activity must have been fairly limited. When

there is a global dollar shortage, who can borrow dollars? Moreover, the crisis went hand in hand with a massive flight to safety, with most investors buying safe Treasury bills and bonds. As a result, many investment funds faced redemptions from risk-averse investors and had little speculative capital to deploy. This confirms an important idea in finance: As Shleifer and Vishny (1997) stress, arbitrage has its limits; it requires capital and is often risky.

## Exchange Controls

Another problem with assessing the validity of interest rate parity is caused by **exchange controls**. Governments of countries periodically interfere with the buying and selling of foreign exchange. They may tax, limit, or prohibit the buying of foreign currency by their residents. They may also tax, limit, or prohibit the inflow of foreign investment into their country. Such exchange controls were common in several developed countries (including the United Kingdom, Switzerland, France, and Italy) until the mid-1980s, after which they were gradually abandoned. In more recent times, exchange controls are found in many developing countries. In 2010, a number of emerging economies (including Brazil and Thailand) reimposed controls or made existing controls more severe to stem the inflow of what authorities perceived as hot speculative capital attracted by high interest rates. Whenever you examine historical data on interest rates and exchange rates, you should be aware that not taking into account exchange controls or differential taxes can cause the appearance of a covered interest arbitrage opportunity that really doesn't exist, as the controls prevent an effective arbitrage.

One way to understand the effects of exchange controls and differential taxes on foreign versus domestic investors is to examine internal interest rates within a country versus external interest rates outside of the country. A large differential may not indicate an arbitrage opportunity but binding exchange controls. Suppose the onshore interest rate is higher than its offshore counterpart. This has often been the case for the Chinese renminbi in recent years.<sup>4</sup> An arbitrageur would like to borrow at low offshore renminbi rates and invest at higher onshore renminbi rates, but investment controls prevent such transactions. The onshore-offshore renminbi yield gap averaged more than 250 basis points during 2004 to 2006, but it has since narrowed considerably. It is possible that the narrowing partially reflects exchange controls becoming less effective at preventing capital inflows into China.

Analogously, when the onshore interest rate is lower than the offshore rate, domestic residents have an incentive to invest abroad, but capital controls prevent them from doing so. Of course, the differences between onshore and offshore interest rates may reflect other factors as well. For example, the instruments used to borrow and lend may have differential liquidity, which could lead to differences in interest rates. We already mentioned the possibility of default risk. Offshore interest rates reflect the credit risk of major financial institutions. In the United States, the difference between 3-month LIBOR and the 3-month Treasury bill rate is known as the TED spread. The TED spread is typically positive because it reflects the credit risk of the major banks in the LIBOR panel. It became particularly large in 2007 to 2010, during the subprime mortgage crisis.

<sup>4</sup>See the articles by Cheung and Qian (2010) and Ma and McCauley (2008). Because offshore borrowing and lending in Chinese renminbi is not yet possible, the offshore rate is computed using the offshore non-deliverable (NDF) forward rate, the spot exchange rate (which is controlled by the Chinese government), and dollar LIBOR. We show how to do this in Section 6.4.

When onshore interest rates reflect the default risk of the local government, it is called political risk, to which we turn next. But first, let's reexamine those very high Brazilian interest rates mentioned in the introduction.

### Example 6.5 Investing in Brazil

Consider the following data from January 25, 2011.

USD 3-month LIBOR: 0.37% p.a.

Brazilian 3-month Treasury bill rate: 11.92% p.a.

Spot exchange rate: BRL1.67/USD

3-month forward rate: BRL1.7042/USD

If covered interest rate parity holds, the 11.92% BRL rate should turn into a measly 0.37% USD return after covering the currency risk of investing in the Brazilian real. To find this “covered yield,” we convert dollars into reais at the spot rate of BRL1.67/USD, invest in the Brazilian Treasury bill, and sell the reais at the forward rate (BRL1.7042/USD). Doing so, gives

$$\text{BRL1.67} (1 + 0.1190/4) (1/\text{BRL1.7042/USD}) - 1 = 0.91\%$$

In annualized terms, this yields 3.65%, much higher than the USD LIBOR. Clearly, covered interest rate parity does not hold.

Nevertheless, the high Brazilian Treasury bill rates will not attract many foreign investors because the Brazilian government taxes fixed-income investors. It initialized a flat tax on foreigners investing in the Brazilian fixed-income market at the end of 2008, and it has raised the tax rate in several installments to 6%! A foreign investor must give up 6 cents of every investment dollar to the Brazilian government. Obviously, the 0.91% return earned over 3 months does not overcome such a steep tax. The longer the investor's horizon, the less impact the tax has on returns. Therefore, the tax mostly affects short-term fixed-income flows, which is exactly the government's intent. During 2009 and 2010, the Brazilian real appreciated by more than 30%, hurting Brazilian exporters. The government felt that this appreciation was primarily driven by speculative capital flows, attracted by the high Brazilian interest rates.

In fact, covered interest rate parity is alive and well for the Brazilian real. International banks do borrow and lend in reais. It turns out that the offshore BRL LIBOR is 8.62%. You should verify that, at this rate, the annualized covered yield on a 3-month Brazilian investment is reduced to 52 basis points, very close to the USD interest rate.

### Political Risk

Even if no exchange controls are currently present, foreign investors may rationally believe that a government will impose some form of exchange controls or taxes on foreign investments in the future. Or, perhaps the government will declare a “bank holiday,” closing the nation's banks for a period of time.<sup>5</sup> All such events would affect an investor's return. The possibility of any of these events occurring is called **political risk**. Recent history is riddled with examples of political risk causing onshore interest rates to be larger than offshore interest rates. Chapter 14 examines political risk in detail. Next, Ante and Freedy discuss a famous historical case involving investing in Mexico.

<sup>5</sup>*Bank holidays* are situations in which governments close banks for periods of time to allow information to be obtained about the solvency of various banks—that is, whether the value of their assets exceeds the value of their liabilities.

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## POINT-COUNTERPOINT

### Mexican Cetes or U.S. Treasury Bills?

Ante and Freedy are working on a case for their international finance class. Their professor has asked them to examine some data from June 20, 1995, to look for arbitrage opportunities between Mexico and the United States. Ante storms into Freedy's room with *Wall Street Journal* quotes in his hand and shouts, "Here is the definite proof. Markets are totally inefficient. Look at these prices. People must have made a killing investing in Cetes. These Mexican treasury bills were offering 44.85% p.a. on a 3-month deposit. And look, the Mexican peso–U.S. dollar forward rate was really attractive, so they could have covered the currency risk cheaply and locked in immediate profits of 1.19% per dollar invested." Freedy peruses the data and urges Ante to stay calm so he can explain why this apparent arbitrage opportunity was illusory.

Ante says, "Look, the USD Treasury bill rate was 5.60% p.a., so you could borrow a dollar at 1.40% for 3 months. Because the spot rate was MXN6.25/USD, each dollar borrowed yielded 6.25 pesos. By investing these pesos at the Cetes rate of 44.85%, they would have grown to

$$\text{MXN}6.25 \times (1 + 44.85/400) = \text{MXN}6.95078$$

With the forward at a rate of MXN6.775/USD, one could sell them for dollars to lock in the profit.<sup>6</sup> In other words, for each dollar that someone borrowed, they got

$$\text{MXN}6.95078 / (\text{MXN}6.775/\text{USD}) = \text{USD}1.0259$$

back, and they only need \$1.014 to pay back the 1-dollar loan. So their profit was a whopping  $\$1.0259 - \$1.0140 = \$0.0119$  per dollar invested. Now that was a money machine, buddy!"

Freedy is totally puzzled. "But that is impossible. Financial markets would not tolerate a money machine. Traders would quickly take advantage of the situation and, via arbitrage, eliminate any opportunity for profit. Maybe these Mexican peso investments were much less liquid than other contracts, or maybe these are just typos in the newspaper. I bet you this opportunity was gone the next day."

At this point, Suttle leisurely walks in, sighing, "Are you guys at it again? What are you fighting about now?" After hearing both Ante's and Freedy's accounts of the great Mexican investment opportunity, Suttle smiles and says there is nothing mysterious about those rates. "It was not a money machine, and it wasn't explained by transaction costs. The higher Cetes rates simply reflected country risk or default risk on the part of the Mexican government. The U.S. government may be expected to always repay its dollar debts, but this is not necessarily true for the governments of developing countries," he says. "As you may remember, Mexico had come close to totally running out of official international reserves at the end of 1994, and it was building up its international reserves during 1995, after having been bailed out by an international aid package early in 1995. In this context, the interest rate differential can be split up into two parts. One part is the Mexican interest rate that would result if the Mexican government had the same credit risk as the U.S. government. This rate can be inferred from spot and forward exchange rates (if conducted with creditworthy counterparties) and the U.S. Treasury bill rate. The remainder is an additional return offered by the Mexican government to compensate for the political risk that investors perceive to be present," he continues.

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<sup>6</sup>The forward exchange rate used here is actually calculated from the price of the peso futures contract trading on the Chicago Mercantile Exchange. (See Chapter 20 for a full account of futures contracts and exchanges.) For our purposes, it is important to realize that the forward rate and the futures rate are virtually identical for identical maturities and that the counterparty in the futures contract (the Chicago Mercantile Exchange) is very likely to honor its contract with you.

Seeing Ante's and Freedy's puzzled faces, Suttle decides to use the actual numbers. "So, if we look at the numbers, the Cetes investment, hedged for foreign currency risk, represents a 10.37% annualized return (2.5945% times 4), which is 4.77% higher than the U.S. Treasury bill rate of return. Because the investment is totally hedged against foreign currency risk, this extra reward must be due to default risk, and it is typically called the **country risk premium**. I remember that for 1993 and 1994, country risk premiums on 3-month Mexican Cetes averaged 2.25%," he finally offers (see Domowitz et al., 1998). Ante and Freedy know that Suttle has taught them a very valuable lesson!

## Epilogue

The Mexican government did not default on the Cetes investments discussed here. Consequently, Ante was right, *ex post*, that investors would have found them to be a good investment relative to USD Treasury bills. Nevertheless, government defaults do happen. For example, both Russia and Ecuador defaulted in the late 1990s on obligations to foreign investors that had similar risk characteristics to Mexican Cetes investments in 1995, Argentina also defaulted on its international debt in 2002, and Ecuador defaulted again in 2008. Therefore, it is difficult to know exactly whether Ante or Freedy is right in an *ex ante* sense.

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## 6.4 HEDGING TRANSACTION RISK IN THE MONEY MARKET

If you have an open position (either an account receivable or an account payable) denominated in foreign currency, you are exposed to transaction foreign exchange risk. When interest rate parity holds, there are two equivalent ways to hedge your transaction exchange risk:

1. Having an appropriate forward contract to buy or sell the foreign currency
2. Borrowing or lending the foreign currency coupled with making a transaction in the spot market

We examined the first technique in Chapter 3. Now let's look at the second, which is also known as a **synthetic forward**. There are several reasons for using such hedges. First, in some currency markets (for instance, those in certain developing countries), forward contracts may not be available. Nevertheless, a forward contract can be manufactured using a **money market hedge**. Second, individual companies are not able to borrow and lend at the interest rates available in the interbank market, which means the two strategies may not be equivalent, depending on the forward quote that the company receives. Third, when time horizons are long, forward contracts can be expensive as the bid-ask spread widens substantially. Therefore, it may be advantageous to consider borrowing and lending to hedge one's currency risk. We discuss this long-term issue explicitly in Section 6.5. For now, we focus on short-term money market hedges to get the logic correct.

The general principal is that if the underlying transaction gives you a liability (an account payable) denominated in foreign currency, you need an equivalent asset in the money market to provide a hedge. If, on the other hand, the underlying transaction gives you an asset (an account receivable) denominated in foreign currency, you need an equivalent liability in the money market to provide a hedge.

## Hedging a Foreign Currency Liability

### Example 6.6 Zachy's Money Market Hedge

Assume, as in Chapter 3, that you are managing Zachy's Wine and Spirits, and you have just contracted to import some Chateau Margaux wine from France. As before, the wine is valued at €4 million, and you have agreed to pay this amount when you have received the wine and determined that it is in good condition. Payment of the money and delivery of the wine are scheduled for 90 days in the future. The spot exchange rate is \$1.10/€; the 90-day forward exchange rate is \$1.08/€; the 90-day dollar interest rate is 6.00% p.a.; and the 90-day euro interest rate is 13.519% p.a.

Remember that because the underlying transaction gives you a euro-denominated account payable, you are exposed to losses if you do not hedge and the euro appreciates relative to the dollar. In this case, the dollar cost of the euros would be higher in the future, which would increase the cost of your wine. In Chapter 3, we eliminated this risk by buying euros forward. Numerically, the dollar cost, which is paid in 90 days, is  $€4,000,000 \times (\$1.08/€) = \$4,320,000$ .

Let's look at the alternative money market hedging strategy. Because you have a euro liability, you must acquire an equivalent euro asset. You can do this by buying the present value of your euro liability at the spot exchange rate and investing these euros in a money market asset. You then use the principal plus interest on this euro asset to offset your underlying euro liability at maturity. The present value of €4,000,000 at 13.519% p.a. is

$$€4,000,000 / [1 + (13.519/100)(90/360)] = €3,869,229.71$$

This amount of euros must be purchased in the spot foreign exchange market:

$$€3,869,229.71 \times (\$1.10/€) = \$4,256,152.68$$

Notice that with the money market hedge, the payment is made today unless you borrow dollars. To compare the money market hedge to the forward market hedge, we must take the present value of the \$4,320,000 at 6% p.a.:

$$\$4,320,000 / [1 + (6/100)(90/360)] = \$4,256,157.64$$

At these interest rates and exchange rates, the two strategies are basically equivalent. The dollar present value of the forward contract is only \$4.96 more expensive.

## Hedging a Foreign Currency Receivable

### Example 6.7 A Shetland Sweater Exporter's Money Market Hedge

Now, consider the example in Chapter 3 of the British manufacturer Shetland Sweaters. As in that example, you have agreed to ship sweaters to Japan, and you will receive ¥500,000,000 in payment. Shipment of the goods and receipt of the yen are scheduled for 30 days from now, and the following data are available:

Spot exchange rate:	¥179.5/£
30-day forward exchange rate:	¥180/£

30-day pound interest rate: 2.70% p.a.

30-day yen interest rate: 6.01% p.a.

As a British exporter, you have a yen-denominated account receivable, which is your yen asset. If you do nothing to hedge the transaction foreign exchange risk, you are exposed to losses if the yen depreciates relative to the pound. In this case, the yen receivable will purchase fewer pounds when you receive the yen payment. In Chapter 3, we eliminated the transaction foreign exchange risk by selling the yen forward for pounds. The amount of pounds that will be received in 30 days from the forward contract is  $(¥500,000,000)/(¥180/£) = £2,777,778$ .

Now, consider the alternative money market hedge. You must acquire a yen liability that is equivalent in value to your yen asset. You borrow the present value of your yen asset and use the yen that you receive from selling your sweaters to pay off the principal and interest on your yen loan. To be hedged, you must convert the yen principal that is borrowed into pounds at the spot exchange rate. The present value of ¥500,000,000 at 6.01% p.a. is

$$¥500,000,000 / (1 + (6.01/100)(30/360)) = ¥497,508,313$$

By borrowing ¥497,508,313 for 1 month at 6.01% p.a., you owe ¥500,000,000 in 30 days, which is the amount you receive for selling your sweaters. Your pound revenue is found by selling the ¥497,508,313 for pounds in the spot market at ¥179.5/£, which is

$$¥497,508,313 / (¥179.5/£) = £2,771,634$$

We can compare this revenue to the revenue available from the forward hedge in 30 days by taking the future value of the £2,771,634. We can invest pounds at 2.70% p.a. Hence, the future value of the pounds received today is

$$£2,771,634 \times (1 + (2.7/100)(30/365)) = £2,777,785$$

Hence, at these interest rates and exchange rates, the money market hedging strategy is basically equivalent to the forward hedging strategy.

## 6.5 THE TERM STRUCTURE OF FORWARD PREMIUMS AND DISCOUNTS

Does interest rate parity hold at long horizons? This is an important question because many international investment projects involve currency exposures that extend over many years. If an exposure is longer term, the short-term money market contracts we discussed earlier might be inadequate. However, before we investigate interest rate parity over longer time frames, we need to explain the term structure of interest rates. Whereas the interest rates for short-term maturities are readily available in the marketplace, interest rates for longer maturities must be derived from the prices of coupon bonds. Long-term interest rates are useful in computing the present value of cash flows of long-term projects.

After we look at the term structures of interest rates for two currencies, we can combine them with interest rate parity to examine the term structure of the forward premiums or discounts between two currencies. That is, we investigate how international interest rate differentials change with different maturities. These computations can be useful for multinational corporations (MNCs) seeking financing in international bond markets. Recent empirical evidence suggests that covered interest rate parity does not hold perfectly at longer horizons. In Chapter 11, we discuss how MNCs can exploit these deviations from parity to lower their financing costs.

## The Term Structure of Interest Rates

### Spot Interest Rates

It is generally true that the time values of different monies for a particular maturity are not equal. The 1-year USD interest rate might be 5%, whereas the 1-year JPY interest rate might be 1.5%. Similarly, the time value of one currency, say the USD, at one maturity is usually not equal to the time value of the USD at a different maturity. The 1-year USD interest rate might be 5%, whereas the 30-year USD interest rate might be 7.5%.

When there are no intervening cash flows between the time a deposit is made and the maturity of the deposit, the interest rates are said to be **spot interest rates**. Interest rate parity only applies to spot interest rates. The **term structure of interest rates** for a particular currency is a description of the different spot interest rates for various maturities into the future. For shorter maturities, these spot interest rates are directly observable because they are widely quoted by banks. However, for longer maturities, we usually have to derive the spot interest rates from the market prices of coupon-paying bonds. Typically, the interest rates are quoted on an annual basis—that is, they reflect the return earned per year. To understand how to determine spot interest rates from bond prices, let's review some additional terminology associated with bond pricing.

### A Review of Bond Pricing

Bonds are financial contracts that obligate the bond issuer to pay the bondholder a sequence of fixed contractual payments until the maturity of the bond. These payments represent the return of principal and interest on the principal. Most bonds with maturities of longer than 1 year have coupon payments that provide the bondholder with intervening interest payments between the purchase of the bond and the maturity date. For example, the coupon payments on U.S. government bonds and American corporate bonds are made every 6 months. A 7% bond with a final payment of \$1,000 would pay \$35 of coupon interest every 6 months because

$$(0.07/2) \times \$1,000 = \$35$$

The simplest bonds, though, are **pure discount bonds**. Such bonds promise a single payment of, say, \$1,000 or €1,000 at the maturity of the bond. The terminal payment is called the *face value* of the bond. The bonds are sold at a discount on the face value such that the difference between the face value of the bond and the market price of the bond when it is purchased provides an interest return to the buyer. Long-maturity pure discount bonds are often called *deep-discount bonds*, *zero-coupon bonds*, or simply *zeros* to emphasize that the only cash flow to the bondholder is the final face value on the bond. Consequently, we can now define the spot interest rate as the market interest rate that equates the price of a pure discount bond to the present value of the face value of the bond.

### Example 6.8 Pure Discount Bonds and Spot Interest Rates

Suppose the market price of a 10-year pure discount bond with a face value of \$1,000 is \$463.19. What is the spot interest rate for the 10-year maturity expressed in percentage per annum?

We want to find the spot interest rate, say  $i(10)$ , such that when \$463.19 is invested today, it can grow at the compound rate of  $i(10)$  to be equal to \$1,000 after 10 years:

$$\$463.19[1 + i(10)]^{10} = \$1,000$$

The solution is

$$i(10) = (\$1,000/\$463.19)^{1/10} - 1 = 0.08$$

The spot interest rate for the 10-year maturity is 8% p.a., and at this rate, the future value of \$463.19 in 10 years is \$1,000, and the present value of \$1,000 to be received 10 years from now is \$463.19 today.

We can put the finding from Example 6.8 in more general terms. Let  $B(n)$  equal the current market price of a pure discount bond with  $n$  periods to maturity, and let  $M$  be the face value of the bond paid at maturity. Let the spot interest rate today for maturity  $n$  be  $i(n)$ . Then, the market price of the bond is the present discounted value of the face value of the bond at the given spot interest rate:

$$B(n) = \frac{M}{[1 + i(n)]^n}$$

The interest rate  $i(n)$  is called a *discount rate*. Mostly, the face values and the prices of bonds are available as information in the market. Then, we can calculate the spot interest rate by solving the following equation for  $i(n)$ :

$$[1 + i(n)]^n = \frac{M}{B(n)}$$

To solve this equation, we must raise each side to the  $1/n$  power and then subtract 1 from both sides:

$$i(n) = \left[ \frac{M}{B(n)} \right]^{1/n} - 1$$

### Yields to Maturity

Let  $B(n, C)$  denote the current market price of an  $n$ -period bond with a face value of  $M$  and a periodic coupon payment of  $C$ . The **yield to maturity** on this bond, denoted  $y(n)$ , is the single discount rate or interest rate that equates the present value of the  $n$  coupon payments plus the final principal payment to the current market price:

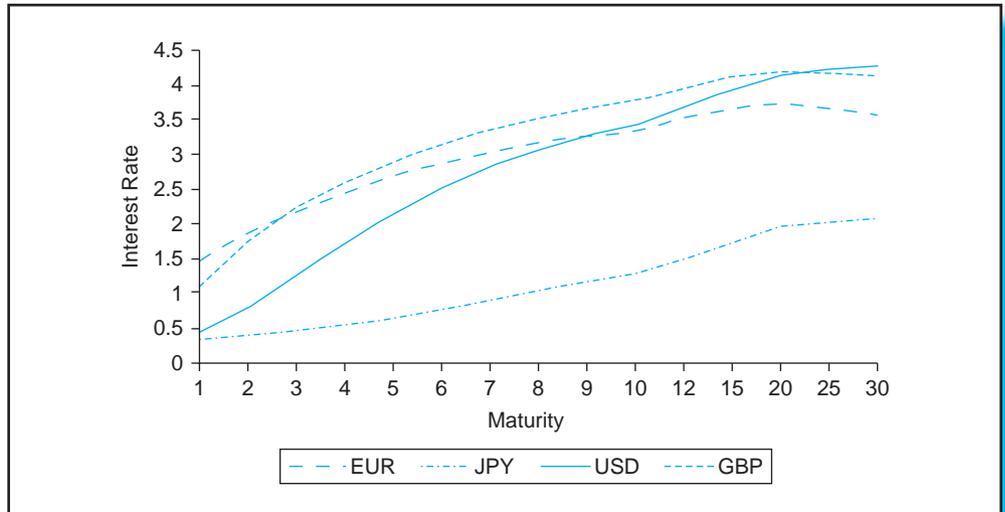
$$B(n, C) = \frac{C}{[1 + y(n)]} + \frac{C}{[1 + y(n)]^2} + \dots + \frac{C}{[1 + y(n)]^n} + \frac{M}{[1 + y(n)]^n} \quad (6.13)$$

Notice that the discount rate is the same for each of the coupons and the final principal, but 1 plus the discount rate is raised to various powers to reflect the number of periods the coupon payments are away from today.

Yields to maturity are straightforward to calculate for a variety of maturities, and market participants often discuss the **yield curve**. Just as the term structure of interest rates refers to the relationship between maturity and spot interest rates for different maturities, the yield curve is the relationship between maturity and the yields on bonds of those maturities. When the yield curve slopes upward, the term structure of interest rates slopes upward as well.

Exhibit 6.5 presents yield curves for the U.S. dollar (USD), the euro (EUR), the British pound (GBP), and the Japanese yen (JPY) that prevailed on January 18, 2011. Note that the yen interest rates are the lowest at all maturities, and the interest rates for the yen's shorter maturities are

### Exhibit 6.5 Yield Curves for Four Currencies



*Notes:* The yield curve data are taken from swap rates (see Chapter 21) for different currencies reported in the *Financial Times* for January 18, 2011. These rates are comparable to yields to maturity for domestic bonds. On the vertical axis, the yields are expressed in annualized terms. The horizontal axis displays the maturity expressed in years.

lower than the interest rates for longer maturities. Consequently, we say that the yield curve for the yen is rising, or upward sloping. Note that the yield curves for all other currencies are also upward sloping, which is what is typically observed.

### Deriving Long-Term Spot Interest Rates

For pure discount bonds, the yield to maturity is the spot interest rate for that maturity because there are no cash flows between now and the maturity date. When there are intervening coupon payments and the spot interest rates for different maturities are not all equal, there must be a difference between the yield to maturity on the bond and the spot interest rate for the maturity of the bond.

### Example 6.9 Spot Interest Rates Versus Yields to Maturity

Consider a 2-year bond with face value equal to \$1,000, an annual coupon of \$60, and a market price of \$980. Suppose the 1-year spot interest rate,  $i(1)$ , is 5.5%. We use this to take the present value of the first coupon payment. Then, the 2-year spot interest rate,  $i(2)$ , is found by solving

$$\$980 = \frac{\$60}{1.055} + \frac{\$1,060}{1 + i(2)^2}$$

and the answer is  $i(2) = 7.1574\%$ .

The yield to maturity is a complicated average of the spot interest rates for the various maturities of the coupon payments and the final repayment of principal. It would be the discount rate  $y(2)$  that solves<sup>7</sup>

$$\$980 = \frac{\$60}{[1 + y(2)]} + \frac{\$1,060}{[1 + y(2)]^2}$$

The value of  $y(2)$  is 7.11%, which is intermediate between the two spot rates but much closer to  $i(2)$  because most of the cash flows of the bond occur in the second year.

The solution procedure applied here indicates that spot interest rates are the appropriate discount rates for the cash flows that take place at a particular maturity. The logic of this conclusion is clearer if you think of a long-term bond with coupon payments and a final principal payment as the sum of several pure discount bonds. Consider each maturity at which a cash flow occurs to be a separate bond. The value of each pure discount bond is found by taking the present value of the single payment with the appropriate spot interest rate for that maturity. The market value of the bond is then the sum of the present values of the different promised payments.

Generally, let  $i(j)$  denote the current spot interest rate for maturity  $j$  periods into the future. Consider the present value  $PV$  of a sequence of known cash flows, denoted  $C(j)$ , for values of  $j$  between 1 and  $n$  periods into the future. By discounting each cash flow with its appropriate pure discount rate, we find the current present value as

$$PV = \frac{C(1)}{[1 + i(1)]} + \frac{C(2)}{[1 + i(2)]^2} + \dots + \frac{C(n)}{[1 + i(n)]^n}$$

Because calculating present values in different currencies is a fundamental part of international finance, understanding the different term structures of spot interest rates for different currencies is quite important.

## Long-Term Forward Rates and Premiums

Let's develop the relationship between long-term forward exchange rates and spot exchange rates with an example. Let  $i(2, ¥)$  and  $i(2, \$)$  denote the spot interest rates today for Japanese yen and U.S. dollar investments, respectively, with 2-year maturities. Let  $S$  be the spot exchange rate of yen per dollar today, and let  $F(2)$  denote the outright forward rate today for delivery in 2 years. If there are no opportunities for arbitrage, the outright forward rate of yen per dollar for the 2-year maturity must be

$$F(2) = S \times \frac{[1 + i(2, ¥)]^2}{[1 + i(2, \$)]^2} \tag{6.14}$$

To see why this must be true, consider that a Japanese investor must be indifferent between investing in yen for 2 years and getting  $[1 + i(2, ¥)]^2$  for each yen or converting the yen into dollars and getting  $1/S$  dollars for each yen, investing these dollars for 2 years to have  $(1/S)[1 + i(2, \$)]^2$  dollars after 2 years, and contracting to sell these dollars forward at  $F(2)$  to get a yen return of  $F(2)(1/S)[1 + i(2, \$)]^2$ . Equating these returns and solving for  $F(2)$  gives Equation (6.14). Example 6.10 is a numeric example that illustrates these issues.

<sup>7</sup>In this simple example, we can analytically solve for  $y(2)$ , but when there are many periods involved, the yield to maturity must typically be found with computational numeric methods. One easy way is with Microsoft Excel. The yield to maturity is the internal rate of return (IRR) on the negative cash flow incurred when the bond is purchased followed by the positive cash flows from holding the bond to maturity.

### Example 6.10 The 2-Year Forward Rate

Let the spot exchange rate be ¥110/\$, and let the spot interest rates for the 2-year maturity be  $i(2, \$) = 5\%$  p.a. and  $i(2, ¥) = 4\%$  p.a. Suppose you invest ¥10,000,000 in a 2-year yen pure discount bond. At the end of 2 years, your investment will grow to

$$¥10,000,000 \times (1.04)^2 = ¥10,816,000$$

At the current spot exchange rate, the dollar cost of ¥10,000,000 is

$$¥10,000,000 / (¥110/\$) = \$90,909.09$$

If you invest \$90,909.09 in a 2-year dollar pure discount bond, at the end of 2 years, you will have

$$\$90,909.09 \times (1.05)^2 = \$100,227.27$$

This analysis indicates that you can either invest \$90,909.09 today to buy ¥10,000,000 and invest it for 2 years to have ¥10,816,000, or you can invest the \$90,909.09 in the dollar bond for 2 years to get \$100,227.27. You would be indifferent between the two investments if the forward sale of ¥10,816,000 for dollars provides you with the same dollar return as investing directly in dollars. That is, if the forward rate satisfies

$$¥10,816,000 / F(2) = \$100,227.27$$

Solving this equation for the forward rate gives

$$F(2) = ¥10,816,000 / \$100,227.27 = ¥107.9147/\$$$

or, rounding to the nearest one-hundredth of a yen,  $F(2) = ¥107.91/\$$ . If the forward exchange rate quoted today for transactions in 2 years is greater than ¥107.91/\$, a dollar investor would receive more dollars by investing in the dollar bond than by investing in the yen bond. Investors of yen would also receive more yen by investing in the dollar bond than by investing in the yen bond. They would, of course, have to sell the dollars forward for yen. This is the same type of arbitrage argument that was used earlier when short-term interest rate parity was developed. Analogously, if the forward exchange rate quoted today for transactions in 2 years is less than ¥107.91/\$, a dollar investor would receive more dollars by investing in the yen bond and contracting to sell yen forward for dollars than by investing directly in the dollar bond. Investors of yen would also receive more yen by investing in the yen bond than by investing in the dollar bond and contracting to sell dollars forward.

What would happen if the forward rate did not satisfy Equation (6.14), implying that there was a difference in returns available in the market? For example, suppose that the dollar and yen interest rates and the spot and forward exchange rates favored investing in the dollar bond over the yen bond. Investors would move funds out of Japanese yen bonds and into U.S. dollar bonds. If investors sold yen bonds, the prices of the yen bonds would fall, and their yields would rise. As money flowed out of Japan to invest in dollar bonds, the dollar would strengthen relative to the yen, causing the spot exchange rate of yen per dollar to rise. As additional dollars flowed into the dollar bond market, the prices of dollar bonds would rise, causing their yields to fall. Finally, the forward rate of yen per dollar would fall as investors sold dollars forward to acquire yen in the future. All four effects make investing in the yen asset more attractive and investing in the dollar asset relatively less attractive.

Notice that we have demonstrated how long-term investment considerations would move the outright forward exchange rate quoted today for delivery  $n$  periods from now to be equal to the spot rate today adjusted for the relative returns on pure discount bonds between now and  $n$  periods from now in the two currencies (in yen per dollar):

$$F(n) = S \times \frac{[1 + i(n, \text{¥})]^n}{[1 + i(n, \$)]^n}$$

Theoretically, this is the way that long-term forward contracts should be priced.

Of course, throughout this discussion, we have ignored bid–ask spreads on the transactions in the bond market as investors buy and sell bonds and on the transactions in the spot and forward foreign exchange markets. These transaction costs become larger as the maturities lengthen. They are also the source of the development of currency swaps, which are discussed in Chapter 21.

## 6.6 SUMMARY

This chapter investigates the relationship between nominal interest rates for two currencies and the corresponding spot and forward exchange rates. When the money markets are free from arbitrage, this relationship between these four variables is called *interest rate parity*. The main points in the chapter are the following:

1. The nominal interest rate is the time value of money. The future value ( $FV$ ) of an amount of money is obtained by multiplying by 1 plus the interest rate:  $[FV = \text{cash flow} \times (1 + i)]$ . The present value ( $PV$ ) today of an amount of money in the future is obtained by dividing by 1 plus the interest rate:  $PV = \frac{\text{Future cash flow}}{1 + i}$ .
2. Covered interest arbitrage is done in four steps: borrowing one currency, converting to a second currency, investing in the second currency, and selling the interest plus principal on the second currency in the forward market for the first currency.
3. When domestic and foreign interest rates and spot and forward exchange rates are in equilibrium such that no covered interest arbitrage is possible, the interest rates and exchange rates are said to satisfy interest rate parity.
4. With exchange rates expressed directly as domestic currency per unit of foreign currency, interest rate parity is satisfied when the forward premium or discount on the foreign currency equals the interest differential between the domestic and foreign interest rates divided by 1 plus the foreign interest rate.
5. The external currency market is an interbank market for deposits and loans that are denominated in currencies that are not the currency of the country in which the bank is operating.
6. Bid–ask spreads in the external currency market (with the bank bidding for deposits and offering an interest rate on loans) are quite small in normal periods.
7. In the presence of transaction costs, interest rate parity is characterized by two inequalities, indicating that covered interest arbitrage leads to losses in both directions. That is, neither lending nor borrowing in a particular currency at the start of the attempted arbitrage leads to profits.
8. The empirical evidence indicates that interest rate parity holds during tranquil periods and for short maturities. During turbulent periods, persistent apparent arbitrage opportunities may arise, as was evident during the 2007 to 2010 crisis.
9. These profit opportunities may merely reflect the differential credit risks of the institutions quoting prices in the market. Credit risk or default risk is the chance that a counterparty will default on its side of a commitment.
10. Exchange controls involve taxes a government imposes on foreign investments, or regulatory restrictions on the use of foreign exchange. Political risk arises when investors rationally believe a government may impose some form of exchange controls or taxes during the life of the investment or even seize the assets of investors. Both exchange controls and political risk can lead to perceived interest rate parity violations that cannot actually be exploited.
11. Transaction exchange risk can be hedged with money market hedges. A money market hedge establishes a

- foreign currency–denominated asset or liability that offsets the underlying transaction exposure. If interest rate parity is satisfied, a money market hedge is identical to a forward market hedge.
12. The only cash flow to the bondholder of a pure discount bond is the final face value of the bond. Spot interest rates are the discount rates that equate the prices of pure discount bonds to the present values of the face values of the bonds. Spot interest rates are the appropriate discount rates for cash flows with no uncertainty that take place at a particular maturity.
  13. The term structure of interest rates for a particular currency represents the different spot interest rates for various future maturities.
  14. A bond's yield to maturity is the single common discount rate that equates the present value of the sequence of all coupon payments and principal payments to the current price of the bond.
  15. Using the spot exchange rate and the domestic and foreign spot interest rates for a particular maturity, we can derive the forward rate for that maturity.

## QUESTIONS

1. Explain the concepts of present value and future value.
2. If the dollar interest rate is positive, explain why the value of \$1,000,000 received every year for 10 years is not \$10,000,000 today.
3. Describe how you would calculate a 5-year forward exchange rate of yen per dollar if you knew the current spot exchange rate and the prices of 5-year pure discount bonds denominated in yen and dollars. Explain why this has to be the market price.
4. If interest rate parity is satisfied, there are no opportunities for covered interest arbitrage. What does this imply about the relationship between spot and forward exchange rates when the foreign currency money market investment offers a higher return than the domestic money market investment?
5. It is often said that interest rate parity is satisfied when the differential between the interest rates denominated in two currencies equals the forward premium or discount between the two currencies. Explain why this is an imprecise statement when the interest rates are not continuously compounded.
6. What do economists mean by the external currency market?
7. What determines the bid–ask spread in the external currency market? Why is it usually so small?
8. Explain why the absence of covered interest arbitrage possibilities can be characterized by two inequalities in the presence of bid–ask spreads in the foreign exchange and external currency markets.
9. Describe the sequence of transactions required to do a covered interest arbitrage out of Japanese yen and into U.S. dollars.
10. Suppose you saw a set of quoted prices from a U.S. bank and a French bank such that you could borrow dollars, sell the dollars in the spot foreign exchange market for euros, deposit the euros for 90 days, and make a forward contract to sell euros for dollars and make a guaranteed profit. Would this be an arbitrage opportunity? Why or why not?
11. The interest rates on U.S. dollar–denominated bank accounts in Mexican banks are often higher than the interest rates on bank accounts in the United States. Can you explain this phenomenon?
12. What is a money market hedge? How is it constructed?
13. Suppose you are the French representative of a company selling soap in Canada. Describe your foreign exchange risk and how you might hedge it with a money market hedge.
14. What is a pure discount bond?
15. What is the term structure of interest rates? How are spot interest rates determined from coupon bond prices?
16. How does a coupon bond's yield to maturity differ from the spot interest rate that applies to cash flows occurring at the maturity of the bond? When are the two the same?

## PROBLEMS

1. In the entry forms for its contests, Publisher's Clearing House states, "You may have already won \$10,000,000." If the Prize Patrol visits your house to inform you that you have won, it offers you \$333,333.33 each and every year for 30 years. If the interest rate is 8% p.a., what is the actual present value of the \$10,000,000 prize?
2. Suppose the 5-year interest rate on a dollar-denominated pure discount bond is 4.5% p.a. and the interest rate on a similar pure discount euro-denominated

- bond is 7.5% p.a. If the current spot rate is \$1.08/€, what forward exchange rate prevents covered interest arbitrage?
3. Carla Heinz is a portfolio manager for Deutsche Bank. She is considering two alternative investments of EUR10,000,000: 180-day euro deposits or 180-day Swiss franc (CHF) deposits. She has decided not to bear transaction foreign exchange risk. Suppose she has the following data: 180-day CHF interest rate of 8% p.a.; 180-day EUR interest rate of 10% p.a.; spot rate of EUR1.1960/CHF; and 180-day forward rate of EUR1.2024/CHF. Which of these deposits provides the higher euro return in 180 days? If these were actually market prices, what would you expect to happen?
  4. If the 30-day yen interest rate is 3% p.a., and the 30-day euro interest rate is 5% p.a. What is the magnitude of the forward premium or discount on the yen?
  5. Suppose the spot rate is CHF1.4706/\$, and the 180-day forward rate is CHF1.4295/\$. If the 180-day dollar interest rate is 7% p.a., what is the annualized 180-day interest rate on Swiss francs that would prevent arbitrage?
  6. As a trader for Goldman Sachs, you see the following prices from two different banks:  
 1-year euro deposits/loans: 6.0%–6.125% p.a.  
 1-year Malaysian ringgit deposits/loans: 10.5%–10.625% p.a.  
 Spot exchange rates: MYR4.6602/EUR–MYR4.6622/EUR  
 1-year forward exchange rates: MYR4.9500/EUR–MYR4.9650/EUR  
 The interest rates are quoted on a 360-day year. Can you do a covered interest arbitrage?
  7. As an importer of grain into Japan from the United States, you have agreed to pay \$377,287 in 90 days after you receive your grain. You face the following exchange rates and interest rates: spot rate, ¥106.35/\$; 90-day forward rate, ¥106.02/\$; 90-day USD interest rate, 3.25% p.a.; and 90-day JPY interest rate, 1.9375% p.a.
    - a. Describe the nature and extent of your transaction foreign exchange risk.
    - b. Explain two ways to hedge the risk.
    - c. Which of the alternatives in part b is superior?
  8. You are a sales manager for Motorola and export cellular phones from the United States to other countries. You have just signed a deal to ship phones to a British distributor, and you will receive £700,000 when the phones arrive in London in 180 days. Assume that you can borrow and lend at 7% p.a. in U.S. dollars and at 10% p.a. in British pounds. Both interest rate quotes are for a 360-day year. The spot rate is \$1.4945/£, and the 180-day forward rate is \$1.4802/£.
    - a. Describe the nature and extent of your transaction foreign exchange risk.
    - b. Describe two ways of eliminating the transaction foreign exchange risk.
    - c. Which of the alternatives in part b is superior?
    - d. Assume that the dollar interest rate and the exchange rates are correct. Determine what sterling interest rate would make your firm indifferent between the two alternative hedges.
  9. Suppose that there is a 0.5% probability that the government of Argentina will nationalize its banking system and freeze all foreign deposits indefinitely during the next year. If the dollar deposit interest rate in the United States is 5%, what dollar interest would Argentine banks have to offer in order to attract deposits from foreign investors?
  10. If the market price of a 20-year pure discount bond with a face value of \$1,000 is \$214.55, what is the spot interest rate for the 20-year maturity expressed in percentage per annum?
  11. Consider a 2-year euro-denominated bond that has a current market price of €970, a face value of €1,000, and an annual coupon of 5%. If the 1-year spot interest rate is 5.5%, what is the 2-year spot interest rate?
  12. Consider some data drawn from Exhibit 6.5. The 1-year rates can be viewed as spot interest rates, and the 2-year rates are yields to maturity in annualized percent. The spot exchange rate is ¥132.192/£.
 

	U.K.	Japan
1 year	1.105	0.370
2 year	1.770	0.430
  13. Go to the Web site of the British Bankers' Association (BBA). Find out which banks are on the panel for the dollar, the euro, the yen, and the Australian dollar.

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