Chapter 2

The Foreign Exchange Market

Whether you are a Dutch exporter selling Gouda cheese to a U.S. supermarket for dollars or a U.S. mutual fund investing in Mexican stocks, you will need to find a way to exchange foreign currency into your own currency and vice versa. These exchanges of monies occur in the **foreign exchange market**. Because different countries use different kinds of money, the globalization process of the past 30 years, described in Chapter 1, has led to spectacular growth in the volumes traded on this market.

This chapter introduces the institutional structure that allows corporations, banks, international investors, and tourists to convert one money into another money. We discuss the size of the foreign exchange market, where it is located, and who the important market participants are. We then examine in detail how prices are quoted in the foreign exchange market, and in doing so, we encounter the important concept of **arbitrage**. Arbitrage profits are earned when someone buys something at a low price and sells it for a higher price without bearing any risk.

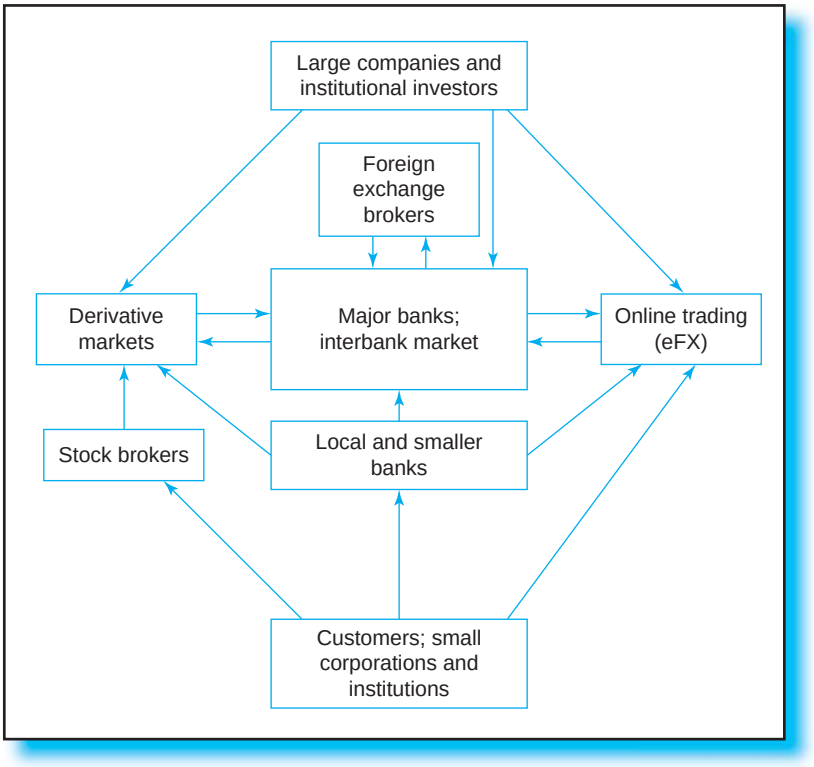
At the core of the foreign exchange market are traders at large financial institutions. We study how these people trade with one another, and we consider the clearing mechanisms by which funds are transferred across countries and the risks these fund transfers entail. We also examine how foreign exchange traders try to profit by buying foreign money at a low price and selling it at a high price.

Finally, the chapter introduces the terms used to discuss movements in exchange rates. Developing the ability to use these terms correctly makes it easier to discuss the risks involved in doing business in an increasingly global marketplace.

2.1 The Organization of the Foreign Exchange Market

The foreign exchange (sometimes abbreviated "forex") market typically conjures up images of a hectic trading room, full of computers and information networks, with traders talking excitedly on telephones. This image is a reality on the trading floors of the world's major banks and other financial institutions that make up the **interbank market**. It may help to think of the interbank market as the wholesale part of the forex market where banks manage inventories of currencies. There is also a less hectic retail side of the forex market, where the customers of the foreign exchange dealers buy and sell foreign currencies. These customers are the multinational corporations that market goods and services throughout the world and the institutional investors and money managers that invest capital or speculate throughout the world.

Exhibit 2.1 The Structure of the Foreign Exchange Market



Note: Our own design, inspired by Figure 1 in Gallaugher and Melville (2004).

Exhibit 2.1 displays the various components of the foreign exchange market. In the middle of the diagram sits the interbank market, which is a very large, diverse, over-the-counter market, not a physical trading place where buyers and sellers gather to agree on a price to exchange currencies. Traders, who are employees of financial institutions in the major financial cities around the world, deal with each other via computer or over the phone, with back-office confirmations of transactions occurring only later.

The foreign exchange market operates 24 hours per day because the major financial centers where currencies are traded are geographically spread out. When it is midnight in London, England, it is morning in the Pacific and Asian markets. The first market activity is in Sydney (Australia) and Wellington (New Zealand), and it is quickly followed by trading in Tokyo and Osaka (Japan), Hong Kong, and Singapore. An abrupt decline in trading then occurs at hour 4, which is lunchtime in those markets. Market intensity picks up again in the afternoon of the Eastern Asian trading session, and it continues as Hong Kong and Singapore close and Frankfurt and London open. Other centers in Europe include Zurich, Switzerland; Copenhagen, Denmark; and Paris, France. Trading intensity increases when New York opens and overlaps with European activity, and trading declines after New York closes until the Eastern Asian markets open again. Other trading centers in the United States include Chicago and Los Angeles.

Because most transactions in the interbank market are large trades with values of $1 million or more, most retail investors and small businesses cannot access the foreign exchange market directly. As a result, many in need of foreign exchange deal with small regional banks or branches of money center banks that quote less advantageous rates than would be prevalent in the interbank market. Retail investors also participate in the foreign exchange markets through their stockbrokers, who can place orders in derivative markets on futures and options

exchanges. As Exhibit 2.1 shows, large multinational corporations, such as IBM, and very large money-management firms, such as the mutual fund company Fidelity, can directly access the foreign exchange interbank market. Some multinational companies even have their own foreign exchange trading desks. An important recent trend is the rapid growth in electronic trading both in the interbank market (through electronic brokering) and on the retail side of the market. We provide further details below.

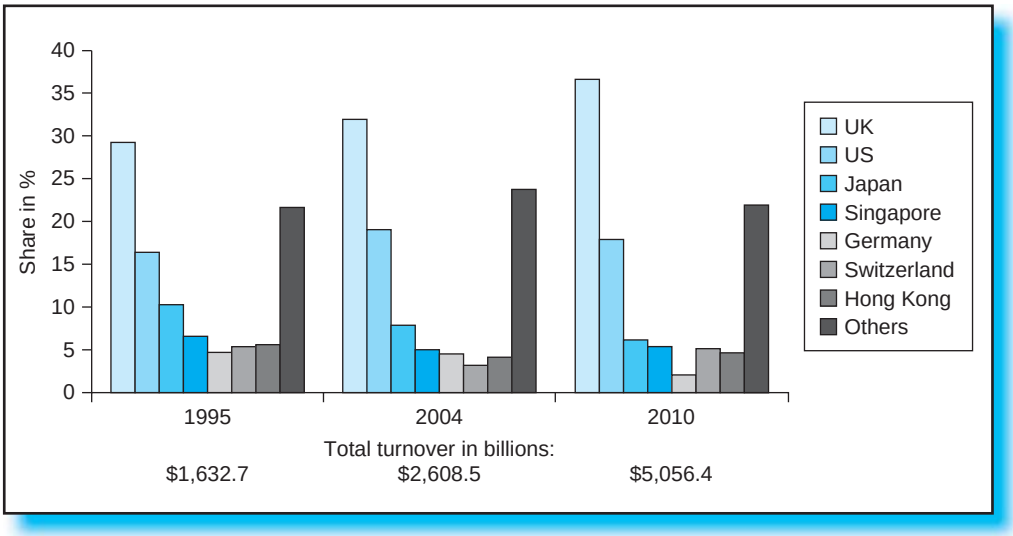
Size of the Market

The foreign exchange market is the largest market in the world, measured by dollar volume of trade. This volume has increased rapidly since the 1970s. In 1973, the estimated daily volume of currency trading was roughly $10 to $20 billion. By the late 1980s, daily volume had grown to around $500 billion. By September 1993, the estimated daily volume in all currencies had grown to over $1 trillion, and by 2004, it had grown to almost $2 trillion. The Bank for International Settlements (BIS) (2010) estimated that daily trading volume in April 2010 was $3.9 trillion. This dollar volume of trade dwarfs the corresponding dollar volume of transactions on stock markets such as the New York Stock Exchange (NYSE), where average daily dollar volume was roughly $50 billion in 2010. Of course, the $3.9 trillion includes all markets and all currencies around the world, not just trade conducted in New York.

The main factor behind the large increase in volumes is undoubtedly the globalization process, which led to increased cross-border trades in goods, services, and securities, all requiring transactions in the forex market. More recently, the speculative activities and high-volume, high-frequency trading by hedge funds have also played an increasingly important role.

Exhibit 2.2 gives an idea of the relative trading activity in the major financial centers around the world and how it grew between 1995 and 2010. The United Kingdom, with London as the major financial center, is the dominant market, accounting for 37% of all trading in 2010, followed by the United States, with the bulk of the trades occurring in New York. London's dominance has increased since 1995.

Exhibit 2.2 Foreign Exchange Trading Activity Across the World



Notes: Amounts are average daily turnover in billions of U.S. dollars. The numbers are not adjusted for interdealer double-counting, which explains why the total turnover in 2010 is about $1 trillion higher than $3.9 trillion.

Source: From the Central Bank Survey of Foreign Exchange and Derivatives Marketing Activity 2010; BIS, September 2010; Table 5, MED Publications for the Bank for International Settlements.

Types of Contracts Traded

Many different types of trades can be conducted in the foreign exchange market. In this chapter, we examine the **spot market**, where "spot" implies the market for immediate exchanges of monies. Another part of the interbank foreign exchange market involves trade in swaps and forward contracts, transactions that involve exchanges of currencies in the future. We discuss these types of trades in Chapter 3. A third part of the market involves derivative securities such as foreign currency futures and options. These contracts are discussed in Chapter 20.

When currencies in the interbank spot market are traded, certain business conventions are followed. For example, when the trade involves the U.S. dollar, business convention dictates that spot contracts are settled in 2 business days—that is, the payment of one currency and receipt of the other currency occurs in 2 business days. One business day is necessary because of the back-office paperwork involved in any financial transaction. The second day is needed because of the time zone differences around the world.

Several exceptions to the 2-business-day rule are noteworthy. First, for exchanges between the U.S. dollar and the Canadian dollar or the Mexican peso, the rule is 1 business day. Second, if the transaction involves the dollar and the first of the 2 days is a holiday in the United States but not in the other settlement center, the first day is counted as a business day for settlement purposes. Third, Fridays are not part of the business week in most Middle Eastern countries, although Saturdays and Sundays are. Hence, Middle Eastern currencies transacted on Wednesday settle on Saturday, not on Friday.

Foreign Exchange Dealers

The main participants in the foreign exchange market are the commercial banks, investment banks, and brokerage firms in the major financial cities around the world. Traders at these banks and firms function as **foreign exchange dealers**, simultaneously "making a market" in several currencies. These **market makers** stand ready to buy and sell the currencies in which they specialize. By standing ready to transact with retail customers or other dealers, they provide **liquidity** to the market—that is, they make it easier and less costly to match buyers and sellers. When there are large numbers of buyers and sellers, markets are very liquid, and transaction costs are low. The foreign exchange markets for the major currencies of the world, such as the markets for the U.S. dollar, the euro, the Japanese yen, and the British pound, are among the most liquid markets in the world.

Forex dealers try to buy a foreign currency at a low rate and sell the foreign currency at a higher rate, thus making a profit. Hence, their provision of liquidity does not go unrewarded. We examine the size of these profits in Section 2.3.

Foreign Exchange Brokers

Foreign exchange brokers do not attempt to buy low and sell high. Instead, brokers fulfill the role of a financial intermediary. They match buyers and sellers but do not put their own money at risk. They then receive a brokerage fee on their transactions.

Forex brokers typically have many lines of communication open to various foreign exchange dealers, and they provide information to dealers on the best available prices. Foreign exchange dealers often use these brokers to unwind very large positions in a particular currency in order to preserve their anonymity. For example, suppose that Citibank finds itself stuck with a very large amount of Australian dollars toward the end of the day. Citibank would like to sell Australian dollars for U.S. dollars before the end of the trading day. Without anonymity in trading, competing dealers would try to profit from the knowledge that Citibank has a short-term excess supply of Australian dollars. If Citibank were to call JPMorgan Chase, for example, the prices quoted to Citibank would likely be unfavorable. By contrast, a broker may

be able to negotiate trades with several foreign exchange dealers, thereby "unwinding" the large position in Australian dollars in small portions, while preserving Citibank's anonymity.

While these "voice brokers" continue to play an important role in foreign exchange trading, a large part of the brokering business now happens through computerized trading systems. In the early 1990s, Reuters (now Thomson Reuters), a large financial information provider, and Electronic Brokering Service (EBS), started by a consortium of 12 banks but now part of the interdealer broker ICAP, launched the first anonymous electronic brokering systems for trading spot foreign exchange. Trading is carried out through a network of linked computer terminals among the participating forex dealers. Currency prices are displayed on computer screens, and deals are completed by keystroke or by automatic deal matching within the system. Before a trade gets executed, either the systems check for mutual credit availability between the initiator of the deal and the counterparty of the deal or each counterparty must have its creditworthiness prescreened.

Trading in each major currency pair has over time become very highly concentrated on only one of the two systems. The top two traded currency pairs, euro–dollar and dollar–yen, trade primarily on EBS, whereas the third, pound–dollar, trades primarily on Reuters. As a result, the exchange rates on EBS and Reuters for these particular currency pairs have become the reference rates for dealers across the world. When EBS allowed institutional investors and hedge funds on its platform in 2005, it confirmed a trend towards the blurring of the distinction between the interbank and retail side of the foreign exchange market, ushered in by the emergence of electronic trading.

Other Participants in the Forex Market

The central banks of different governments around the world periodically participate in the foreign exchange market as they try to influence the foreign exchange value of their currencies. (We discuss how this works in Chapter 5.) Other participants include multinational corporations, which need to exchange currencies to conduct their international trade; institutional investors buying and selling foreign securities; hedge funds speculating on currency movements; and smaller domestic banks that service firms or individuals wanting to exchange currencies. If the trades are large enough, the highly liquid interbank market can be tapped. The more removed from the interbank market participants are (see Exhibit 2.1), the higher the transaction costs likely are.

The interbank market used to dominate the foreign exchange market, accounting for over 80% of trading volume, but this has recently drastically changed. The 2010 BIS survey on foreign exchange activity reports that turnover accounted for by trading between foreign exchange dealers fell below 50% of the total trading volume for the first time ever. Corporations accounted for 13.4% of transactions, a proportion that has not changed much over time. However, almost 48% of total volume is now accounted for by what the BIS survey calls "other financial institutions," which include smaller banks, mutual funds, pension funds, hedge funds, central banks, and so on. This change reflects a change in the dominant clientele of foreign exchange dealers. Before the 1980s, international trade was the main source of non-bank demand and supply. Since then, the explosion in international capital flows and the growth of the hedge fund industry have made professional money managers increasingly important participants in the forex market. The emergence of electronic trading has also contributed to this trend.

Electronic Foreign Exchange Trading (eFX)

The Internet revolution has not bypassed the foreign exchange market. The fastest growing segment of the foreign exchange market, already representing more than 30% of all trading volume (and more than 50% in spot markets), is electronic "online" trading. It is possible that the old telephone-based system will eventually be supplanted by pure electronic trading.

Electronic trading platforms may offer multiple quotes from a number of foreign exchange dealers and/or can house an electronic communication network (ECN). An ECN electronically collects and matches buy and sell orders, and it displays the best available prices.

In such a system, it is possible that a pension fund trades with a hedge fund, so that banks lose their traditional role of market makers. Trades are often totally anonymous. Because the market price for a particular currency is visible for all participants on the platform, electronic trading ensures price transparency. Another advantage of electronic trading is the possibility of straight-through processing (STP): A foreign exchange trade takes place from placement of the order to settlement and even entry in accounting systems in an automated fashion without errors induced by faulty paperwork. Electronic trading has greatly enhanced the liquidity of the foreign exchange market and reduced trading costs.

There are three different categories of "eFX," as electronic trading has come to be known: single bank–sponsored platforms (or "portals"), multi-bank portals, and independent companies offering electronic trading. To offer better services to their clients, many banks developed electronic trading platforms. For example, Deutsche Bank's platform is imaginatively called the "Autobahn," perhaps to make potential clients associate its speed of execution with the German highway, which has no speed limits. By far, the best known and most active platform is FXConnect from State Street. This platform was launched in 1996, originally to serve the foreign exchange trading needs of State Street's client base, consisting mostly of institutional investors making use of State Street's custody services. It has since been expanded to include quotes from a large number of other foreign exchange dealers; that is, it evolved into a multi-bank portal. Another market leader is the portal FXall, offered by a consortium of banks. FXall started operations in May 2001 and focuses primarily on corporate clients. Finally, there are a number of independent companies trying to muscle their way into online foreign exchange trading, such as HotSpot and Currenex. The Currenex box discusses the success story of Currenex, a Silicon Valley technology firm that created a successful forex electronic trading platform.

Electronic platforms were originally focused on attracting either corporate clients or institutional investors, but they got a great boost by the rapid development of hedge funds trading currencies and the emergence of "retail aggregators." Currency speculation happens in three different types of hedge funds. First, there are funds, such as FX Concepts, dedicated solely to currency trading. Second, the so-called "global macro" funds trade a wide variety of international securities, including currencies. Finally, algorithmic trading firms connect their computers directly to the ECN to trade currencies, typically at a very high frequency. Such funds use computer algorithms to attempt to profit from incremental price movements by conducting frequent small trades, executed in milliseconds. These systems make up an increasingly larger portion of trading (some estimates suggest 25% of spot trading!) and can be viewed as liquidity providers to the market, further undermining the traditional market-making role of the money center banks (see Chaboud et al., 2009). The advent of such systems accounts for why foreign exchange turnover has grown much faster than underlying economic activity as measured by gross domestic product (GDP), equity turnover, or gross trade flows (see King and Rime, 2010).

The growing importance of hedge funds in foreign exchange trading went hand-in-hand with the increased prevalence and availability of prime brokerage. The prime broker, typically a large security firm such as Morgan Stanley, offers the hedge fund a bundle of services, including securities lending, cash management, and access to various markets. Importantly, the prime broker's customers trade in the prime broker's name using its existing credit lines with the foreign exchange dealers, so that a hedge fund does not need to establish credit relationships with numerous banks.

A retail aggregator is a financial firm that acts as an intermediary, aggregating bid-offer quotes from the top foreign-dealing banks and electronic platforms, which are then streamed live to customers via the aggregator's online platform at very competitive spreads. Retail aggregators cater to the smallest accounts, including households, as well as small corporations, asset managers, trading firms, and institutional investors. A well-known example is

Currenex

At the end of the 1990s, the foreign exchange market was an over-the-counter dealer market dominated by major banks such as Citibank and Deutsche Bank. It seems almost foolhardy to think that a small technology firm with a handful of people could compete with these giants. Yet, this is what Currenex, founded in 1999, attempted. The key to Currenex's success was its anticipation of the usefulness of increased automation in foreign exchange trading and the fact that it managed to stay at the technological frontier of trading systems. Its initial strategy was to attract multi-national companies to its trading platform, and the oil company, Shell, was an early financial backer of the company. Currenex's corporate clients not only had to be convinced to use Currenex's services, but they also had to convince their foreign exchange dealers to quote prices on Currenex's platform. Currenex's focus on technology eventually paid off. Over time, the company offered an increasingly larger variety of trading possibilities to its clients. Clients could request a particular quote from the participating dealers (with whom they had a credit relationship). The platform also offered transactable quotes, leading to automated trade execution ("executable streaming prices"), and in 2004, Currenex started an ECN, called FXTrades, attracting liquidity from as many sources as it possibly could. The ECN allowed anonymous trading and worked essentially like an organized exchange with a clearinghouse and central counterparty (see Chapter 20).

Currenex foresaw more quickly than other market participants the need for speedy execution required by hedge funds and algorithmic traders. It also successfully leveraged the business of order flow aggregators. These wholesale or retail aggregators are financial institutions (e.g., Man Financial) that provide eFX trading platforms to their clients. These clients include small institutions, mutual funds, pension funds, and retail investors (such as foreign exchange day traders) that do not have sufficient resources or credit characteristics to access market makers directly. The aggregator firms incur the credit risk of these end-users by operating like a futures exchange with margins (see Chapter 20). All major prime brokers also participated on Currenex. Its platform could also be used and branded by a broker, aggregator, prime broker, or bank to deploy to their customers.

Having successfully taken advantage of the new technological trends, Currenex became an important player in foreign exchange markets. It now offers both spot and forward trading in a very large number of currency pairs. However, its independence would not last. State Street realized that Currenex's technological edge and client base provide good synergies with its own currency offerings, such as FXConnect, and bought the firm in 2007.

Oanda, whose Web site has become a retail benchmark for currency quotes. Retail aggregators now account for over 10% of foreign exchange trading volume, with this percentage being by far the highest in Japan. The stories about Japanese housewives (the proverbial Mrs. Watanabes) speculating in the currency markets from their kitchens are real!

The Competitive Marketplace

Retail customers of banks should pay only slightly more than participants in the interbank market if the foreign exchange market is competitive. In what economists refer to as a *perfectly competitive market*, many firms compete with one another, and the cost of entering the market is low. Competition is most intense when the product being sold is the same across the firms. We already know that the foreign exchange market satisfies this latter condition: A dollar is a dollar and a euro is a euro wherever and by whomever they are bought or sold. In such markets, firms are unable to earn abnormally high profits. On the other hand, when the number of firms in a market is small and entering the market is costly, firms may possess market power, which leads to less competitive pricing.

Exhibit 2.3 lists the major foreign exchange dealers and their market shares and shows that there has been tremendous consolidation in foreign exchange trading. The top four dealers now account for over 45% of trading volume and the top 20 for over 90%. In the past, the top four dealers accounted for less than 30% of the trading, the top 20 for less than 75%, and Citibank, helped by its global presence, was consistently the top foreign exchange

Exhibit 2.3 Top 20 Dealers in the Foreign Exchange Market

Rank 2010	Company	Market Share	Rank 2009	Market Share 2000[1]
1	Deutsche Bank	18.06%	1	12.53%
2	UBS[2]	11.30%	2	5.02%
3	Barclays	11.08%	3	2.07%
4	Citigroup	7.69%	5	8.07%
5	Royal Bank of Scotland[3]	6.50%	4	2.71%
6	JPMorgan Chase[4]	6.35%	6	12.10%
7	HSBC	4.55%	7	4.55%
8	Credit Suisse	4.44%	9	2.89%
9	Goldman Sachs	4.28%	8	4.38%
10	Morgan Stanley	2.91%	11	2.87%
11	BNP Paribas	2.89%	10	—
12	Bank of America	2.27%	12	1.86%
13	Société Générale	2.06%	13	0.60%
14	Commerzbank	1.46%	—	—
15	Standard Chartered	1.25%	16	0.62%
16	State Street	1.11%	15	1.95%
17	Calyon	0.81%	18	—
18	Nomura	0.80%	—	—
19	SE Banken	0.74%	—	—
20	Royal Bank of Canada	0.71%	17	1.96%
	Total	91.26%		

Note: Based on the Foreign Exchange Polls by *Euromoney* in 2010 and 2001.

[1]If the bank was not in the top 25 in 2000, we do not have market share information. The market share missed would then in any case be less than 0.60%.

[2]Market share for 2000 is for Warburg Dillon Read, then the investment banking division of UBS.

[3]Market share for 2000 is for NatWest, which was later acquired by the Royal Bank of Scotland.

[4]Market share for 2000 also includes the share of Chase Manhattan, which was later acquired by JPMorgan.

dealer. Now, the three European banks, Deutsche Bank, UBS, and Barclays, have overtaken Citibank as the major foreign exchange dealers after making significant investments in foreign exchange trading. These three banks account for 40% of the trading volume.

Competitive pressures and the growing importance of online trading have made foreign exchange trading a high volume–low margin business, which requires tremendous investments in technology. Smaller banks can no longer afford to make markets in the major currencies, but they now tend to specialize in regional currencies.

Despite the somewhat increased market shares of the major traders, no single dealer dominates the market, and the foreign exchange market remains very competitive. We examine how this competition affects pricing later in this chapter, when we discuss bid–ask spreads. According to guidelines by the U.S. Department of Justice regarding industry concentration, the foreign exchange market would not even be considered "moderately concentrated" (see Cetorelli et al., 2007).

2.2 Currency Quotes and Prices

You now know about the participants in the forex market and its organization but have yet to learn about the currencies that are traded and how their prices are quoted. Because more than 150 countries in the world have their own currencies, it makes sense that currency trading is governed by an intricate set of conventions and practices.

Exchange Rates

An **exchange rate** is the relative price of two monies, such as the Japanese yen price of the U.S. dollar, the British pound price of the euro, or the Brazilian real price of the Mexican peso. Rather than write out the full name of these currencies, contractual parties use abbreviations. In banking and commercial transactions, it is important that all parties understand which currencies are being used. Hence, there is a need for standardization of the abbreviations. The International Organization for Standardization (called ISO from the Greek word for equal) sets these standards. Exhibit 2.4 provides a list of some of the ISO currency abbreviations used to represent the different currencies. In most cases, the abbreviation is the ISO two-digit country code plus a letter from the name of the currency.

For example, the notation for the U.S. dollar is USD, the British pound is GBP, the Japanese yen is JPY, and the euro is EUR. In examples throughout the book, we use these codes to illustrate the units involved in different transactions. At other times, though, common symbols for the major currencies are used, such as $ for the U.S. dollar, £ for the pound, € for the euro, and ¥ for the yen.

If it takes 100 yen to purchase 1 dollar, we can write

$$\text{JPY}100 = \text{USD}1$$

The exchange rate can be written as JPY100/USD, or ¥100/$, where the 1 dollar in the denominator is implicit. Similarly, if it takes 1.75 U.S. dollars to purchase 1 British pound, then

$$\text{USD}1.75 = \text{GBP}1$$

and the exchange rate can be written as USD1.75/GBP or simply $1.75/£.

Notice that we treat the slash symbol (/) as a divisor in a ratio to indicate the amount of the first currency that is necessary to purchase one unit of the second currency. While we continue to use this logical notation throughout the book, you will encounter foreign exchange quotations, such as EUR/USD or EURUSD, in which the first currency in the quote is the base currency and the second currency is the numerator currency or "quote currency." In other words, if you type EUR/USD into Google, it will return the price of the euro in terms of dollars, or how many dollars you can buy with 1 euro. Presentations that use this convention typically contain lists of numbers without letters or symbols. We retain our ratio presentation with either letters or symbols throughout the book to make it easy for the reader to understand the relative price aspect of exchange rates.

Exchange Rate Quotes

Because exchange rates are relative prices, they can be expressed in two ways. Exchange rates can be quoted in direct terms as the domestic currency price of the foreign currency or in indirect terms as the foreign currency price of the domestic currency.

Because direct prices are, perhaps, the most natural way to discuss exchange rates, let's consider **direct quotes** first. For example, in the United Kingdom, people discuss the pound prices of various goods and assets. If you were in the United Kingdom, you might inquire, "How many pounds does it take to purchase that car?" or "What does that car cost?" In each case, you want to know the number of pounds that must be given up to purchase a specific car. An economist would say the answer to these questions is the value of the car in terms of the pound.

Now, suppose you were in the United Kingdom, and you wanted to travel to Germany. If you thought you might need 1,000 euros on your trip, it would also be natural for you to inquire, "How many pounds does it take to purchase 1,000 euros?" or "What do 1,000

Exhibit 2.4 Currencies and Currency Symbols

Country	Currency	ISO Currency Code
Argentina	Peso	ARS
Australia	Dollar	AUD
Bahrain	Dinar	BHD
Brazil	Real	BRL
Canada	Dollar	CAD
Chile	Peso	CLP
China	Yuan	CNY
Colombia	Peso	COP
Czech Republic	Koruna	CZK
Denmark	Krone	DKK
Ecuador	US dollar	USD
Egypt	Pound	EGP
European Union	Euro (€)	EUR
Hong Kong	Dollar	HKD
Hungary	Forint	HUF
India	Rupee	INR
Indonesia	Rupiah	IDR
Israel	Shekel	ILS
Japan	Yen (¥)	JPY
Jordan	Dinar	JOD
Kuwait	Dinar	KWD
Lebanon	Pound	LBP
Malaysia	Ringgit	MYR
Mexico	Neuvo Peso	MXN
New Zealand	Dollar	NZD
Norway	Krone	NOK
Pakistan	Rupee	PKR
Peru	New Sol	PEN
Philippines	Peso	PHP
Poland	Zloty	PLZ
Russia	Ruble	RUR
Saudi Arabia	Riyal	SAR
Singapore	Dollar	SGD
South Korea	Won	KRW
South Africa	Rand	ZAR
Sweden	Krona	SEK
Switzerland	Franc	CHF
Taiwan	Dollar	TWD
Thailand	Baht	THB
Turkey	Lira	TRL
United Arab Emirates	Dirham	AED
United Kingdom	Pound (£)	GBP
United States	Dollar ($)	USD
Uruguay	Peso	UYU
Venezuela	Bolivar	VEB
Vietnam	Dong	VND

Note: For a more complete list of ISO Currency Codes, see www.iso.org.

euros cost?" In each case, you want to know the number of pounds that must be given up to purchase this specific number of euros. Once again, economists would say that the answer is the value of 1,000 euros in terms of the pound.

If the pound price of the euro is £0.90/€, the pound cost of 1,000 euros is

$$€1{,}000 \times (£0.90/€) = £900$$

Notice that with direct exchange rates, converting from a foreign currency amount (in this case, the euro) into a domestic currency value (in this case, the pound) simply involves multiplying the amount of foreign currency by the exchange rate expressed in units of domestic currency per foreign currency.

For the U.S. dollar, it is common for many exchange rates to be quoted in **indirect quotes**, such as ¥100/$ for the Japanese yen or CHF1.8/$ for the Swiss franc. These exchange rates represent the amount of foreign currency that is equivalent to 1 dollar, which is also the amount of foreign currency required to purchase 1 dollar.

Conventions in the foreign exchange market have converged on an order for how exchange rates are usually quoted. This clearly facilitates communication between traders across the world. For major currencies, the base currency or denominator of the exchange rate in a quote follows this order: euro, British pound, Australian dollar, New Zealand dollar, U.S. dollar, Canadian dollar, Swiss franc, and Japanese yen. Thus, people quote the pound price of the euro, as in our earlier example, but they quote the U.S. dollar price of the pound. Similarly, traders quote the Australian dollar price of the British pound but quote the New Zealand dollar (or "kiwi," as it is often referred to) price of the Australian dollar. Exchange rates between Asian and Latin American currencies and the U.S. dollar are also quoted in indirect terms from the U.S. perspective.

Because exchange rates are the relative prices of monies, an exchange rate expressed in direct terms is the reciprocal (inverse) of the exchange rate expressed in indirect terms. For example, suppose it takes 100 yen to purchase 1 dollar—that is, the exchange rate in indirect terms from the U.S. perspective is ¥100/$. Then, the exchange rate in direct terms from the U.S. perspective, which is the dollar price of the Japanese yen, is the reciprocal of the exchange rate quoted in indirect terms:

$$1/(¥100/\$) = \$1/¥100 = \$0.01/¥$$

The reciprocal nature of direct and indirect terms often confuses students. Earlier in the chapter, we converted money between pounds and euros when traveling between the United Kingdom and Germany. Now, suppose you are in the United States, and you want to travel to Japan. If you were advised that you needed 500,000 yen for your trip, it would be natural for you to inquire, "How many dollars does it take to purchase 500,000 yen?" Now, though, because the exchange rate is typically quoted as ¥100/$, the dollar cost of the ¥500,000 is

$$¥500{,}000/(¥100/\$) = \$5{,}000$$

Notice that with the exchange rate quoted as an indirect price, converting from a foreign currency amount (the yen, in this case) into a domestic currency value (the dollar, in this case) involves dividing the amount of foreign currency (the yen) by the exchange rate expressed in units of foreign currency per domestic currency (¥ per $). Because such currency conversions lie at the heart of all international financial transactions, it clearly pays to be careful to remember how the exchange rate is being quoted before converting from one currency into another.

The indirect method of quoting exchange rates is also commonly referred to as a **European quote** (the amount of foreign currency needed to buy dollars) because most former European currencies, such as the Deutsche mark and the French franc, were quoted this way relative to the dollar. The phrase **American quote** refers to the dollar price of a foreign currency—that is, the number of dollars it takes to purchase one unit of the foreign currency. Exchange rates of the British pound versus the dollar and the euro versus the dollar are commonly expressed directly in dollars per pound (for example, as $1.65/£) and in dollars per euro (for example, $1.15/€).

The following table summarizes the different ways of quoting exchange rates:

DIRECT AND INDIRECT, EUROPEAN AND AMERICAN QUOTES

	In the United States	**In Britain**
$ per £	Direct	Indirect
$ per £	American	American
£ per $	Indirect	Direct
£ per $	European	European
	In Thailand	**In the European Union**
Thai baht per €	Direct	Indirect

When you are in the United States, quoting the pound exchange rate as $ per £ means you are using domestic currency per foreign currency; it is a direct quote. Similarly, when you are in Thailand, quoting the euro exchange rate as Thai baht per € is an example of a direct quote. When you are in Europe, quoting the Thai baht as Thai baht per € is an example of an indirect quote because you use foreign currency per domestic currency. The terminology *American* and *European* only refers to exchange rates relative to the dollar.

Major financial newspapers such as the *Wall Street Journal* and the *Financial Times* provide daily lists of foreign exchange rates, and many Web sites such as www.oanda.com provide currency converters. Exhibit 2.5 presents a typical listing from the *Wall Street Journal*. These exchange rates are supplied to the *Wall Street Journal* from the interbank market by Reuters. The exchange rate information pertains to Tuesday, December 21, 2010.

One set of quotes is in direct terms from the U.S. perspective (American quotes) and is reported "in US$." These columns indicate the number of U.S. dollars equivalent to one unit of the other currency, which is also the U.S. dollar price of one unit of the other currency. The second set of quotes is in indirect terms from the U.S. perspective (European quotes). These columns are labeled "per US$," which is the foreign currency price of 1 U.S. dollar.

Notice that many of the exchange rates listed under the columns titled "per US$" are greater than one in value (although there are a number of exceptions, including the euro, the British pound, the Swiss franc, and the SDR[1]). Most people find this way of discussing exchange rates superior to discussing small fractions. It is much easier to state the yen rate as "83.74 yen per dollar" (¥83.74/$) than it is to state its reciprocal, which is "Eleven thousand, nine hundred, and forty-two millionths of a dollar per yen" ($0.011942/¥). No doubt this is why indirect terms have become the common way of discussing many dollar exchange rates.

Most of the quotations in Exhibit 2.5 represent spot exchange rates, but the currencies of Britain, Canada, Japan, and Switzerland have quotes for 1-month, 3-month, and 6-month forward contracts. These financial instruments are discussed in Chapter 3.

Vehicle Currencies and Currency Cross-Rates

Our focus on the U.S. dollar exchange rates versus other currencies of the world is warranted because the U.S. dollar is a **vehicle currency**, meaning it is actively used in many international financial transactions around the world. The transaction costs of making markets in many currencies lead the market to use only a few currencies as the major vehicles for international transactions.

[1]SDR stands for *Special Drawing Right*, a unit of account created by the International Monetary Fund (IMF). The IMF and the SDR are discussed in Chapter 5.

Exhibit 2.5 U.S. Dollar Currency Quotes from Tuesday, December 21, 2010

G-10 Currencies	Code	Per USD	In USD
Australian dollar	AUD	1.0138	0.9864
Canadian dollar	CAD	1.0207	0.9797
Swiss franc	CHF	0.9719	1.0289
Euro	EUR	0.7636	1.3096
UK pound	GBP	0.6461	1.5477
Japanese yen	JPY	84.12	0.011888
Norwegian krone	NOK	6.0052	0.1665
New Zealand dollar	NZD	1.3606	0.7350
Swedish krona	SEK	6.8661	0.1456

Other OECD	Code	Per USD	In USD
Chilean peso	CLP	470.21	0.002127
Czech koruna	CZK	17.259	0.0579
Estonian kroon	EEK	11.713	0.0854
Hungarian forint	HUF	188.37	0.005309
Icelandic krona	ISK	115.42	0.008664
Israeli shekel	ILS	3.6154	0.2766
South Korean won	KRW	1155.67	0.0008653
Mexican peso	MXN	12.4278	0.0805
Polish zloty	PLN	2.7875	0.3587
Slovak koruna	SKK	0.7014	1.4257
Turkish lira	TRL	1.5622	0.6401

Emerging Markets	Code	Per USD	In USD
Argentine peso	ARS	3.9874	0.2508
Azerbijan manat	AZN	0.7983	1.2527
Bahraini dinar	BHD	0.3773	2.6504
Bangladeshi taka	BDT	69.286	0.01443
Belarusian ruble	BYR	4947.8	0.0002021
Belize dollar	BZD	1.9536	0.5119
Bhutan ngultrum	BTN	45.173	0.02214
Botswana pula	BWP	6.5081	0.1537

Emerging Markets	Code	Per USD	In USD
Brazilian real	BRL	1.7118	0.5842
Brunei dollar	BWP	1.2202	0.8195
Bulgarian lev	BGN	1.3716	0.7291
Cambodian riel	KHR	4080	0.0002451
Chinese yuan	CNY	6.6681	0.1500
Columbian peso	COP	1929.51	0.0005183
Egyptian pound	EGP	5.7841	0.1729
Hong Kong dollar	HKD	7.7794	0.1285
Indian rupee	INR	46.292	0.02160
Indonesian rupiah	IDR	8952	0.0001117
Iranian rial	IRR	10,555	0.0000947
Jamaican do Mar	JMD	84.052	0.0119
Jordanian dinar	JOD	0.7035	1.4215
Kazakhstan tenge	KZT	143.55	0.006966
Kuwaiti dinar	KWD	0.2826	3.5386
Lebanese pound	LBP	1499.41	0.0006669
Malayasian ringgit	MYR	3.1467	0.3178
Nigerian naira	NGN	156.75	0.006380
Pakistani rupee	PKR	85.751	0.01166
Peruvian new sol	PEN	2.877	0.3476
Philippines peso	PHP	44.473	0.0225
Russian ruble	RUB	28.195	0.0355
Saudi Arabian riyal	SAR	3.7499	0.2667
Singapore dollar	SGD	1.3225	0.7561
South African rand	ZAR	6.8872	0.1452
Taiwan dollar	TWD	29.925	0.03342
Tajikistani somoni	TJS	4.5926	0.2177
Thai baht	THB	30.168	0.03315
UAE dirham	AED	3.6735	0.2722
Uruguayan peso	UYU	19.39	0.05157
Venezuelan bolivar	VEB	4.2705	0.2342
Vietnamese dong	VND	19500	0.00005128

Note: Original data in foreign currency per dollar are from www.oanda.com and are the highest bid prices of the day.

For example, if there are N different currencies issued by various countries throughout the world, there are $N(N-1)/2$ possible exchange rates. With more than 150 different currencies, there are more than 11,175 possible exchange rates. Because the demands to trade between many of these different currency pairs are often low or nonexistent, there is no direct market made. Rather, traders make a direct market in one or two important currencies, referred to as *vehicle currencies*. In the 19th century, the world's primary vehicle currency was the British pound; now, it is the U.S. dollar.

Exchange rates between two currencies that do not involve the dollar are often called **cross-rates**. Exhibit 2.6 provides examples of cross-rates taken from the *Wall Street Journal* for December 21, 2010.

The rows represent "direct quotes" from the perspective of the country whose currency begins the row. For example, 83.47 is the Japanese yen price of 1 dollar. The columns thus represent the indirect quotes from the perspective of the country whose currency is at the top

Exhibit 2.6 Representative Cross-Rate Quotes from December 21, 2010

	USD	EUR	GBP	CHF	MXN	JPY	CAD
Canada CAD	1.0207	1.3367	1.5798	1.0502	0.08217	0.01213	.....
Japan JPY	84.118	110.16	130.19	86.5495	6.7715	.....	82.411
Mexico MXN	12.422	16.268	19.226	12.781	.....	0.14768	12.170
Switzerland CHF	0.97191	1.2728	1.5042	.....	0.07824	0.01155	0.95218
United Kingdom GBP	0.64612	0.84616	.....	0.66479	0.05201	0.00768	0.63300
Euro	0.76359	.....	1.1818	0.78566	0.06147	0.00908	0.74809
United States USD	.....	1.3096	1.5477	1.0289	0.08050	0.01189	0.97970

Source: www.oanda.com and authors' calculations.

of the column. For example, the Swiss franc column tells you how many foreign currency units it takes to buy 1 Swiss franc.

Although there appears to be a trend toward more cross-rate transactions, an estimated 85% of all transactions have the dollar as one side. Some analysts think the euro, which replaced 11 different currencies in Europe in 1999, may someday replace the dollar as a vehicle currency. In fact, a BIS (2010) survey of foreign exchange activity reveals that about 40% of all trades during 2010 involved the euro.

Triangular Arbitrage

Triangular arbitrage is a process that keeps cross-rates (such as euros per British pound) in line with exchange rates quoted relative to the U.S. dollar. A trader can conduct a triangular arbitrage in many ways. For example, a trader might start with euros, buy pounds with the euros, then simultaneously sell those pounds for dollars and sell those dollars for euros. In other words, instead of exchanging just two currencies, the trader exchanges three (hence the term "triangular" arbitrage). If the number of euros the trader has at the end of these three transactions is greater than the number of euros at the beginning, there is a profit.

If such transactions can be done profitably, the trader can generate pure arbitrage profits—that is, earn risk-free profits. Obviously, in perfectly competitive financial markets, it is impossible to earn arbitrage profits for very long. If the euro price of the pound were not equal to the euro price of the U.S. dollar multiplied by the U.S. dollar price of the pound, arbitrage activity would immediately restore equality between the quoted cross-rate and the cross-rate implied by two dollar quotes:

$$(\text{Euros/Pound}) = (\text{Euros/Dollar}) \times (\text{Dollars/Pound})$$

In other words, the direct quote for the cross-rate should equal the implied cross-rate, using the dollar as an intermediary currency.

To see how a triangular arbitrage works, suppose that the euro price of the pound quoted in the market is €1.1555/£. Also, suppose that this quoted cross-rate is lower than the indirect rate, using the dollar as the intermediary currency. That is,

$$(\text{Euros/Pound}) < (\text{Euros/Dollar}) \times (\text{Dollars/Pound})$$

This means there is some room to make a profit. In this situation, buying the pound first with euros (or selling euros for pounds), and then selling those pounds for dollars, and finally selling that number of dollars for euros would make a profit because we would be buying the pound at a low euro price and selling the pound at a high euro price.

To check this logic, let's go through the steps in a triangular arbitrage.

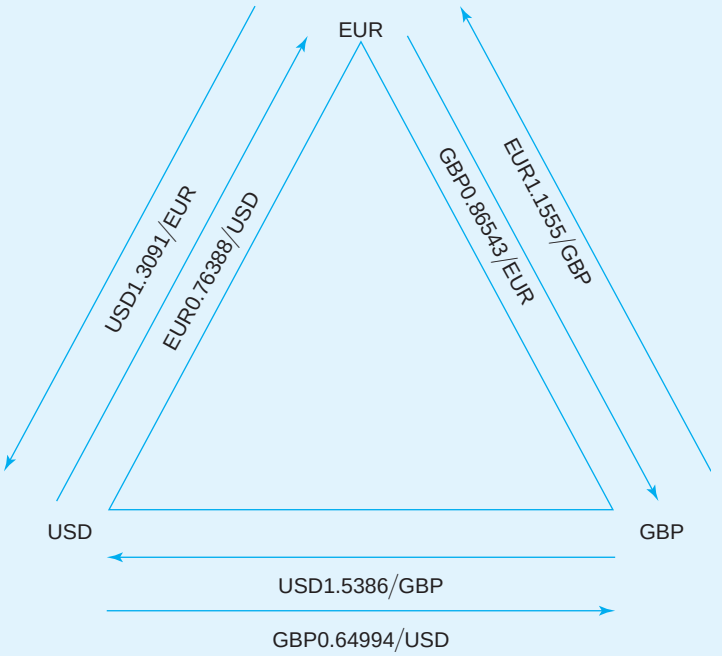
Example 2.1 A Triangular Arbitrage

Suppose David Sylvian, a trader at the foreign exchange desk of Goldman Sachs in London, observes the following exchange rates of the euro relative to the pound and the dollar and the dollar relative to the pound:

EUR1.1555/GBP or GBP0.86543/EUR
EUR0.76388/USD or USD1.3091/EUR
USD1.5386/GBP or GBP0.64994/USD

Determine the arbitrage profits when David starts with EUR10,000,000 and buys GBP. Exhibit 2.7 presents the situation in a triangle diagram.

Exhibit 2.7 Triangular Arbitrage Diagram



Notes: The exchange rates beneath the arrows indicate the amount of currency at the head of the arrow obtained by selling one unit of the currency at the tail of the arrow. For example, at the EUR node, selling 1 euro yields 0.86543 GBP going in the clockwise direction, and it yields 1.3091 USD going in the counterclockwise direction.

The exchange rates beneath the arrows in Exhibit 2.7 indicate the relevant prices, denominated in the currency at the next node (the buyer's node), of selling one unit of the currency at the starting node (the seller's node). You can use these prices to follow along on the transactions, recognizing that in some cases, we want to buy a currency, and in others, we want to sell.

Step 1. The revenue in pounds of selling EUR10,000,000 at the direct cross-rate would be

$$\text{EUR}10{,}000{,}000 \times (\text{GBP}0.86543/\text{EUR}) = \text{GBP}8{,}654{,}300$$

Step 2. Because the exchange rate of dollars per pound is (USD1.5386/GBP), David would be able to sell GBP8,654,300 for dollars to get

$$\text{GBP}8{,}654{,}300 \times (\text{USD}1.5386/\text{GBP}) = \text{USD}13{,}315{,}506$$

Step 3. Then, because the exchange rate of euros per dollar is EUR0.76388/USD, he would sell the USD13,315,506 for euros to get

$$\text{USD13,315,506} \times (\text{EUR0.76388/USD}) = \text{EUR10,171,449}$$

If David had truly been able to make these transactions simultaneously, he would have made

$$\text{EUR10,171,449} - \text{EUR10,000,000} = \text{EUR171,449}$$

for an instantaneous rate of return of

$$1.71\% = (\text{EUR171,449/EUR10,000,000})$$

Example 2.1 demonstrates how triangular arbitrage provides an instantaneous opportunity for profit *if* these were the actual market quotes. The data for the dollar exchange rates are, in fact, from Exhibit 2.6—quotes from the *Wall Street Journal* on December 21, 2010. We can use them to calculate the true cross-rate of EUR/GBP using the dollar as an intermediary currency:

$$(\text{EUR0.76388/USD}) \times (\text{USD1.5386/GBP}) = \text{EUR1.1753/GBP}$$

as in Exhibit 2.7. This is 1.71% larger than the rate quoted in Example 2.1 of EUR1.1555/GBP. Traders in the foreign exchange market will quickly capitalize on such a situation, figuring out which direction to move around the triangle in order to make a profit. David Sylvian made money by going in the clockwise direction; he first sold euros for pounds, then obtained dollars with the pounds, and finally euros with dollars. He knew this was the way to go because he compared the direct revenue in pounds (GBP0.86543/EUR) with the implied one we computed using the dollar:

$$1/[\text{EUR1.1753/GBP}] = \text{GBP0.85085/EUR}$$

You should convince yourself that going in the counterclockwise direction loses money. Three things are important to note about triangular arbitrage. First, to be an effective arbitrage, the transactions must all be conducted simultaneously. Because it is not physically possible to do all three transactions simultaneously, there is some risk involved in any attempted triangular arbitrage because prices might change between transactions. Second, as traders place orders to conduct the arbitrage in Exhibit 2.7, market forces are created that bring the quoted direct cross-rate back into alignment with the indirect cross-rate—the rate we calculated. In our example, we have

$$\text{GBP0.86543/EUR} > \text{GBP0.64994/USD} \times \text{USD1.3091/EUR}$$

As traders sell euros for pounds to conduct the arbitrage, the supply of euros (that is, the demand for pounds) increases in this market, which tends to drive down the GBP/EUR rate. Selling pounds for dollars tends to drive up the GBP/USD rate because it increases the supply of pounds (demand for dollars) in this market, and selling dollars for euros tends to drive up the USD/EUR rate because it increases the supply of dollars (that is, the demand for euros) in this market. Eventually, the two sides of the equation will once again equal one another. At that point, arbitrage profits will no longer be possible.

The third point is that the arbitrage need not start by using the euro to purchase pounds. The triangular arbitrage would be profitable starting from any of the currencies, as long as we trade in the same direction and go completely around the triangle.

Example 2.2 Ringgits and Bahts

Suppose you would like to know the Thai baht (THB) price of the Malaysian ringgit (MYR). For these emerging market currencies, it is unlikely that cross-rate quotes will be available except possibly at Thai or Malaysian banks. However, quotes relative to the dollar are easy to find. For example, the December 21, 2010, Reuters quotes were as follows:

$$\text{MYR3.1348}/\$$$

$$\text{THB30.157}/\$$$

By using triangular arbitrage, we would expect the THB/MYR exchange rate to be

$$(\text{THB30.157}/\$)/(\text{MYR3.1348}/\$) = \text{THB9.6201}/\text{MYR}$$

Of course, in our examples, we ignored bid–ask spreads, the main source of transaction costs in the forex market. From our discussion in the next section, you will see that the bid–ask spreads in the spot foreign exchange market are quite small and are often ignored in this book. We also assume that triangular arbitrage works perfectly from now on.

2.3 Inside the Interbank Market I: Bid–Ask Spreads and Bank Profits

A foreign exchange trader is typically responsible for buying and selling a particular currency or a small group of currencies and holds an inventory or portfolio of positions in those currencies. One reason for the activity in the interbank market is that forex traders at one bank use forex traders at other banks to adjust their portfolios in response to transactions that arise from their customers in the corporate market. They also trade with other banks to try to make a profit, and their desired positions in various currencies change in response to the news events of the day.

For example, suppose corporate customers buy yen from a trader at Deutsche Bank. The trader's inventory is now imbalanced, and the trader is likely to use the interbank market to buy yen, thereby "passing along" the original corporate order. For example, after completing the corporate trade, the Deutsche Bank trader may enter the interbank market to buy yen from Nomura to replenish his inventory of yen. The repeated passing of inventory imbalances among dealers has been dubbed "hot potato trading" and may be one reason for the large volumes we see in the interbank market (see Lyons, 2001).

Bid–Ask Spreads

Ultimately, traders in the interbank market try to buy and sell various foreign currencies with the goal of generating profits. To do so, they quote two-way prices. The **bid rate** is the rate at which they want to buy a base currency (to remember this, think *b* for buy), and the **ask rate** is the rate at which they sell base currency (think *s* for sell). The difference between these two rates is known as the **bid–ask spread**. The bid price is always less than the ask price because the trader bids for the base currency when they buy it and asks a price for the base currency when they sell it. Let's illustrate the concept of bid–ask spreads with an example.

Example 2.3 Yen–Dollar and Dollar–Yen Bid and Ask Rates

A yen–dollar bank trader would quote a bid price of yen per dollar at which she is willing to buy dollars in exchange for yen of, say, ¥110.25/$. The trader would then quote a higher ask price of yen per dollar (also called the **offer price**) at which she is willing to sell dollars for yen, say, at an exchange rate of ¥110.30/$. In this latter transaction, the trader can be said to be offering dollars, the base currency in the denominator, to the market, and she is willing to accept yen in return.

What are the dollar per yen bid and ask rates? The bid rate is the dollar price of yen at which the bank trader is willing to buy yen with dollars from the market, and the ask rate is the dollar price at which the bank trader is willing to sell yen for dollars to the market. Since buying yen from the market is equivalent to selling dollars to the market, the dollar per yen bid rate must be the reciprocal of the yen per dollar ask rate, $[1/¥110.30/\$]^{ask} = (\$0.009066/¥)^{bid}$. Similarly, selling yen to the market is the equivalent of buying dollars from the market, thus $[1/(¥110.25/\$)^{bid}] = (\$0.009070/¥)^{ask}$

We can summarize the reciprocal nature of bid–ask spreads with a line diagram, as represented in Exhibit 2.8. Each node in the diagram represents a currency at a point in time. In Exhibit 2.8, we have only the dollar and the yen at the current time period.

The arrows indicate the direction of sale. The exchange rates under the arrows are direct revenues to the seller (in terms of the currency at the next node) from selling one unit of the currency at the starting node. We take the perspective of the seller being a corporation or a client (with foreign currency) and the buyer being a bank trader. In selling yen for dollars, the seller will receive the bid price of $(\$ \text{ per } ¥)^{bid}$, which is the reciprocal of the bank's ask yen price per dollar. That is

$$(\$ \text{ per } ¥)^{bid} = 1/(¥ \text{ per } \$)^{ask}$$

The person selling yen to the bank for dollars gets the lower dollar bid price because the bank trader buying yen with dollars wants to make a profit when reselling the yen she obtains. Similarly, in going from dollars to yen, the seller of dollars to the bank receives the bank's bid price of $(¥ \text{ per } \$)^{bid}$, which Exhibit 2.8 demonstrates is the reciprocal of the bank's ask price of dollars for yen. That is,

$$(¥ \text{ per } \$)^{bid} = 1/(\$ \text{ per } ¥)^{ask}$$

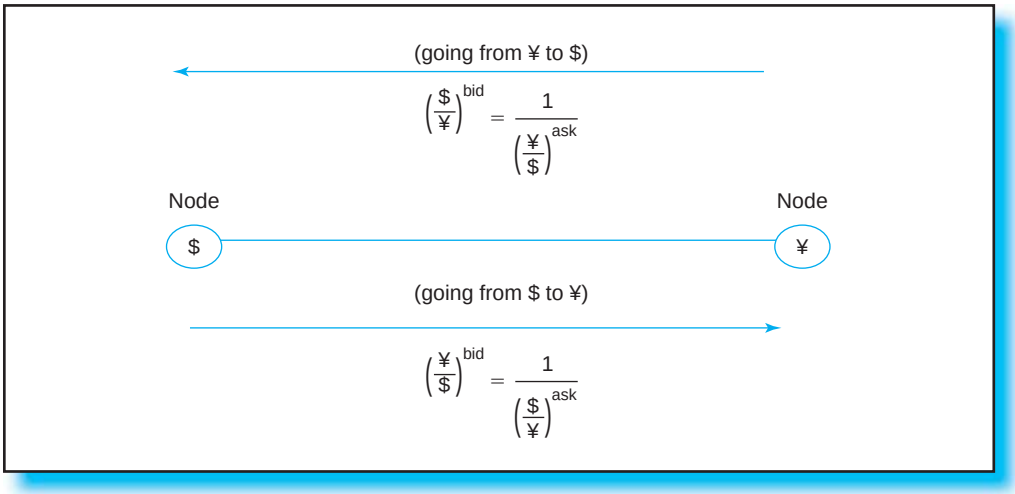
If you are confused about whether to use the bid or ask exchange rate in a particular transaction, just remember that you will *always* transact with the bank to your disadvantage. If you are purchasing dollars with yen, you will have to pay the high price of ¥ per $, which is the bank's ask price for dollars. Similarly, if you are selling dollars to the bank to obtain yen, you will get the low price of ¥ per $, which is the bank's bid price for dollars.

The Magnitude of Bid–Ask Spreads

The competitive nature of the foreign exchange market and the growth of electronic trading have greatly compressed bid–ask spreads over the last decade. In the interbank market, spreads for major currencies have become negligible.

Even in the customer market, bid–ask spreads are now also within 5 "pips" for the major currencies and large transaction sizes. **Pip** is trader jargon for the fourth decimal point in a currency

Exhibit 2.8 The Reciprocal Nature of Bid and Ask Exchange Rates



Notes: The exchange rates beneath the arrows indicate the amount of currency at the head of the arrow obtained by selling one unit of the currency at the tail of the arrow to the bank. We take the perspective of a corporation or individual at the starting node and a bank trader at the ending node.

quote.[2] For example, Exhibit 2.5 shows that the USD/EUR quote on December 21, 2010, is \$1.3096/€. Assuming a spread of 2 pips and taking the \$1.3096/€ rate as the midpoint, the ask rate is \$1.3097/€ and the bid rate is \$1.3095/€. Therefore, 1 pip reflects 1/100 of a U.S. cent in this case. However, to get an idea of transaction costs involved in trading currencies, it's better to express the bid–ask spread in percentage points. The percentage bid–ask spread is computed as:

$$\text{Percentage spread} = \frac{(\text{ask} - \text{bid})}{\text{midpoint}}$$

Hence, for the example, we obtain

$$\frac{1.3097 - 1.3095}{1.3096} = 0.00015$$

That is, the bid–ask spread represents 0.015% or 1.5 basis points. The difference between the ask price and the bid price actually represents two transaction costs. In the first transaction, you buy from a bank at its ask price; then you turn around and sell to another bank at its bid price. To understand how small these transaction costs are, consider the following example.

Example 2.4 Paying the Bid–Ask Spread

Suppose the treasurer of a U.S. company purchases pounds with dollars in anticipation that the manufacturing manager will want to purchase some British goods, but the treasurer is told immediately after the purchase of the pounds that the deal for the goods is off. The treasurer then sells the pounds back to the bank for dollars. Because the treasurer bought pounds at the bank's ask price of \$/£ and immediately sold the pounds

[2]For the currencies not trading around a value of 1, the convention is different. For example, for a quote of ¥110.25/\$, a pip represents 0.01.

back to the bank at the bank's bid price of \$/£, the treasurer has made two transactions and has lost the bid–ask spread on every pound bought and sold. (Of course, this presupposes that the quoted exchange rates did not change.)

Assume that the percentage bid–ask spread the treasurer faced for the pound–dollar exchange rate is 4 pips. If the ask rate is \$1.50/£, then the bid rate is \$1.4996/£, and the percentage spread is:

$$[(\$1.50/£) - (\$1.4996/£)]/(\$1.4998/£) = 0.03\%$$

Thus, if the treasurer bought, say, £1,000,000 at \$1.5000/£, the cost would have been

$$£1{,}000{,}000 \times (\$1.5000/£) = \$1{,}500{,}000$$

Selling £1,000,000 back to the bank at the bank's bid price for pounds of \$1.4996/£ would provide

$$£1{,}000{,}000 \times (\$1.4996/£) = \$1{,}499{,}600$$

Hence, the treasurer would lose \$400 on the two transactions, which is 0.03% of \$1.5 million.

The cheapest currencies to trade are the major ones like the EUR versus USD (with spreads sometimes as low as 1 pip), the GBP versus USD, and the USD versus JPY. The most liquid currencies, typically trading at less than 10 pips, are called the "G10" currencies and also include the AUD, CHF, CAD, NZD, SEK, and NOK (see Exhibit 2.4 for the meaning of these acronyms). Emerging market currencies trade at higher spreads.

Bid–ask spreads are not constant over time and even vary through the day. Traders seek to profit from their currency positions on a daily basis and do not want to be stuck with large open positions at the end of the day. Varying the magnitude of the bid–ask spread as a function of market conditions helps traders manage their inventory risk. For example, when markets are more volatile (that is, exchange rate values are undergoing relatively large changes), bid–ask spreads tend to increase. The effect of volatility is even apparent within each trading day, with spreads being wider at the open or close of particular markets (because there is more uncertainty then) or around the time important economic statistics are released.

The volatility in currency markets varies considerably through time, as was abundantly clear during the 2008 global financial crisis. After Lehman Brothers failed, volatility in the foreign exchange market rose to unprecedented heights, increasing bid–ask spreads on the major currencies by a factor of 4 to 5 times (see Melvin and Taylor, 2009).

Bid–ask spreads also vary with the nature of the particular customer order. For example, bid–ask spreads tend be lower for larger orders. While processing costs could explain this size pattern, recent research suggests that dealers tend to pay for informative order flow in the form of lower spreads (see, for example, Mende et al., 2007; Osler, 2009; and Ding, 2009). Foreign exchange dealers use information in order flow to speculate on foreign exchange movements and manage the risk of their trading books. Recent research also finds that financial customers obtain better spreads than corporate customers and that better performing money managers obtain better spreads than poorly performing ones (see Ramadorai, 2008; and Bjonnes and Rime, 2005).

While retail customers can now also obtain competitive spreads on certain online trading Web sites, spreads for exchanging physical currencies in the tourist market continue to be quite large at 5% or more. Banks and currency exchanges quote larger bid–ask spreads in this market because they must hold physical inventories of different monies, and these inventories are not interest bearing. They must also transact with brokers who move physical amounts of currencies between different countries in response to excess supplies and demands. It is interesting to note that using credit cards when traveling as a tourist actually saves on transaction costs because the credit card companies give their customers an exchange rate that is quite close to the interbank rate on the day of the transaction. However, be careful because some card companies also charge steep fees for international transactions.

POINT–COUNTERPOINT

Are Speculative Trading Profits in the Foreign Exchange Market Excessive?

The top foreign exchange banks, such as Deutsche Bank, UBS, Barclays, and Citibank, earn billions of dollars per year from foreign exchange trading. Our two sidekick brothers engage in a heated discussion of this fact. Ante Handel views these profits as a typical example of speculative excess. "Compare the dollar volume of interbank foreign exchange trading to the dollar volume of international trade flows," he fumes. "The difference is enormous. All that trading only makes the banks rich, and it causes exchange rates to be more volatile than they should be, which hurts our exporters. The government ought to tax speculative trading and make sure our banks simply support our exporters, who need these foreign currencies," he concludes.

Freedy Handel, on the other hand, claims that foreign exchange dealers are primarily market makers who trade with one another to adjust their portfolios in response to fundamental buy and sell transactions from the corporate world. "These banks' profits are simply the normal reward for providing liquidity in a market, and liquidity is of vital importance to the well-being of our economy," he politely argues.

As often happens, their cousin, Suttle Trooth, comes in and reconciles their differences by analyzing the available facts. "First," Suttle says, "Freedy, you are wrong in presuming that banks do not speculate. There is plenty of evidence that they do." (In this book, we will encounter several examples of speculative trading strategies that major banks follow in order to profit from exchange rate movements. As we mentioned in this section, large banks may attempt to exploit information from their order flow to predict exchange rate movements and develop a position before their competitors do. Many banks apparently attempt to profit from short-term, within-the-day, trading strategies.)

"Second," Suttle continues, "Ante, you are wrong to conclude that the profits are necessarily due to speculative excess. If most of the enormous trading volume in the foreign exchange market is trading between banks, you should realize that as a whole, the interbank market cannot profit from interbank trades. Interbank trading is a 'zero sum' game: Some other bank must lose every dollar one bank gains."

"Third," Suttle goes on, "Freedy might be right to think that market making alone may indeed lead to substantial profits for foreign exchange dealers because of the huge trading volumes. Let's make a quick back-of-the-envelope computation." Suttle produces the following numbers. Suppose that 50% of all trading is between banks and their customers. In 2010, Citibank's share of the total market is 7.69%. Hence, if total volume in the foreign exchange market is $3.9 trillion, the volume of transactions per day handled by Citibank is

$$0.0769 \times \$3.9 \text{ trillion} = \$299.9 \text{ billion}$$

However, 50% of these transactions involve other foreign exchange dealers, and we assume that overall, Citibank does not earn money on these deals. However, it does earn the bid–ask spread from dealing with corporate and other customers, which represents 50% of their market or $0.50 \times \$299.9$ billion $= \$149.96$ billion.

If a typical bid–ask spread is 0.015%, the annual revenue from pure market making is

$$\$149.96 \text{ billion/day} \times \frac{1}{2} \times (0.015/100) \times 250 \text{ trading days/year} = \$2.812 \text{ billion/year}$$

The $\frac{1}{2}$ arises because the volume applies to both sell and buy transactions, and Citibank needs a round-trip transaction to earn the full spread. Of course, these numbers represent revenues, not profits. Moreover, it is also possible that part of the customer flow is no longer intermediated by forex dealers, given the rapid growth in "eFX."

Yet, for a number of reasons, this estimate still probably understates Citibank's earnings from providing liquidity services in the foreign exchange market. First, we used indicative spreads for large transaction sizes for major currency pairs. Smaller orders and transactions involving other currency pairs carry higher spreads. Second, spreads are much higher for less liquid emerging currencies, in which Citibank tends to have a larger market share. Finally, spreads are larger on the part of the foreign exchange trading volume that involves forward contracts and other derivative contracts. Given our computations, it seems very likely that the bulk of Citibank's profits arise from its market-making function and not from its taking of speculative positions.

Several academic studies have examined whether speculative position taking was a major source of earnings from foreign exchange trading for a number of banks.[3] While there are some caveats to these studies, they all confirm that most profits come from conventional market-making activities rather than from speculation.

While Suttle's arguments have reconciled our two brothers on their main points of disagreement, Suttle has to concede that he is not sure whether the taking of speculative positions by banks could drive up exchange rate volatility, as Ante claimed. He promises to revisit this issue in later chapters.

2.4 Inside the Interbank Market II: Communications and Fund Transfers

The enormous volume of trade in the foreign exchange market requires an extensive communication network between traders and a sophisticated settlement system to transfer payments in different currencies between the buyers and sellers in different countries.

Communication Systems

Until the introduction of computers in the 1970s, the participants in the foreign exchange market communicated with their clients and each other on the telephone and via telex. Today, traders watch information displayed on computer screens, provided by major commercial information distributors such as Reuters and Bloomberg. The firms distributing financial information have long provided information about market prices of different currencies that is *not* contractually binding. Traders then contact each other to obtain actual prices and negotiate deals. For example, suppose Citibank wants to obtain a large number of euros. Citibank has three avenues to conduct a trade. First, it may contact traders at other major banks, such as BNP Paribas. Second, it may contact a foreign exchange broker to obtain quotes and broker a deal. Third, Citibank can trade on an electronic brokerage system, where quotes on a screen are transactable.

When a trade is agreed upon, banks communicate and transfer funds electronically through computer networks. The most important interbank communications network is the **Society of Worldwide Interbank Financial Telecommunications (SWIFT)**, which began operations in Europe in 1973 and is jointly owned by more than 2,000 member banks. The SWIFT network links more than 9,000 financial institutions in more than 200 countries. Banks use SWIFT to send and receive messages pertaining to foreign exchange transactions, payment confirmations, documentation of international trade, transactions in securities, and other financial matters. In particular, SWIFT is used to confirm foreign exchange deals agreed upon on the phone. In 2010, SWIFT's global network processed close to 4 trillion messages.

[3]See, for example, Ammer and Brunner (1997), Lyons (1998), and Mende and Menkhoff (2006).

After the verbal deal is electronically confirmed over SWIFT, the deal also has to be settled. Citibank will transfer dollars to BNP Paribas in the United States, and Citibank will receive euros from BNP Paribas in Europe. The transfer of dollars will be done through the **Clearing House Interbank Payments System (CHIPS)**, and the transfer of euros will be done through the **Trans-European Automated Real-time Gross Settlement Express Transfer (TARGET)**.

CHIPS is a private-sector system, owned and operated by The Clearing House Interbank Payments Company L.L.C. (CHIPCo), whose membership consists of many of the world's largest commercial banks. CHIPS is an electronic payment system that transfers funds and settles transactions in U.S. dollars. It is the central clearing system in the United States for international transactions, handling the bulk of all dollar payments moving between countries around the world. On a typical day in New York, about $1.5 trillion in business payments pass through CHIPS computers. This amount corresponds to more than 350,000 international transactions, such as foreign trade payments, foreign exchange transfers, securities settlements, and money market transactions, as well as a growing number of domestic payments. CHIPS participants receive same-day settlement of funds through a special Fedwire account at the Federal Reserve Bank of New York.

Fedwire is a real-time gross settlement (RTGS) system operated by the Federal Reserve System of the United States. Fedwire links the computers of more than 7,000 U.S. financial institutions that have deposits with the Federal Reserve System. Transactions on Fedwire instantly move dollar balances between financial institutions. A transfer occurs when the originating office transmits a message to a Federal Reserve Bank, indicating who the paying and receiving banks are. The Federal Reserve Bank then debits the account of the paying bank and credits the account of the receiving bank. "Real time" means that the transactions are settled as soon as they are processed, and "gross settlement" means that the transactions are settled on a one-to-one basis without bunching or netting with other transactions.

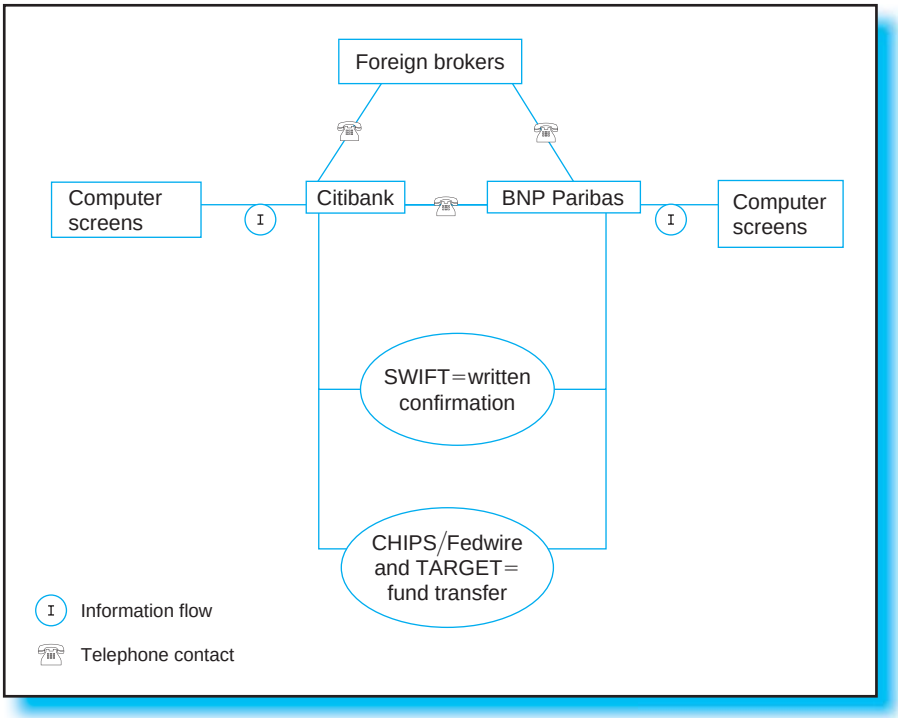
Transactions on CHIPS are facilitated with a universal identifier (UID), a unique identification number for a bank or a corporation that tells the CHIPS system what private account and bank information to use for sending or receiving payments. Because Citibank owes dollars to BNP Paribas, it uses BNP Paribas's UID to ensure that it is paying to the right account.

Cross-border transactions in euros are facilitated through the Trans-European Automated Real-time Gross settlement Express Transfer (TARGET2) system, which is the euro counterpart of Fedwire. For each of the European countries using the euro, the national RTGS systems were superseded by an international RTGS system (TARGET2) run through the European Central Bank. Hence, BNP Paribas would indicate to TARGET2 that it was paying euros to a particular European Citibank office, and TARGET2 would debit BNP Paribas's account and credit that of Citibank. The system also allows clearing of foreign exchange transactions between the members of the European Union that do not use the euro and those that do, although Sweden and the United Kingdom do not participate in TARGET2. Switzerland links to the euro through the Swiss Interbank Clearing (SIC) system. Exhibit 2.9 summarizes the communication systems used in the foreign exchange market, using two banks, Citibank and BNP Paribas, as an example.

Cross-Currency Settlement (or Herstatt) Risk

Of course, the settlement of a foreign exchange trade requires the payment of one currency and the receipt of another. However, the settlement procedures described previously do not guarantee that the final transfer of one currency occurs if and only if the final transfer of the other currency occurs as well. Because foreign currency transactions often involve the payment systems of two countries in different time zones, simultaneous exchange of currencies

Exhibit 2.9 Communication Systems in the Forex Market



is difficult. The risk that only one leg of the transaction may occur is very real. It is known as **cross-currency settlement risk**, or **Herstatt risk**.

The term *Herstatt risk* derives from the first modern occurrence of settlement risk. On June 26, 1974, Bankhaus Herstatt, a small bank in Cologne, Germany, went bankrupt at a very inopportune time for some of its foreign exchange trading partners. Herstatt had purchased Deutsche marks with dollars, and it was expected to wire dollars to various trading partners in the United States that day in return for the Deutsche marks. But that same day, the German regulatory authorities withdrew Herstatt's banking license and ordered it into liquidation after several of its U.S. counterparties in the foreign exchange market had irrevocably paid Deutsche marks to Herstatt. However, Herstatt had not yet delivered the U.S. dollars it owed its trading partners because the U.S. trading day had only just begun. After Herstatt's closure, its New York correspondent bank suspended outgoing U.S. dollar payments from Herstatt's account.

Herstatt risk is thus the risk that a bank will fail to deliver on one side of a foreign exchange deal even though the counterparty to the trade has delivered its promised payment. With the growing volumes of foreign exchange trading, the major central banks have understandably been worried about the ramifications of another Herstatt crisis. In particular, there is fear among government authorities that a large settlement failure could create an international liquidity crisis and jeopardize the health of the worldwide financial system.

Indeed, after the 1974 Herstatt event, several U.S. banks suddenly faced a short-term liquidity crisis because the millions of dollars they expected to receive failed to materialize. Daily gross funds transfers in the United States fell by half. Fortunately, the crisis was short-lived. The banks gradually regained confidence in each other, and normal operations soon resumed, indicating that the banks were basically solvent despite their losses from Herstatt's failure to deliver.

With the explosion in trading volume that is occurring today, systemic risk is much larger. Central banks worry that foreign exchange trading is so large that even highly capitalized major banks could be wiped out by a Herstatt-style event. Recently, foreign exchange dealers, encouraged by the BIS, have developed a number of practices to limit settlement risk. First, banks now have strict limits on the amount of transactions they are willing to settle with a single counterparty on a given day. This generally helps curtail Herstatt risk.

Second, banks have started to engage in a variety of netting arrangements, in which they agree to wire the net traded amounts only at the end of a trading day. That is, a series of gross currency payments going both ways are converted into a single netted payment. When Citibank owes JPMorgan Chase $50 million from one foreign exchange transaction, and JPMorgan Chase owes Citibank $30 million from another transaction, it sounds reasonable to have only one wiring of funds from Citibank to JPMorgan Chase for the net amount of $20 million rather than to have JPMorgan Chase wire $30 million to Citibank and Citibank wire $50 million to JPMorgan Chase. **Bilateral netting** reduces the amount of settlement risk by lowering the number and size of payments that would otherwise be needed to settle the underlying transactions on a trade-by-trade basis. SWIFT has recently started to offer netting services for its users.

In the 1990s, several financial institutions set up organizations that offered multilateral netting services. The multilateral systems take all of a given bank's foreign exchange payments with other members of the system and then net them down to a single payment. This results in a further reduction in the number of payments actually required at the end of the day.

To illustrate these various netting arrangements, suppose that, in addition to Citibank and JPMorgan Chase, Bank of America participates in a multinetting system. Suppose Bank of America owes Citibank $30 million and is owed $20 million by JPMorgan Chase. Exhibit 2.10 illustrates this numeric example to demonstrate how gross flows, in which every payment is made, differ from the payments made under both bilateral and multilateral netting.

When there is no netting at all, the gross flows equal the sum of all transactions $(30 + 20 + 50 + 30 = 130)$. Under bilateral netting, Citibank and JPMorgan Chase recognize that one payment between them ($20 million from Citibank to JPMorgan Chase) settles their net position, reducing the gross flows to $70 million. With all three banks in the netting organization, JPMorgan Chase does not have to pay anything because it owes Bank of America 20, but it is owed 20 by Citibank. The netting organization simply settles the overall net debt and credit positions, significantly reducing the amount of payment flows between banks.

Third, settlement risk is eliminated if the exchange of the two monies happens simultaneously in a process known as payment versus payment (PvP). The dream of a global clearing bank that would ensure the simultaneous settlement of all currency transactions between members of its system became a reality with the establishment of CLS Bank in 2002. CLS Bank (where CLS stands for *Continuous Linked Settlement*) is owned by the world's largest financial groups. CLS Bank collects details of all the currency trades between its member banks, uses multilateral netting to figure net payments for each bank, and finalizes pay-ins and pay-outs to the system over a 5-hour window. This window represents the overlapping hours of the participating settlements systems. Because of its multilateral netting feature, CLS estimates that for each $1 trillion of value settled, only $50 billion has to be transferred between counterparties.

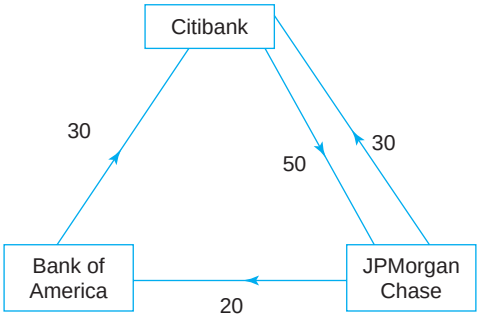
While CLS Bank is a private institution, its creation and operation require unprecedented cooperation between central banks, as the accounts that the financial institutions hold at central banks are used for all the transactions. The Federal Reserve organizes and administers the CLS Oversight Committee on behalf of the other participating central banks, and CLS bank now covers 17 currencies, including the G10 currencies and the currencies of Denmark, Hong Kong, Israel, Mexico, Singapore, South Korea, and South Africa. CLS Bank handles over 1.5 million transactions per day. Recent data suggest that well over 50% of foreign exchange trades are now settled through CLS bank, but over 30% of transactions still use the classic correspondent banking model. The CLS bank continued to operate seamlessly throughout the 2007 to 2010 global crisis, facing in fact record levels of transactions.

Exhibit 2.10 Netting Arrangements

Situation

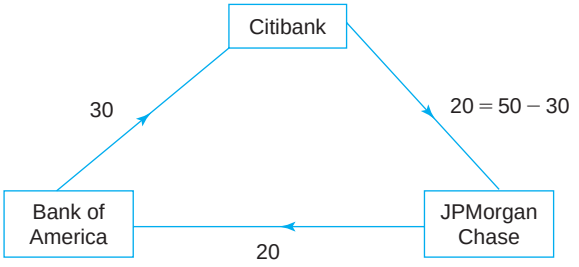
- Citibank owes JPMorgan Chase $50 million from a foreign exchange deal.
- JPMorgan Chase owes Citibank $30 million from another foreign exchange deal.
- Bank of America owes Citibank $30 million from a foreign exchange deal.
- JPMorgan Chase owes Bank of America $20 million from another foreign exchange transaction.

Cash flows under no netting



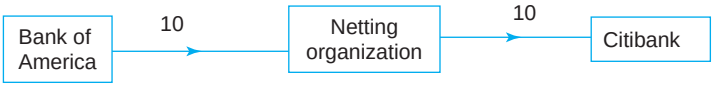
Total flows: 30 + 20 + 50 + 30 = 130 million

Cash flows under bilateral netting



Total flows: 30 + 20 + 20 = 70 million

Cash flows under multilateral netting



Total flows: 10 + 10 = 20 million

2.5 Describing Changes in Exchange Rates

Section 2.3 explains how exchange rates are quoted at one point in time. Now, we turn to the topic of how to describe changes in exchange rates that occur over time. The first thing to remember about describing changes in exchange rates is that they are relative prices. Consequently, there are always two ways to describe the same situation. After

the change in the exchange rate, it will always be true that it takes relatively less of one currency to purchase the other currency and relatively more of the latter currency to purchase the former.

Consider an example. Suppose the exchange rate between the dollar and the yen changes from ¥120/$ to ¥100/$. Because it now takes fewer yen to purchase the dollar, the yen is said to have *strengthened*, or appreciated, in value relative to the dollar. The dollar consequently is said to have *weakened*, or depreciated, in value relative to the yen. After this depreciation of the dollar, it will take more dollars to purchase a given number of yen. Formerly, at ¥120/$, it took $8,333.33 to purchase ¥1,000,000. Now, at ¥100/$, it takes $10,000.00 to purchase ¥1,000,000. The terms **appreciation** and **depreciation** are typically used to describe changes in exchange rates when exchange rates are allowed to be flexible—that is, to fluctuate freely in response to changes in demand and supply.

Sometimes, the government authorities of a country "fix," or "peg," the exchange rate of their money relative to a foreign money. (We discuss how they do this in Chapter 5.) Discrete changes in the values of exchange rates under such a fixed exchange rate system are called **devaluations** and **revaluations** of the currencies. If the monetary authorities increase the domestic currency price of foreign exchange, they are *devaluing* their money. Such actions increase the domestic currency prices of foreign monies and are often the result of a failure in government policy. One famous historical devaluation occurred in November 1967, when Britain devalued the pound relative to the dollar by changing the price from $2.80/£ to $2.40/£, or by over 14% $[(2.40 - 2.80)/2.80 = -14.29\%]$.

If the dollar prices of foreign imports into Britain remain constant after such a devaluation, the pound prices of foreign goods will rise with the devaluation. This is because, after the devaluation, it takes more pounds to purchase a given number of dollars. Similarly, if the pound prices of British export goods remain constant after the devaluation, the dollar price of British goods will fall after the devaluation.

The simple logic that a devaluation increases the prices of foreign goods relative to domestic goods for domestic residents and decreases the relative prices of domestic goods to foreign buyers makes devaluations a tempting way for government authorities to try to "cure" unemployment problems in a country at the expense of the country's consumers. By devaluing their currency, which changes the relative prices of goods, the government induces more foreign demand for the domestic goods produced in its country. Unfortunately, the policy does not always work because the prices of goods are not fixed. They can adjust rapidly in response to devaluations. In addition, if a devaluation does work, it can lead to a cycle of competitive devaluations as countries across the world try to gain a competitive advantage in international trade.

If the authorities of a country decrease the domestic currency price of foreign exchange, they are said to be *revaluing* the country's money. For example, in October 1969, Germany lowered the DEM price of the dollar from DEM4/$ to DEM3.66/$, a change of $8.5\% = (4 - 3.66)/4.0$. This action decreased the DEM cost of imports to Germany and increased the dollar cost of goods exported from Germany. If a revaluation changes the relative prices across countries, it benefits domestic consumers but hurts domestic workers and producers. This is because the goods and services produced in the country have to compete with imports that have become cheaper after the revaluation. In recent years, the U.S. government has exerted much political pressure on the Chinese government to revalue its currency relative to the dollar and other Western currencies, claiming that its weak currency gives Chinese companies an unfair trade advantage.

Example 2.5 Baseball Caps in Turkey

Suppose a Turkish importer buys American baseball caps for $10 per cap. The exchange rate is 685,000 Turkish lira (TRL) per dollar, and the baseball caps are put up for sale in Ankara, with a 50% markup over the export price. Hence, the price of the baseball caps for Turkish consumers is

$$\$10 \times \text{TRL}685{,}000/\$ \times 1.50 = \text{TRL}10{,}275{,}000$$

The Turkish lira was pegged to a "basket" (combination) of the dollar and the euro until February 23, 2001. A political crisis earlier that week led to a financial crisis: Interest rates soared, and the Turkish stock market plummeted. On February 23, the Turkish government let the lira "float," or fluctuate, rather than keep it pegged to the dollar–euro basket. In just 1 day, the value of the dollar increased to TRL962,499/$, which represents a 40.51% increase in the value of the dollar relative to the lira. If the baseball cap export price and the markup remain unchanged, the Turkish lira price becomes

$$\$10 \times \text{TRL}962{,}499/\$ \times 1.50 = \text{TRL}14{,}437{,}402$$

This increase in price should certainly decrease the demand for baseball caps in Turkey. In 2005, the Turkish government dropped 6 zeroes from the lira, and the Turkish lira traded at a rate of TRL1.5591/$ on December 21, 2010.

Rates of Appreciation and Depreciation

Now that you know how to describe the movements in exchange rates, you can quantify those changes. The rate of appreciation or depreciation of one currency relative to another can be calculated as the percentage rate of change of the exchange rate:

$$\frac{(\text{New exchange rate} - \text{Old exchange rate})}{\text{Old exchange rate}}$$

It is important to note that technically, the description of an appreciation or a depreciation refers to the currency that is in the denominator of the exchange rate. For example, for dollar–pound exchange rates, the percentage change in the exchange rate describes an appreciation or a depreciation of the pound:

$$\text{Percentage appreciation or depreciation of the pound} = \frac{(\text{new \$ per £}) - (\text{old \$ per £})}{(\text{old \$ per £})}$$

For example, if the exchange rate changes from $2.00/£ to $2.50/£, the pound is said to have appreciated relative to the dollar by 25%:

$$25\% = \frac{(\$2.50/£) - (\$2.00/£)}{(\$2.00/£)}$$

Now, let's examine the rate of depreciation of the dollar relative to the pound in the same situation. Unfortunately, it will turn out to be a slightly different percentage change. Because the old exchange rate of pounds per dollar is £1/$2.00 = £0.50/$, and the new exchange rate is £1/$2.50 = £0.40/$, the dollar is said to have depreciated relative to the pound by 20%, because

$$\frac{(£0.40/\$) - (£0.50/\$)}{(£0.50/\$)} = -20\%$$

The fact that these rates of appreciation and depreciation are not the same causes some confusion. The explanation for the difference begins with the observation that the exchange rate quoted in direct terms from the U.S. perspective is the reciprocal (inverse) of the exchange rate quoted in indirect terms. Let $S(t, \$/£)$ be the dollar–pound exchange rate at time t. Then, the rate of appreciation of the pound relative to the dollar is $\frac{S(t+1, \$/£) - S(t, \$/£)}{S(t, \$/£)}$. If we want to find the rate of appreciation of the dollar relative to the pound, we must consider the indirect quotes. Let us denote these exchange rates with a different symbol, $E(t, £/\$)$. Then, the rate of appreciation of the dollar relative to the pound is $\frac{E(t+1, £/\$) - E(t, £/\$)}{E(t, £/\$)}$. But, by definition, the indirect and direct quotes are each other's reciprocal, $S(t, \$/£) = 1/[E(t, £/\$)]$. Hence, the rate of appreciation of the dollar relative to the pound can be rewritten as $\frac{[1/S(t+1, \$/£)] - [1/S(t, \$/£)]}{[1/S(t, \$/£)]}$. If we multiply the numerator and the denominator of the rate of appreciation of the dollar by $S(t, \$/£)$, we find

$$\frac{S(t, \$/£)}{S(t+1, \$/£)} - 1 = \frac{S(t, \$/£) - S(t+1, \$/£)}{S(t+1, \$/£)}$$

Hence, the numerator in the rate of appreciation of the dollar is the negative of the numerator in the rate of appreciation of the pound, but the denominators are different. One uses the exchange rate at time t, and the other uses the exchange rate at time $t+1$.

While the distinction in terminology (that appreciation or depreciation refers to the currency in the denominator of the exchange rate) may seem like little more than an annoying and potentially confusing curiosity, the different descriptions are sometimes used for political purposes, which makes the distinction important to understand.[4] In Greece, before the advent of the euro, for example, different newspapers tended to describe the change in the exchange rate in the way that was most favorable to the political party that the newspaper supported. For example, suppose the Greek drachma value of the dollar rose from GRD200/\$ to GRD220/\$. Newspapers that wanted to heighten concern about the event would report "Dollar Strengthens Relative to Drachma by 10%," while newspapers that wanted to reduce concern would announce "Drachma Weakens Relative to Dollar by 9%." You should be able to explain why these statements actually describe the same event.

Continuously Compounded Rates of Appreciation (Advanced)

It turns out that using continuously compounded rates of change reconciles the two descriptions of the same event and makes them equal but opposite in sign. Let's look at what happens to the description as we change the time interval over which the event happened. For example, if the appreciation of the pound, from \$2.00/£ to \$2.50/£, took place over the course of a year, we would say that the annual rate of appreciation of the pound was 25%. That is, to go from the old rate at the end of a year to the new rate at the end of the current year requires multiplication by 1.25:

$$(\$2.00/£) \times (1.25) = (\$2.50/£)$$

If portfolio decisions are made monthly, we might also be interested in describing the rate of appreciation on a compound monthly basis while still expressing the percentage change at an annual rate. In this case, we ask what value of a in $[1 + (a/12)]$ when raised to the 12th power satisfies the following equation:

$$(\$2.00/£)[1 + (a/12)]^{12} = (\$2.50/£)$$

[4]Thanks to Ekaterini Kryiazidou for this example.

To solve for a, we first divide both sides by \$2.00/£ and then take the $(1/12)$ power on each side:

$$[1 + (a/12)] = [(\$2.50/£)/(\$2.00/£)]^{1/12}$$

Try this with your calculator. Then, subtract 1 and multiply by 12. The answer is $a = 0.2256$, or an annualized compound monthly rate of appreciation of the pound of 22.56%. The annualized compound monthly rate of depreciation of the dollar, d, can analogously be calculated as

$$(£0.50/\$)[1 - (d/12)]^{12} = (£0.40/\$)$$

and we find through similar steps that $d = 0.2208$, or 22.08%. Notice that the difference in the two descriptions of the same event is now smaller.

If we drive the compounding interval smaller and smaller, we will eventually ask what continuous rate of appreciation of the pound relative to the dollar over the course of a year caused the pound to strengthen from \$2.00/£ to \$2.50/£. Continuous compounding uses the symbol e, which represents the base of natural logarithms, and the value of e rounded to five decimal places is 2.71828.[5]

Now, the annualized continuously compounded rate of appreciation of the pound is the value of a that satisfies

$$(\$2.00/£)e^{a} = \$2.50/£$$

To solve for the value of a, we take the natural logarithm of both sides of the equation and find

$$a = \ln(\$2.50/£) - \ln(\$2.00/£) = 0.2231$$

or 22.31%. Similarly, the annualized continuously compounded rate of depreciation of the dollar is the value of d that satisfies

$$(£0.50/\$)e^{-d} = £0.40/\$$$

To solve for the value of d, we take the natural logarithm of both sides of the equation and find

$$d = -[\ln(£0.40/\$) - \ln(£0.50/\$)] = 0.2231$$

or 22.31%. With continuous compounding, the rates of appreciation of the pound and depreciation of the dollar are the same.

2.6 Summary

This chapter discusses the foreign exchange market. The main points in the chapter are as follows:

1. The foreign exchange market is a large, over-the-counter market composed of banks and brokerage firms and their customers in the financial centers of countries around the world. Volume of trade in the market is estimated to be almost \$4 trillion on active days.
2. The traditional phone-based system, where trades are agreed upon over the phone and confirmed later, is increasingly being supplanted by electronic trading.
3. The foreign exchange market is very competitive, with no single bank dominating the worldwide trading of currencies, but the top three banks nonetheless capture more than 40% of the trading volume.

[5]The appendix to this chapter discusses logarithms and continuous compounding.

4. Exchange rates—that is, the prices of currencies—are relative prices. They can be quoted in direct terms as the domestic currency price of the foreign currency (sometimes called *American terms* in the United States) or in indirect terms as the foreign currency price of the domestic currency (sometimes called *European terms* in the United States).
5. Exchange rates between two currencies that do not involve the dollar are called *cross-rates*. Triangular arbitrage keeps cross-rates in line with exchange rates quoted relative to the U.S. dollar.
6. Traders quote two-way prices in a bid–ask spread. They attempt to buy one currency at their low bid price and to sell that currency at their higher ask, or offer, price. Competition keeps bid–ask spreads in the market quite small.
7. In the interbank market, traders agree on currency transactions by phone or through electronic trading systems. Confirmation and settlement of a trade occurs later through SWIFT and CHIPS.
8. Settlement risk, the risk that one leg of the currency transaction may not occur, is also called Herstatt risk. In recent years, more and more foreign exchange transactions are settled through the CLS bank, which drastically mitigates settlement risk using a centralized, simultaneous settlement system.
9. Changes in flexible exchange rates are described as currency appreciations and depreciations. When it takes fewer yen to purchase the dollar, the yen is said to have *strengthened*, or *appreciated*, in value relative to the dollar. The dollar consequently has *weakened*, or *depreciated*, in value relative to the yen. It will take more dollars to purchase a given number of yen.

QUESTIONS

1. What is an exchange rate?
2. What is the structure of the foreign exchange market? Is it like the New York Stock Exchange?
3. What is a spot exchange rate contract? When does delivery occur on a spot contract?
4. What was the Japanese yen spot price of the U.S. dollar on December 21, 2010?
5. What was the U.S. dollar spot price of the Swiss franc on December 21, 2010?
6. How large are the bid–ask spreads in the spot market? What is their purpose?
7. What was the euro price of the British pound on December 21, 2010? Why?
8. If the direct euro price of the British pound is higher than the indirect euro price of the British pound using the dollar as a vehicle currency, how could you make a profit by trading these currencies?
9. What is an appreciation of the dollar relative to the pound? What happens to the dollar price of the pound in this situation?
10. What is a depreciation of the Thai baht relative to the Malaysian ringgit? What happens to the baht price of the ringgit in this situation?

PROBLEMS

1. Mississippi Mud Pies, Inc., needs to buy 1,000,000 Swiss francs (CHF) to pay its Swiss chocolate supplier. Its banker quotes bid–ask rates of CHF1.3990–1.4000/USD. What will be the dollar cost of the CHF1,000,000?
2. If the Japanese yen–U.S. dollar exchange rate is ¥104.30/$, and it takes 25.15 Thai bahts to purchase 1 dollar, what is the yen price of the baht?
3. As a foreign exchange trader, you see the following quotes for Canadian dollars (CAD), U.S. dollars (USD), and Mexican pesos (MXN): USD0.7047/CAD, MXN6.4390/CAD, and MXN8.7535/USD. Is there an arbitrage opportunity, and if so, how would you exploit it?
4. The Mexican peso has weakened considerably relative to the dollar, and you are trying to decide whether this is a good time to invest in Mexico. Suppose the current exchange rate of the Mexican peso relative to the U.S. dollar is MXN9.5/USD. Your investment advisor at Goldman Sachs argues that the peso will lose 15% of its value relative to the dollar over the next year. What is

Goldman Sachs's forecast of the exchange rate in 1 year?

5. Deutsche Bank quotes bid–ask rates of \$1.3005/€ –\$1.3007/€ and ¥104.30–104.40/\$. What would be Deutsche Bank's direct asking price of yen per euro?
6. Alumina Limited of Australia has called Mitsubishi UFJ Financial Group to get its opinion about the Japanese yen–Australian dollar exchange rate. The current rate is ¥67.72/A\$, and Mitsubishi UFJ thinks the Australian dollar will weaken by 5% over the next year. What is Mitsubishi UFJ's forecast of the future exchange rate?
7. Go to www.fxstreet.com, find the "Live Charts Window," and plot the exchange rate of the dollar versus the euro with a "candle stick" high–low chart at 5-minute intervals for 1 day, daily intervals for 1 month, and weekly intervals for 1 year. Now, cover the units and ask a classmate to identify the different graphs. Are you surprised?
8. Pick three currencies, and go to www.oanda.com to get their current bilateral exchange rates. Is there an arbitrage opportunity?
9. Go to the CLS Bank Web site, www.cls-group.com, and read about In/Out Swaps. How do they help participants manage their risks?

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Appendix

Logarithms

Logarithms are useful because they simplify growth calculations. The logarithm of a number is taken with respect to a particular base number, such as base 10 or base 2. The logarithm of a number X under base B is the number Y to which the base number B must be raised to make it equal to X. That is, because

$$B^Y = X$$

Base B logarithm of X is Y.

For example, if the base number is 10, and $X = 1{,}000$, then $Y = 3$, because $10^3 = 1{,}000$. Thus, in base 10, we say the logarithm of 1,000 is 3, and we can write $\log10(1{,}000) = 3$.

In finance, we often encounter the *natural logarithm*. Natural logarithms arise because of continuous compounding and discussions of growth at continuous rates.

Banks usually quote interest rates at annual rates such as 10%, and they specify a compounding period, which might be annual, semiannual, monthly, daily, or even continuously. We know that the more often the bank credits interest to our account, the more money we will have at the end of a year because we will earn interest on previously credited interest. For example, if the quoted interest rate is 10%, at the end of 1 year, we will have the following amounts, depending on the compounding interval:

Compounding Interval	**Amount in 1 Year**
Annual	$(1 + 0.1) = 1.1$
Semiannual	$(1 + (0.1/2))^2 = 1.1025$
Quarterly	$(1 + (0.1/4))^4 = 1.1038$
Monthly	$(1 + (0.1/12))^{12} = 1.1047$
Daily	$(1 + (0.1/365))^{365} = 1.10516$

The return from continuously compounding at an interest rate, i, is obtained by taking the limit as the number of compounding intervals goes to infinity:

$$\lim_{n\to\infty} (1 + (i/n))^n = e^i$$

where e turns out to be the number that is the base for natural logarithms, which is approximately equal to 2.71828. In our example with a 10% annual interest rate, the amount of money in 1 year if interest is continuously compounded is $e^{0.1} = 1.10517$.

The natural logarithm of 1.10517 is 0.1 because raising 2.71828 to the 0.1 power is 1.10517. Sometimes, people write $\exp(i)$ rather than e^i to mean evaluate the exponential function, $\exp(i)$, at the value of i, which means simply to raise the number e to the i-th power.

Because raising the number e to a power tells you how much your principal grows when it is compounded continuously at a certain interest rate, the exponential function can be used to describe other growth rates, such as rates of appreciation or depreciation of currencies and rates of inflation. For example, if the dollar price of the pound were to grow at a continuous rate of 5% during 2012, then the exchange rate at the end of the year would be

$$S(\$/£, 2012) = S(\$/£, 2011)e^{0.05}$$

There are several useful properties of natural logarithms, which are represented by ln and their base number, e, that we will exploit:

1. $\ln(\exp(A)) = A$
2. $\exp(\ln(A)) = A$
3. If $A = BC$, then $\ln(A) = \ln(B) + \ln(C)$
4. If $A = B/C$, then $\ln(A) = \ln(B) - \ln(C)$
5. If $A = B^C$, then $\ln(A) = C \ln(B)$

We can combine these properties to establish that differences in natural logarithms are growth rates or percentage differences at continuous rates.

For instance, you can use the rules to demonstrate that

$$\ln[S(\$/£, 2012)] - \ln[S(\$/£, 2011) = 0.05]$$