Chapter 3

Spot Markets for Foreign Currency

In this chapter, we study the mechanics of the spot exchange market. The first section explains the various ways in which exchange rates can be quoted, and the second section how the exchange markets themselves operate. Section 3 then considers exchange transactions in greater detail, focusing on bid and ask rates (that is, the rates at which a bank buys and sells). This also gives us an opportunity to learn about arbitrage. Specifically, in the third section, we shall already apply arbitrage arguments to the simplest possible problem, the relation between rates quoted by different banks for the same currency. Understanding this simple application now will make it easier to digest more complicated versions of similar arguments later. One such application already occurs in the fourth section, where we use arbitrage arguments to explain how exchange rates quoted, for example, by German banks (against EUR) relate to rates offered by New Zealand banks (against the NZD).

The chapter ends with the concepts of, and empirical evidence on, "Purchasing Power Parity (PPP)" rates and real exchange rates. The conclusion of that part will be that exchange rates can make or break an exporting company, not just because of capital losses on foreign-currency-denominated receivables but possibly also because of a loss of competitiveness. Exchange risk even interferes with capital market equilibrium and the capital asset pricing model. These findings motivate the attention given to exchange rates in this book.

3.1 Exchange Rates

As we begin exploring exchange rates, we first provide a definition. We then describe the convention that is used to quote exchange rates throughout this book, as well as the conventions used in the exchange market. Finally, we explain how exchange rates are quoted in the presence of bid-ask spreads.

3.1.1 Definition of Exchange Rates

An exchange rate is the amount of a currency that one needs in order to buy one unit of another currency, or it is the amount of a currency that one receives when selling one unit of another currency. An example of an exchange rate quote is 0.8 USD per CAD (which we will usually denote as "USD/CAD 0.8"): you can, for instance, buy a CAD by paying USD 0.80.

In the above, we have combined currency names following the conventions in physics: EUR/USD means euros per dollar just like km/hr means kilometers per hour. This is the most logical. For instance, if you exchange 3m dollars into euros at a rate of 0.8 euros per dollar, the result is a number of euros. This fits with our notation:

$$\text{USD } 3m \times \text{EUR/USD } 0.8 = \text{EUR } 2.4m. \tag{3.1}$$

This may seem self-evident. The reason why we bring this up is that pros do it differently. In the convention typically adopted by traders, bankers and journalists, EUR/USD is not the dimension of the quote but the name of the exchange rate: the Euro quoted in dollars, not its dimension. That is, traders etc. write "EUR/USD = 1.2345" whereas we write "S_t = USD/EUR 1.2345". The dimension the trader asks for is USD/EUR, the inverse of what they write—but they do not mean a dimension, they mean a name.[1] In all our examples *we* use dimensions. The "name" notation pops up occasionally in press clippings or pictures of trading screens etc, and should not be a problem. To harden yourself, stare at the following line for a full minute:

$$\underbrace{\text{EUR/USD}}_{\text{name}} : \underbrace{\text{USD/EUR}}_{\text{dimension}} 1.25. \tag{3.2}$$

The tell-tale difference is that the dimension is immediately followed (or, occasionally, preceded) by the number. If there is no number, or if there is an "=" or "is" or "equals" etc between the ratio and the number, it must be the name of a rate. Sometimes practitioners drop the slash in the name and write EURUSD or EUR:USD instead of EUR/USD, which makes more sense.

It is even more crucial that you understand how exchange rates are quoted. While the notation is occasionally confusing—are we using dimensions or names?—there could be even more confusion as to which currency should be used as the numeraire. While you are familiar with the idea of buying goods and services, you may be less used to buying money with money. With exchange transactions, you need to agree which money is being bought or sold. There would be no ambiguity if one of the currencies were your home currency. A purchase then means that you obtained foreign currency and paid in home currency, the way you would do it with your other

[1] It is sometimes whispered that the trader notation comes from a kind of pseudo math like "EUR 1 = USD 1.2345", where one then "divides both sides by USD". The mind boggles. This is like denoting a speed as "1 hr = 100 km" instead of $v = 100$ km/hr.

purchases too; and a sale means that you delivered foreign currency and received home currency. If neither currency is your home currency, then you need to establish which of the two acts as the home currency.

Example 3.1

In a Paris bank, a tourist hands over USD 1,000 to the bank clerk and receives CAD 1,250 in return. This event would be described differently depending on whether the person is a US tourist, a Canadian, or a Frenchman:

- The US tourist would view this as a purchase of CAD 1,250 at a total cost of USD 1,000, implying a unit price of [USD 1,000]/[CAD 1.250] = USD/CAD 0.8.
- The Canadian would think of this transaction as a sale of USD 1,000 for CAD 1,250, implying a unit price of [CAD 1,250]/[USD 1,000] = CAD/USD 1.25.
- The Frenchman would regard this as an exchange of two foreign currencies, and would be at a loss if he would be asked which of these is being sold and which bought.

Among pros, the currency in which the price is expressed is called the *quoting currency*, and the currency whose price is being quoted is called the *base currency* or *reference currency*. We avoid the terms, except in the next two lines. We just noted that pros denote a rate as base/quoting (or, better, base:quoting) while its dimensions are quoting/base. A different issue is whether the quoting currency is the home or the foreign one.

3.1.2 Our Convention: Home Currency per Unit of Foreign Currency

Once we agree which country is, or acts as, the home country, we can agree to quote exchange rates as the price in units of home currency (HC), per unit of foreign currency (FC). That is, we quote the rate as HC/FC throughout this text, meaning that one unit of foreign currency is worth N home-currency units (dimension HC/FC). As we shall see, some people do it differently and state that with one unit of home currency, they can buy $M = 1/N$ units of foreign currency (FC/HC). We adopt the HC/FC convention because it is the most natural one. It is the convention we use when buying goods. For example, we say "the price is 5 dollars per umbrella" (HC/umbrella) not, "with one dollar you can buy one-fifth of an umbrella" (umbrellas per unit of home currency).

Example 3.2

1. A quote like USD/EUR 1.25 is an American's natural quote for the EUR; it is the USD price an American gets or pays per EUR. For Germans or other Eurolanders, a quote as EUR/USD (euros per dollar) is the more natural one.
2. A quote like USD/CAD 0.75 is an American's natural quote for the CAD, since the CAD is the currency in the denominator: a price in USD per CAD

Expressing prices in HC is the convention for not just umbrellas but also for financial assets. Thus, standard finance results hold: the current market value is the expected future value (including interest earned), discounted at a rate that takes into account the risk. Under the alternative quotation, confusingly, the current value would be determined by the inverse of the expected inverse of future value, multiplied by unity plus the required return. (If you just felt you had to read this sentence twice, you may want to consider reading end-of-chapter Teknote 3.1 instead.)

The direct (HC/FC) quoting convention used to be standard in continental Europe, and is called the direct quote, or the "right" quote. In the US, a price with dimension USD/FC is called "American terms". The alternative is called the "indirect" or "left" quote or, in the US, "European terms". Let's see who uses which and why.

3.1.3 The Indirect Quoting Convention

One group of people using mostly indirect quotes are professional traders in the US. Between 1944 and the mid-80s, each and every exchange deal went through the USD; even when a German needed to buy CHF, the DEM would first be converted into USD and these dollars were then exchanged for CHF. Naturally, when NY traders talk to, say, their German counterparts, both must talk the same language, quotewise; otherwise too much time would be wasted inverting each other's rates all the time. Both Germans and Americans actually preferred to quote in terms of DEM/USD rather than USD/DEM, for the simple reason that the official parities, set by the German government, were expressed in DEM/USD.[2] More in general, US professionals use the exchange-rate convention as quoted in the other country. Thus, for countries that quote directly themselves, like Japan, New York traders would talk JPY/USD. But in the case of countries that quote indirectly themselves, like the UK, pros would also use USD/GBP. Thus, US pros use indirect quotes for countries that themselves quote directly, and direct quotes for countries that themselves quote indirectly.

As already hinted at, in the UK one uses the reverse quote, the number of foreign units that can be bought with one pound, or FC/HC. Some former British-Commonwealth countries (for instance, Australia, New Zealand, and pre-EUR Ireland) do likewise.[3] One reason is that, prior to WW1, the pound was the world's reserve currency and played the role taken over by the dollar after WW2. In addition, until 1967 the GBP was still severely non-decimal—one pound consisted of twenty shilling, each worth twelve pence[4]—while non-pound currencies had gone

[2]Recall from the previous chapter that, until 1972, countries declared an official parity in relation to the USD, say DEM/USD 4. Intervention kept the actual rates between an upper and lower bound expressed, likewise, in DEM/USD.

[3]Canada and South Africa had gone off the pound ages ago, that's why they quote differently.

[4]Recall there also was a dollar (10s), a crown (5s), and a Guinea, worth 21 shillings in the end;

Figure 3.1: **Key exchange rates: pros' notation, dimensions, and nicknames**

Symbol	Currency Pair	dimension	Trading Terminology
USDJPY	US Dollar, in Japanese Yen	JPY/USD	Dollar Yen
USDCHF	US Dollar, in Swiss Franc	CHF/USD	Dollar Swiss, or Swissy
USDCAD	US Dollar, in Canadian Dollar	CAD/USD	Dollar Canada
USDZAR	US Dollar, in South African Rand	ZAR/USD	Dollar Zar or South African Rand
GBPUSD	British Pound, in US Dollar	USD/GBP	Cable
GBPCHF*	British Pound, in Swiss Franc	CHF/GBP	Sterling Swiss
GBPJPY*	British Pound, in Japanese Yen	JPY/GBP	Sterling Yen
AUDUSD	Australian Dollar, in US Dollar	USD/AUD	Aussie Dollar
NZDUSD	New Zealand Dollar, in US Dollar	USD/NZD	New Zealand Dollar or Kiwi
EURUSD	Euro, in US Dollar	USD/EUR	Euro
EURGBP*	Euro, in British Pound	GBP/EUR	Euro Sterling
EURJPY*	Euro, in Japanese Yen	JPY/EUR	Euro Yen
EURCHF*	Euro, in Swiss Franc	CHF/EUR	Euro Swiss
CHFJPY*	Swiss Franc, in Japanese Yen	JPY/CHF	Swiss Yen
GLDUSD	Gold, in US Dollar per troy ounce	USD/ozXAU	Gold
SLVUSD	Silver, in US Dollar per troy ounce	USD/ozXAG	Silver

Key *: cross rate, from the US perspective. Most names should be obvious, except perhaps CHF (*Confederatio Helvetica*, Latin for Switzerland—the way a four-language country solves a political conundrum). The ZAR, South-African Rand, is not to be confused with SAR, Saudi Riyal. GLD and SLV are onorthodox: the official codes as used by e.g. Swift are XAU and XAG, with X signalling a non-standard currency (like also the CFA franc and the Ecu of old), and the Latin *Aurum* and *Argentum*. "Cable" for USDGBP refers to the fact that it is about bank-account money, with payment instructions wired by telegram cable rather than sent by surface mail. There *has* been a time when wiring was cutting-edge technology.

decimal ages ago. It is much easier to multiply or divide by a decimal number, say FC/GBP 0.79208, than with a number like £1/s5/d3 (one pound, five shillings, three pence). So both Brits and non-Brits preferred to talk FC units per pound.

A third (and more recent) class of people using the indirect quote are the Eurolanders, who always quote rates like USD/EUR or JPY/EUR even though they traditionally quoted directly (like DEM/USD). Cynics conjecture that the Europeans may have coveted the reserve-currency status associated with an indirect quote. Another possible reason is that, initially, the Euro was foreign to all existing currencies. For example, to Germans the Euro was introduced as worth two DEM, so they would think it quite naturally to introduce it to Americans and Japanese as worth 1.20 USD or 110 JPY. When, eventually, the Euro had become the home currency, the habit simply stuck.

Example 3.3

Have a look at Figure 3.1, showing the most important rates in the way they are always quoted by pros. The primary rates are in non-US currency except for the

and in Elisabethan times many wages were expressed in marks (13s 4d, i.e. 160d). But by modern times most prices were in £, *s* and *d*.

Figure 3.2: **Sample Spot Exchange Rate Quotes—WSJ Europe**

AMERICAS	Per euro	In euros	U.S. dollar	U.S. dollar	EUROPE	Per euro	In euros	U.S. dollar	U.S. dollar
Argentino peso-a	3.9628	0.2523	3.0838	0.3243	**Euro zone** euro	1	1	0.7782	1.2851
Brazil real	2.9588	0.3380	2.3025	0.4343	**Czech Rep** koruna-b	28.260	0.0354	21.992	0.0455
Canada dollar	1.438	0.7073	1.1002	0.9089	**Denmark** krone	7.4576	0.1341	5.8034	0.1723
Chile peso	683.07	0.001464	531.55	0.001881	**Hungary** forint	262.82	0.003805	204.52	0.004890
Columbia peso	3186.28	0.0003138	2479.50	0.0004033	**Malta** lira	0.4294	2.3288	0.3342	2.9926
Ecuador US dollar-f	1.2850	0.7782	1	1	**Norway** krone	7.800	0.1282	6.0698	0.1648
Mexico peso-a	14.5307	0.0688	11.3075	0.0884	**Poland** zloty	3.9369	0.2540	3.0637	0.3264
Peru sol	4.2368	0.2360	3.2970	0.3033	**Russia** ruble-d	34.669	0.02884	26.979	0.03707
Uruguay peso-e	30.841	0.0324	24.000	0.0417	**Slovak Rep** koruna	37.7856	0.02647	29.4040	0.03401
U.S. Dollar	1.2850	0.7782	1	1	**Sweden** krona	9.2662	0.1079	7.2108	0.1387
Venezuala bolivar	2759.39	0.000362	2147.30	0.000466	**Switzerland** franc	1.5604	0.6109	1.2103	0.8262
...	...	...	...	...	...	...	...	...	...

a—floating rate b—commercial rate c—government rate d—Russian Central Bank rate f—Special Drawing Rights from the International Monetary Fund ; based on exchange rates for U.S., British and Japanese currencies.
Note: Based on trading among banks in amounts of $1million and more, as quoted by Reuters

Key: The *Wall Street Journal Europe* sensibly shows both the natural and indirect quotes.

GBP, NZD and AUD or for the EUR; you know why. Cross rates for the EUR are in non-EUR currency, and likewise for the GBP.

Example 3.4

Look at the *Wall Street Journal Europe* excerpt in Figure 3.2, conveniently showing both quotes; the value in USD or EUR of one unit of the third ("foreign") foreign curency, and the value of one USD or EUR in units of that third ("foreign") currency. The natural quote for Americans or Europeans would be the first one, but U.S. traders and Eurolanders may use the other quote. Take a minute to look at Figure **??** and see if you understand the exchange rates as quoted.

Q1. What is the dollar equivalent of one Euro, according to the quotes in *The Wall Street Journal*?
A1. If your answer is USD 1.285, you are correct.

Q2. Determine the amount of Peruvian sol per EUR.
A2. If you answered 4.2368 sol per EUR, you are right.

3.1.4 Bid and Ask Rates

When you deal with foreign currency, you will discover that you pay a higher price at the time of purchase than when you sell one currency for another. For example, for dollar-rouble deals the currency booth in your hotel will quote two numbers, say RUB/USD 35-36. This means that if you sell USD for RUB, you receive RUB 35, while if you wish to buy USD you will have to pay RUB 36. The rate at which the bank will buy a currency from you is called the *bid* rate: they bid (*i.e.* they announce that they are willing to pay) 35 per dollar; and the rate at which the bank will sell a currency to you is the *ask* rate (they ask 36 per dollar). It is, initially, safer not

to think about the meaning of bidding and asking because the words refer to the bank's view, not yours. Just remember that *you* buy at the bank's ask rate, and *you* sell at the bank's bid rate. The bid is the lower quote, and ask is the higher one. The Ask comes higher in the alphabet—use any trick that works, until you get used to it.

Indeed, if exchange rates are being quoted with the currency of interest—the currency you are buying or selling—in the denominator, then the ask rate will be higher than the bid rate. Obviously, it could not be the other way around: with a bid rate above the ask rate you would be able to make huge risk-free profits by buying at a the ask and immediately reselling at the assumedly high bid. No bank will allow you to buy low and then immediately resell at a profit without taking any risk, because your sure gains would obviously mean sure losses for the bank. In theory, there could still be room for a situation "bid rate = ask rate" (which offers no such arbitrage opportunities). Yet, the real-world situation is invariably "bid rate < ask rate": banks want to make some money from foreign-currency transactions.

Another way to think of this difference between the ask and the bid rate in fact is that the difference contains the bank's commission for exchanging currencies. The difference between the buying and selling rates is called the *spread*, and you can think of the bank's implicit commission as being equal to half the spread. The following example explains why the commission is half of the spread rather than the spread itself.

Example 3.5

Suppose that you can buy CAD at RUB/CAD 38.6, and sell at RUB/CAD 38.0. With these rates, you can think of a purchase as occurring at the midpoint rate (RUB/CAD 38.3), grossed up with a commission of 0.30. Likewise, a sale can be thought of as a sale at the midpoint, 38.3, from which the bank withholds a commission of 0.30. Thus, the equivalent commission per one-way transaction is the difference between the bid (or ask) and the midpoint rate, that is, half the spread. (The spread itself would be the cost of a round-trip deal—buy and then sell).

To get an idea of whether your house bank charges a low commission, you can ask for a two-way quote to see if the spread is small. If this is the case, you probably do not have to check with other banks. However for large transactions, you should also compare the spot quotes given by different banks. (This will be examined further in Sections 3.3 and 3.3.3.) We discuss the determinants of spreads later, after we have described the market microstructure.

3.1.5 Primary rates *v* cross rates

As of 1945 and until well into the 1980s, all exchange rates in the wholesale segment were against the USD. They were and are called *primary rate*s, while any rate not

Figure 3.3: **Cross rates as in the Wall Street Journal Europe**

values of one Euro

Cross rates U.S. dollar and euro foreign-exchange rates in global trading

	USD	GBP	CHF	SEK	RUB	NOK	JPY	ILS	EUR	DKK	CDN	AUD	
Australia	1.3253	2.4818	1.0915	0.1838	0.0491	0.2183	0.0118	0.2934	1.7031	0.2284	1.2046	—	
Canada	1.1002	2.0603	0.9061	0.1526	0.0408	0.1813	0.0098	0.2436	1.4038	0.1896	—	0.8302	
Denmark	5.8034	10.867	4.7794	0.8048	0.2151	0.9561	0.0518	1.2847	7.4576	—	5.2748	4.3789	
Euro	*0.7782*	*1.4573*	*0.6409*	*0.1079*	*0.0288*	*0.1282*	*0.0069*	*0.1723*	—	*0.1341*	*0.7073*	*0.5872*	values in euro
Israel	4.5173	8.4592	3.7202	0.6265	0.1674	0.7442	0.0403	—	5.8049	0.7784	4.1058	3.4085	
Japan	112.11	209.93	92.325	15.547	4.1553	18.469	—	24.817	144.06	19.317	101.90	84.589	
Norway	6.0698	11.367	4.9988	0.8418	0.2250	—	0.0541	1.3437	7.8000	1.0459	5.5170	4.5800	
Russia	26.978	50.521	22.218	3.7414	—	4.4448	0.2407	5.9724	34.669	4.6488	24.521	20.357	
Sweden	7.2108	13.503	5.385	—	0.2673	1.1880	0.0643	1.5963	9.2662	1.2425	6.5541	5.4409	
Switzerland	1.2145	2.2739	—	0.1684	0.0405	0.2000	0.108	0.2688	1.5604	0.2092	1.1037	0.9162	
U.K.	0.5340	—	0.4398	0.0741	0.0198	0.0880	0.0048	0.1182	0.6862	0.0920	0.4854	0.4029	
U.S.	—	1.8726	82.236	0.1387	0.0371	0.1648	0.0089	0.2214	1.2850	0.1723	0.9089	0.7546	

involving the USD would be called a *cross rate* and would traditionally be regarded as just implied by the primary rates. You find an example for midpoint rates in Figure 3.3. The primary rates are in the first column (FC/USD) or the bottom line (USD/FC).[5] The rest of the table is obtained by division or multiplication: GBP/EUR = GBP/USD × USD/EUR, for example. Each of the resulting new rows or columns is a set of quotes in HC/FC (row) or FC/HC (column). With 12 currencies you have 144 entries, of which 12 are on the information-free diagonal, and half of the remaining 132 are just the inverses of the others.

We have a whole section on the relation between primary and cross rates in the presence of spreads, so at this stage we just consider why, among pros, there were just primary rates, until the 1980s. There were several reasons:

- Official parities were against the USD; there was no official parity (in the sense of being defended by any central bank) for rates against other currencies.

- The USD market had the lowest spreads, so all real-world transactions would effectively be done via the dollar anyway. That is, pounds were converted into marks by buying dollars first and then exchanging these for marks, for example, because that was the cheapest way to do so (see below). The cross-rate would just be the rate implied by the two primary rates used in the transaction.

- In pre-electronic days it would be quite laborious to keep track of, say, a 30×30 matrix of cross rates with 435 distinct meaningful entries, making sure all cross rates are consistent with the primary ones all the time. So rather than quoting

[5] Many newspapers give currency j the j-th row and the j-th column instead of the $(N-j)$-th row and the j-th column, but the lay-out is not crucial. The orientation of the empty diagonal (or the unit diagonal, as other tables might show it) is the sign to watch.

cross rates all the time, banks just showed primary quotes and then computed cross rates if and when needed.

By the 1980s desktop computers were around everywhere and, for many pairs of "big" currencies the volume of cross transactions had become large enough to make direct cross exchanges competitive compared to exchanges via the USD. Official exchange rates were gone in many cases, or in the ERM case had become multilateral. So we now see explicit quotes for some of the cross rates. Look at Figure 3.2 to see what rates have active multilateral electronic markets—a good indication of there being a reasonable volume. Note also that for some new EU members the market against the EUR works well while the market against the USD lacks liquidity; that is, for these countries the rate against the euro is economically the key one even though Americans would regard it as just a cross rate.

3.1.6 Inverting Exchange Rates in the Presence of Spreads

The next issue is how a pair of quotes for one currency can be translated into a pair of quotes for a different currency. The rule is that the inverse of a bid quote is an ask quote, and vice versa. To conceptualize this, consider the following illustration.

Example 3.6

An Indian investor wants to convert her CAD into USD and contacts her house bank, Standard Chartered. Being neither American nor Canadian, the bank has no natural preference for either currency and might quote the exchange rate as either USD/CAD or CAD/USD. The Indian bank would make sure that its potential quotes are perfectly compatible. If it quotes from a Canadian viewpoint, the bank gives a CAD/USD quote (which says how many CAD the investor must pay for one USD—for instance, CAD/USD 1.5). If it uses the US perspective, the bank gives a USD/CAD quote, which says how many USD the US investor gets for one CAD, 0.66667.

The bank's alternative ways of quoting will be fully compatible if

$$S_{bid,t}^{CAD/\text{USD}} = \frac{1}{S_{ask,t}^{\text{USD}/CAD}} \tag{3.3}$$

$$S_{ask,t}^{CAD/\text{USD}} = \frac{1}{S_{bid,t}^{\text{USD}/CAD}} \tag{3.4}$$

To fully understand this, recall that what looks like buying (at the ask) to a US resident looks like selling to a Canadian—at the Canadian's bid. Alternatively, recall that the ask is the higher of the two quotes. But if you invert two numbers, the inverse of the larger number will, of course, be smaller than the inverse of the smaller number. Because the inverse of a larger number is a smaller number, the inverse ask must become the bid, and vice versa.

Example 3.7

Suppose that you read the following quote on the Reuters screen: USD/CAD 1.000-1.005.

Q1. What is the bank's buying and selling rate for CAD?
A1. The bank's buying rate for CAD is USD 1.000 and its selling rate is USD 1.005; that is, *you* sell CAD at USD 1.000 and buy at 1.005.

Q2. What, therefore, are the bank's buying and selling rates for USD (in CAD)?
A2. The bank's buying rate or bid for USD is $1/1.005 =$ CAD/USD 0.995025 (probably rounded to 0.9950) and the selling rate or ask is $1/1.000 = 1.000$; that is, wearing your Canadian hat, *you* sell USD at CAD 0.9950 and buy at 1.000.

One corollary is that in countries like the UK, where the reverse or indirect quote is used, the rate relevant when you buy is the lower of the two, while the higher quote is the relevant rate when you sell. Thus, it is important to be aware of what the foreign currency is, and what convention is being used for quoting the exchange rate. Again, it is always easier and more convenient to have the foreign currency in the denominator. That way the usual logic will work: banks buy low and sell high.

3.2 Major Markets for Foreign Exchange

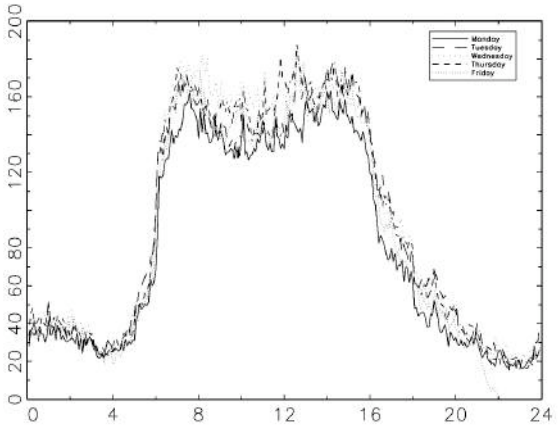
In this section, we describe the size and structure of the exchange market and the type of transactions one can make in this market.

3.2.1 How Exchange Markets Work

The foreign exchange market is not an organized market. Stock markets or futures markets are: they have fixed opening hours, a more or less centralized mechanism to match supply and demand, standardized contracts, an official publication channel for data on volumes and prices, and a specific location or one designated group of computers running everything. In contrast, the exchange market consists of a wholesale tier, which is an informal network of about 500 banks and currency brokerages that deal with each other and with large corporations, and a retail tier, where you and I buy and sell foreign exchange. At any point in time, wholesale exchange markets on at least one continent are active, so that the world-wide exchange market is open twenty-four hours a day (see Figure 3.4). Until the mid-90s, most interbank dealing was done over the telephone; most conversations were taperecorded, and later confirmed by mail, telex, or fax. Reuters—which was already omnipresent with its information screens—and EBS[6] have now built computer networks which

[6] EBS (Electronic Broking Services) was created by a partnership of the world's largest foreign exchange market-making banks. Approximately USD 125 billion in spot foreign exchange transac-

Figure 3.4: **Trader activity over the day**



Key Graph courtesy of Luc Bauwens, Université Catholique de Louvain. The graph shows, per 5-minute interval over 24 hours, the evolution of the average number of indicative quotes entered into the Reuters FX/FX pages. Time is GMT in summer, GMT+1 in winter; that is, European time is t+2 hrs, London +1, NY −4 hrs; Sydney and Tokyo time are at t+10 and t+9 hrs, respectively. Below I describe working days as 8:00-17:00, but many a trader starts earlier and/or works later. At 0:00, when the morning shift in Sydney has been up and running for about 2 hrs and Tokyo for 1 hr, Hong Kong starts up, to be followed by Singapore in 1 hr and Bahrain in 3. Between 6:00 and 8:00 the Far East bows out but Western Europe takes over—first the continent (6:00 GMT), then London (7:00) ; activity soars. A minor dip follows around the European noon but activity recovers again in the afternoon, peaking when New York takes over (12:00) and Europeans close their positions (15:00 on the continent, 16:00 London). NY does less and less as time passes. By 22:00 Sydney is starting up, and Tokyo is preparing breakfast.

allow direct trading and that now largely replace the phone market. The way the computer systems are used depends on the role the bank wants to play. We make a distinction between deals via (*i*) market makers, (*ii*) auction platforms, or (*iii*) brokers.

Market Making

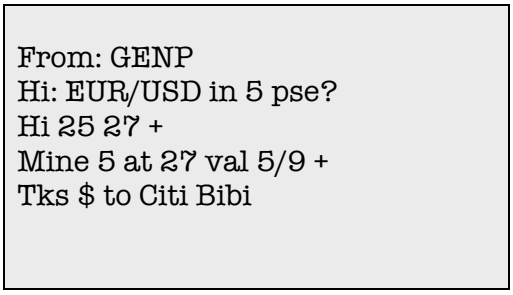
Many players in the wholesale market act as market makers. If a market-making credit agreement between two banks has been signed, either party undertakes to provide a *two-way* quote (bid and ask) when solicited by the other party, without even knowing whether that other party intends to buy, or rather sell. Such a quote is *binding*: market makers undertake to effectively buy or sell at the price that was

---

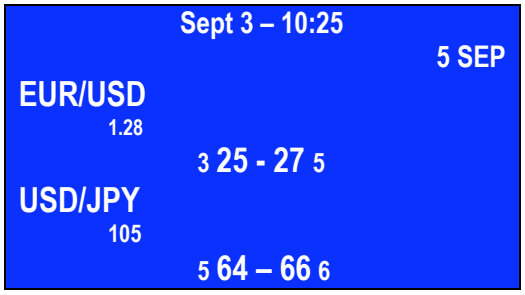
tion, 700,000 oz in gold and 7 million oz in silver is traded every day over the EBS Spot Dealing System. It was created in 1990 to challenge Reuters' threatened monopoly in interbank spot foreign exchange and provide effective competition. ICAP Plc, the world's largest broker of transactions between banks, agreed in 2006 to buy EBS.

Figure 3.5: **A Reuters conversation and an EBS Broking Window**

A *Reuters* conversation



An EBS broking screen



Key In the Reuters conversation window, GENP is an abbreviated name (Jenpi, Jean-Pierre); he asks for a quote for EUR in USD for quantity 5m (dollar); pse is GENPs code for please. The counterparty answers by keying in the small numbers, and Jenpi replies he buys 5 (million) at the ask, 27, for value date Sept 5. The counterpart closes with "Thanks, I'll send the dollars to your correspondent, CitiBank. Bye bye."

The second picture shows part of an EBS broking screen. On top, the current date and time. Next line: the spot delivery date, Sept 5. For two currencies you then see in small font the big figure (the part of the quote that is usually omitted) and in big font the smallquotes: bid and ask, each preceded/followed by the quantity available, in millions. Thus, somebody bids 1.2825 for 3 million dollar, another party offers 5 million dollar at 1.2827.

indicated.

Example 3.8

Deutsche may ask Hong Kong & Shanghai for a quote of EUR against USD. HSBC must then provide a bid and an ask without knowing the direction of Deutsche's possible trade; and if Deutsche replies with "I buy 10 million" then HSBC must sell that quantity at the price they quoted.

Of course there are limits to the market makers' commitments to their quotes. First, potential customers should decide almost immediately whether to buy ("mine"), or to sell ("yours"), or not to deal; they cannot invoke a quote made, say, three minutes ago. Second, if the intended transaction exceeds a mutually-agreed level, laid down in the prior credit agreement—say USD 25m—market makers can refuse. For larger transactions, the trader asking for a quote should reveal immediately what the size of the transaction will be. Third, the credit agreement also provides a limit to the total amount of open contracts that can be outstanding between the two banks at any moment;[7] if the limit is reached, no more deals are allowed.

[7]Exchange transactions are settled with a delay of at least two days, so each contract remains outstanding at least two days; many live much longer. See Section 3.2.3.

Transactions via binding two-way quotes are typically concluded on computers, via kind of chatting windows (more grandly called "conversations"). Bank A's trader X clicks his conversation window with trader Y at bank B—there may be up to 64 such windows open at any given point of time—and might type in, for instance, `PLS EUR/USD`, meaning "please provide a quote for the EUR, in USD". Player A can also mention the quantity, in millions. The millions are omitted; that is, 5 means five million; and the quantity bears on the currency in the denominator, traditionally the USD or the GBP. B's trader may answer, for instance, `13-16` meaning that (the last two digits of) her bid and ask are 13 and 16. (Traders never waste time by mentioning the leading numbers: everybody knows what these are. Only the "small" numbers are mentioned.) The first party can let the offer lapse; if not, he answers `MINE` or `YOURS`, mentions the quantity if not already indicated, and hits the `SEND` key. The deal's done, and both traders now pass on the information to their "back office", which enters the data into the information systems. The back offices will also check with each other to see whether the inputs match; with the logs of the conversations, disputes are of course far less likely than before, when everything went by phone and when traders handed down hand-scribbled "tickets" to the accountants who then checked with each other via telexes. Voice deals still exist, but they are getting rarer.

Implications of Market Making for the Size of the Bid-ask Spread and the Maximum Order Size

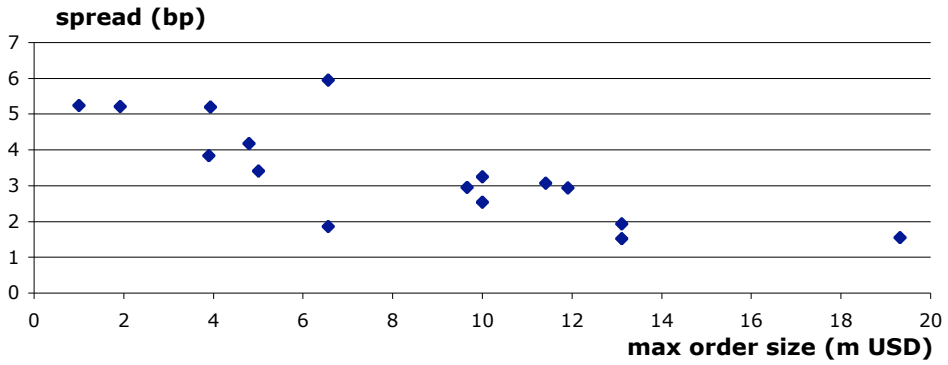
Normally, the lower the volume in a particular market, the higher the spread. Also, during holidays, weekends, or lunch times, spreads widen. Spreads are also higher in periods of uncertainty, including the open and close of the market every day. Maximum order quantities for normal quotes follow a similar pattern: a market maker is prepared to handle large lots if the market is liquid (thick) or the volatility low.

All these phenomena are explained by the risk of market making. Notably, if a customer has "hit" a market maker, the latter normally wants to get rid of that new position quickly. But in a thin or volatile market, the price may already have moved against the market maker before he or she was able to close out. Thus, in a thin or volatile market, the market maker wants a bigger commission as compensation for the risk, and puts a lower cap on the size of the deals that can be executed at this spread. For the same reason, quotes for an unusually large position are wide too: getting rid of a very large amount takes more time, and during that time anything could happen. In the retail end of the market, in contrast, the spread increases for smaller transactions. This is because 100 small transactions, each for USD 100,000, cost more time and effort than one big transaction of USD 10m.

For high-volume currencies like the USD/EUR, the difference between one market-maker's own bid and ask is often as low as three basis points (in a quote of four or

Table 3.1: **Order limits and spreads for various rates, semi-professional**

Ticker	Size of 1.0 lot	Instant Execution	Spread	Limit & Stop levels	March 9, 2007 rate (in pips)	spread, %^2
EURUSD	EUR 100,000	up to 10M	2 pips	2 pips	13,115	1.5
GBPUSD	GBP 100,000	up to 10M	3 pips	3 pips	19,319	1.6
EURCHF	EUR 100,000	up to 5M	3 pips	3 pips	16,163	1.9
EURJPY	EUR 100,000	up to 10M	3 pips	3 pips	15,489	1.9
USDJPY	USD 100,000	up to 10M	3 pips	3 pips	11,810	2.5
GBPCHF	GBP 100,000	up to 5M	7 pips	7 pips	23,810	2.9
EURGBP	EUR 100,000	up to 5M	2 pips	2 pips	6,788	2.9
GBPJPY	GBP 100,000	up to 5M	7 pips	7 pips	22,817	3.1
USDCHF	USD 100,000	up to 10M	4 pips	4 pips	12,325	3.2
USDCAD	USD 100,000	up to 5M	4 pips	4 pips	11,735	3.4
AUDUSD	AUD 100,000	up to 5M	3 pips	3 pips	7,802	3.8
CHFJPY	CHF 100,000	up to 5M	4 pips	4 pips	9,583	4.2
EURCAD	EUR 100,000	up to 3M	8 pips	8 pips	15,389	5.2
NZDUSD	NZD 100,000	up to 2M	5 pips	5 pips	9,583	5.2
USDSGD	USD 100,000	up to 1M	8 pips	8 pips	15,267	5.2
EURAUD	EUR 100,000	up to 5M	10 pips	10 pips	16,810	5.9

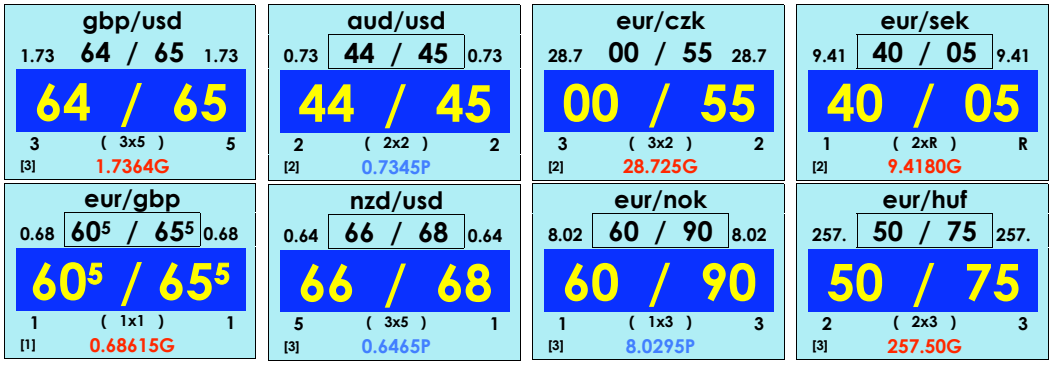


Key The table shows conditions for various currencies from a particular internet broker. The min and max quantities are not interbank, but still aiming at semi-professionals or perhaps day traders rather than pop&mom investors, the hardcore retail. The spread and the tick size for limit and stop levels are likewise wider than interbank. Do note how the spread vary depending on liquidity and the level of the rate, and how the max order size (imperfectly) relates to spread (graph). Source: http://www.alpari.co.uk/en/cspec/ for columns 1-5; WSJ Europe March 12, 2007 for column 6; spread in bp has been added. Data have been re-arranged by increasing relative spread. For the graph the order sizes have been converted from reference currency (the FC in the quote) to USD.

five digits, like 1.2345 or 0.9876), and the difference between the best bid (across all market makers) and the best ask (also across all market makers) may be just two or one or, occasionally, zero basis points. See Section 3.3.2 for more information on quoting behavior.

Table 3.1 shows the minimum and maximum amounts quoted by an internet

Figure 3.6: **A Panel of Reuters Broking Windows**



Key The entries should be obvious, by now, except the bottom line, which shows the last trade (quantity and price).

dealer;[8] they are smaller than interbank (and spreads are bigger than interbank), but you can still notice how the maximum amounts and the spreads relate to each other, presumably both reflecting liquidity and volatility.

Auctioning off Through a Broking System

All the above was about market making. Beside these purely bilateral deals—the successors to bilateral phone conversations—there nowadays are increasingly many semi-multilateral deals. If a trader actively wants to buy, or sell, she may enter a limit order into EBS' or Reuters' limit-order book rather than calling a number of market makers or waiting until someone else calls her. This is comparable to you offering, say, a used car for sale on eBay rather than calling various car dealers or posting a sign on your door and then waiting until someone rings your bell. For instance, bank A may have EUR 30m for sale and want at least USD/EUR 1.3007 for them—an ask price. The bank posts this info, for instance, on Reuters' "3000" system. Reuters' window, at any moment, then shows the best bid across all "buy" limit orders, and the best ask among all "sell" limit orders outstanding at that moment. For instance, on Reuters' 3000 screen a line `EUR/USD 10-11 3×R` means that the highest bid posted at that very moment is 10, the lowest ask 11, and that the quantities for these limit orders are, respectively, 3 and "a number exceeding

[8] "Size of one lot" shows the minimum, which is clearly targeting players out of the interbank league (where the lot size is 1m) but still above the micro-investor's league. "Instant execution" is the maximum amount you can buy or sell at the trader's regular quotes.

Table 3.2: **EBS *v* Reuters D2: who leads, who follows, who fails**

	EBS	Reut		EBS	Reut		EBS	Reut
primary			*primary (cont'd)*			*Cross against EUR*		
EUR/USD	+	+/–	USD/RON		–	EUR/AUD		–
AUD/USD	+/–	+	USD/RUB		+	EUR/CAD		–
GBP/USD	+/–	+	USD/SAR		+	EUR/CHF	+	+/–
NZD/USD		+	USD/SEK		–	EUR/CZK	–	+
USD/CAD	+/–	+	USD/SGD	–	+	EUR/DKK	–	+
USD/CHF	+	+/–	USD/THB		+	EUR/GBP	+/–	+
USD/CZK		–	USD/TRY		+	EUR/HUF	–	+
USD/DKK		–	USD/ZAR		+	EUR/ISK		+
USD/HKG	–	+				EUR/JPY	+	+/–
USD/HUF		–	*Other cross rates*			EUR/NOK	–	+
USD/ILS		+	AUD/JPY		–	EUR/NZD		+/–
USD/INR		+	AUD/NZD		+/–	EUR/PLN	–	+
USD/ISK		–	CHF/JPY	–		EUR/RON		–
USD/JPY	+	+/–	GBP/JPY		–	EUR/SEK	–	+
USD/MXN	–	+				EUR/SKK		+
USD/NOK		–				EUR/TRY		–
USD/PLN	–	+				EUR/ZAR		+/–

+: primary liquidity source; +/–: supported, but liquidity not good or not stable; –: supported but not used in practice. Rates are expressed following the "name" convention, not the dimensions. **Source:** www.londonfx.c.uk/autobrok.html, feb 2007

50" (=R).[9] You see the EBS counterpart of Reuters 3000 in Figure 3.5. Any party interested in one of these offers can then click on the quote they like (either the bid or ask) and specify the quantity taken. Or another bank may enter a limit order that is automatically matched, wholly or partly, with an already outstanding limit order. Reuters' computer then informs the IT systems of both banks of the transactions that were concluded so that no more human intervention with "tickets" and telexes and faxes is needed (*straight through processing*, STP).

The decision by an FX trader whether to use EBS or Reuters Dealing 3000 (aka D2) is driven largely by currency pair. In practice, EBS is used mainly for EUR/USD, USD/JPY, EUR/JPY, USD/CHF and EUR/CHF, and Reuters D2 is used for all other interbank currency pairs. Have a look at Table 3.2 to see who leads where. In these multilateral electronic dealing systems, the spread for EUR/USD is typically one pip, that is, one hundredth of a USD cent. (Online currency brokers targeting private investors typically offer a 2-pip spread; just feed "foreign exchange" into your web search engine to find these brokers.) For other exchange rates spreads are often

[9]The quotes are, again, "small numbers" and the quantities mean millions of dollars. Remember also that, for traders, EUR/USD means "the value of the Euro in dollars".

Figure 3.7: **The Bank of International Settlements (BIS)**

The Bank for International Settlements (BIS) is commonly described as the bank of the Central Banks. It was first set up after WW1 to act as a payent agent distributing the German and Austrian war reparation payments. After WW2 it ran the European Payment Union (EPU), serving as a netting institute for payments among EPU members. By netting the international payments, the volume of actual payments was reduced, which alleviated the problems of dollar shortages in the first years after the war. Currently, the BIS still is the bank of the central bankers: all central banks have accounts there, in various currencies, and can route their payments to each other via the BIS. But nowadays the BIS mainly serves as a talking club for central bankers and regulators. One of its missions is to gather data on exchange markets, euro- and OTC-markets, new financial instruments, bank lending to sovereign borrowers, and so on. Another mission is to provide a forum where regulators coordinate the *capital adequacy* rules that they impose on financial institutions. The Basel-1 rules covered credit risk—in a crude way, perhaps, but it was a useful first step; the recent Basel-2 rules refine Basel-1 and add market-price risks, see the chapter on Value at Risk.

wider.

Note that the advent of these multilateral systems has made the market somewhat more like an organized market: there is centralization of buy and sell orders into one matching mechanism, there are membership rules (not anyone can log on into the program), rules about orders, etc. But the exchange market is still fully private, whereas many exchanges are semi-official institutions that are heavily regulated and need, at least, a license.

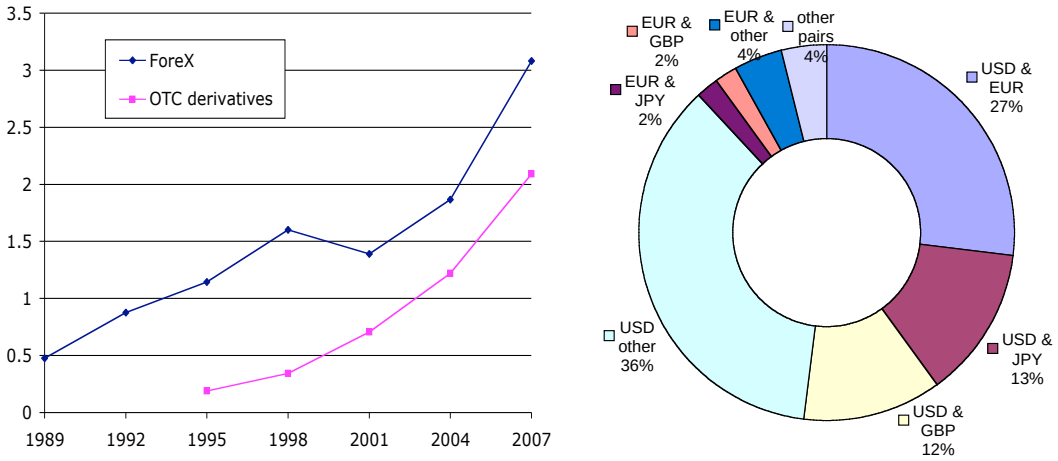
Brokers

A last way of shopping around in foreign exchange markets is through currency brokers. In the telephone-market days, brokers used to do the middleperson stuff that nowadays is handled via limit-order books: on behalf of a bank or company, the broker would call many market makers and identify the best counterpart. Roughly half of the transaction volume in the exchange market used to occur through brokers. Nowadays, brokers are mainly used for unusually large transactions, or "structured" deals involving, say, options next to spot and/or forward; for bread-and-butter deals their role is much reduced.

3.2.2 Markets by Location and by Currency

Every three years, in April, the Bank of International Settlements (see box in Figure 3.7) makes a survey of the over-the-counter markets, including forex. At the latest count, April 2007, the daily volume of trading on the exchange market and its satellites—futures, options, and swaps—was estimated at more than USD 3.2 trillion. This is over 45 times the daily volume of international trade in goods and services, 80 times the US' daily GDP, 230 times Japan's GDP, and 400 times Germany's GDP, and

Figure 3.8: **Forex turnover, daily, USDb, and market shares of currency pairs**



Source BIS, *Triennal Central Bank Survey of Foreign Exchange and Derivatives Market Activity in April 2007*, Preliminary global results, September 2007.

7500 times the world's official development-aid budget.[10] The major markets were, in order of importance, London, New York, Tokyo, Frankfurt (the European Central Bank's home base). London leads clearly, easily beating even New York, Tokyo, and Singapore taken together, and still increasing its market share. Frankfurt is a fast riser but from a low base.

The most important markets, per currency, are the USD/EUR and the USD/JPY markets; together they represent almost half of the world trading volume. Add in the GBP, and the transactions involving just the top four moneys represent two thirds of all business. The USD still leads: in 88 % of transactions it takes one of the sides (down from 90 in 2004), while the EUR is one of the two currencies in less than 40% (up from 35) of that volume—and the bulk of that is USD/EUR trade.

3.2.3 Markets by Delivery Date

The exchange market consists of two core segments—the spot exchange market and the forward exchange market.

The **spot** market is the exchange market for quasi-immediate payment (in home currency) and delivery (of foreign currency). For most of this text we shall denote

[10] All data are from the CIA Factbook—see Google. Trade and aid: 2004; GDP: early 2007 estimates for 2006.

Table 3.3: **Market shares. %, for foreign exchange trading**

	UK	US	Japan	Singa-pore	Other
1998	32.5	17.9	6.9	7.1	35.6
2001	31.2	15.7	9.1	6.2	37.8
2004	31.3	19.2	8.3	5.2	36.0
2007	34.1	16.6	6.0	5.8	37.5

Source BIS, *Triennal Central Bank Survey of Foreign Exchange and Derivatives Market Activity in April 2007*, Preliminary global results, September 2007.

this spot rate by S_t, with t referring to current time. In practice, "quasi-immediate" means "right now" only when you buy or sell notes or coins. (This section of the market is marginal.) For electronic money (that is, money that will be at your disposal in some bank account), delivery is in two working days for most currencies ("$t+2$"), and one day between Canada and the US or between Mexico and the US ("$t+1$"). Thus, if you buy AUD 2m today, at AUD/EUR 2, the AUD 2m will be in your account two working days from now, and the EUR 1m will likewise be in the counterpart's account two days from now. The two-day delay is largely a tradition from the past, when accounts were kept by hand. The hour of settlement depends on the country, but tends to be close to noon. Thus, the EUR side of a EUR/USD transaction is settled in Europe about six hours before the USD leg of the seal is settled in NY.[11]

The **forward** market is the exchange market for payment and delivery of foreign currency at some future date, say, three months from now. For example, supposing today is January 3, you could ask your bank to quote you an exchange rate to sell dollars for pounds for a date in March, say March 5, and the transaction would be settled on that date in March, at the rate agreed upon on January 3 (irrespective of the spot rate prevailing on March 5). The forward market, in fact, consists of as many subsegments as there are delivery dates, and each subsegment has its own price. We shall denote this forward rate by $F_{t,T}$, with T referring to the future delivery date. (Forward rates and their uses will be discussed in great detail in Chapters 4 and 5.)

The most active forward markets are for 30, 90, 180, 270, and 360 days, but nowadays bankers routinely quote rates up to ten years forward, and occasionally even beyond ten years. Note that months are indicated as thirty days. In principle, 30-day contract is settled one month later than a spot contract, and a 180-day for-

[11]This leads to the risk that, in between the two settlement times, one party may file for bankruptcy or be declared bankrupt. This is called "Herstatt risk", after a small German bank that pulled off this feat on June 26, 1974. Nowadays, regulators close down banks *outside* working hours.

ward contract is settled six months later than a spot contract—each time including the two-day initial-delay convention.[12]

Example 3.9

A 180-day contract signed on March 2 works as follows. Assuming that March 4 is a working day, spot settlement would have been on March 4. For a 180-day forward deal, the settlement date would be moved by six months to, in principle, September 4, or the first working day thereafter if that would have been a holiday. The actual number of calendar days is at least (2+)184 days: there are four 31-day months in the March-September window.

The above holds for standard dates, But you can always obtain a price for a "*broken date*" (i.e. a non-standard maturity), too. For instance, on April 20 you can stipulate settlement on November 19 or any other desired date.

Worldwide, spot transactions represent less than 50 percent of the total foreign-exchange market volume. The forward market, together with the closely related swap market (see Chapter 7), make up over 50 percent of the volume. About 3 percent of total trade consists of currency-futures contracts (a variant of forward contracts traded in secondary markets—see Chapter 6) and currency options (see Chapter 8).

After this digression on the meaning of exchange rates and their relation to real quantities, we now return to the operations of the spot exchange market. We want to introduce one of the cornerstones of finance theory, the Law of One Price.

3.3 The Law of One Price for Spot Exchange Quotes

In frictionless markets, two securities that have identical cash flows must have the same price. This is called the Law of One Price. There are two mechanisms that enforce this law. The first one is called *arbitrage* and the second one can be called *shopping around*. We explain these two concepts below.

Suppose that two assets or portfolios with identical cash flows do not have the same price. Then any holder of the overpriced asset could simultaneously sell this asset and buy the cheaper asset instead, thus netting the price difference without taking on any additional risk. If one does not hold the overpriced asset, one could still take advantage of this mispricing by short-selling[13] the overpriced asset and covering this with the purchase of the cheaper security. For example, you sell an overpriced

[12] Further details of settlement rules are provided in Grabbe (1995).

[13] see box in Figure 3.9.

Figure 3.9: **What's shortselling?**

In a shortsale you hope to be able to buy low and sell high, but with the selling preceding the buying, unlike in a long position. Thus, a shortseller hopes to make money from falling prices rather than from rising prices.

In markets with delivery a few working days later, you can always go short for a few hours: sell "naked" in the morning, for instance, and then buy later within the same day so as to be able to deliver n days later.

For longer horizons one needs more. In the case of securities, shortselling then requires borrowing a security for, say, a month and selling it now; at the end of the month you then buy back the number of securities you borrowed and restitute them to the asset lender, including dividends if any were paid out during that period.

For currencies, longer-term shortselling can be done by just borrowing forex and selling it, hoping to be able to buy back the forex (including interest) later at a lower price. If there is a forward market, lastly, going short is even easier: promise to deliver on a future date at a price that is fixed now. If prices have dropped by then, as you hope, you'll be able to close out (buy spot) cheaply and make money on the forward deal.

asset at 1.2135 and buy a perfect substitute at 1.2133, netting 0.0002 per unit right now and no net cash flow at T. Such transactions are called arbitrage. These arbitrage transactions generate an excess supply of the overpriced asset and an excess demand for the underpriced asset, moving the prices of these two assets towards each other. In frictionless markets, this process stops only when the two prices are identical. Note that apart from the arbitrage gain, an arbitrage transaction does not lead to a change in the net position of the arbitrageur; that is, it yields a sure profit without requiring any additional investment.

The second mechanism that enforces the Law of One Price is shopping around. Here, in contrast to arbitrage, investors do intend to make particular changes in their portfolios. Shopping around has to do with the fact that, when choosing between different ways of making given investments, clever investors choose the most advantageous way of doing so. Therefore, when choosing between assets with identical cash flows, investors buy the underpriced assets rather than the more expensive ones. Likewise, when choosing which assets to sell, investors sell the overpriced ones rather than the ones that are relatively cheap. This demand for the underpriced assets and supply of the overpriced ones again leads to a reduction in the difference between the prices of these two securities.

Although the arbitrage and shopping-around mechanisms both tend to enforce the Law of One Price, there are two differences between these mechanisms.

- First, an arbitrage transaction is a round-trip transaction. That is, you buy and sell, thus ending up with the same position with which you started. As arbitrage requires a two-way transaction, its influence stops as soon as the price difference is down to the *sum* of the transactions costs (buying and selling). In contrast, in shopping around one wishes to make a particular transaction,

and the issue is which of the two assets is cheaper to trade.[14] As a result, the influence of shopping around can go on as long as the price difference exceeds the *difference* of the two transactions costs.[15]

- Second, arbitrage is a strong force because it does not require any capital and can, therefore, generate enormous volumes. In contrast, shopping around can be a price-equalizing mechanism only if there are investors who wish to make that particular transaction. This exogenously triggered volume, if any, is always finite and may be exhausted before it has actually equalized the prices.

In this section, we apply these arguments to spot rates quoted for the same currencies by different market makers. In a perfect exchange market with zero spreads, arbitrage implies that the rate quoted by bank X must equal the rate quoted by bank Y: there can be only one price for a given currency—otherwise, there is an arbitrage opportunity.

Example 3.10

If Citibank quotes DEM/USD 1.6500, while Morgan Chase quotes DEM/USD 1.6501, both at zero spreads, then

- there is an arbitrage opportunity. You can buy cheap USD from Citibank and immediately sell to Morgan Chase, netting DEM 0.0001 per USD. You will, of course, make as many USD transactions as you can. So will everybody else. The effect of this massive trading is that either Citibank or Morgan Chase, or both, will have to change their quotes so as to stop the rapid accumulation of long or short positions. That is, situations with arbitrage profits are inconsistent with equilibrium, and are eliminated very rapidly.
- there is also a shopping-around pressure. All buyers of USD will buy from Citibank, and all sellers will deal with Morgan Chase.

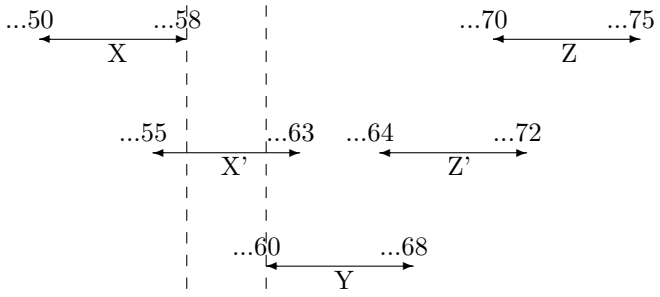
The only way to avoid such trading imbalances is if both banks quote the same rate.[16]

[14] Accordingly, Deardorff (1979) refers to standard arbitrage as *two-way arbitrage* and to shopping-around as *one-way arbitrage*.

[15] Denote by P_U and k_U the price and transaction cost when dealing in the underpriced asset, and denote by P_O and k_O the counterparts for the overpriced asset. The advantage of buying the cheap asset rather than the expensive one remains positive as long as $P_U + k_U < P_O + k_O$; that is, as along as $P_O - P_U > k_U - k_O$. In contrast, the advantage of buying the cheap asset and selling the expensive one remains positive as long as $P_O + k_O - (P_U - k_U <) > 0$; that is, as along as $P_O - P_U > k_U + k_O$: you pay both costs instead of replacing one by another.

[16] This is often put as "by arbitrage, the quotes must be the same," or "arbitrage means that the quotes must be the same." Phrases like this actually mean that to rule out arbitrage opportunities, the quotes must be the same.

Figure 3.10: **Arbitrage and Shopping-around opportunities across market makers**



What we now want to figure out is how arbitrage works when there are bid-ask spreads. The point is that, because of arbitrage, the rates cannot be systematically different; and if the quotes do differ temporarily, they cannot differ by too much.

3.3.1 Arbitrage across Competing Market Makers

Suppose bank X quotes you INR/NZD 20.150–20.158 while bank Y quotes INR/NZD 20.160–20.168. If you see such quotes, you can make money easily: just buy NZD from bank X at INR 20.158, immediately resell it to bank Y at INR 20.160, and pocket a profit worth INR 0.002 for each NZD. Note two crucial ingredients: (1) you are not taking any risk, and (2) you are not investing any capital since the purchase is immediately reversed and both transactions are settled on the same day. The fact that you immediately reverse the transaction explains why this is called arbitrage.

If such quotes are found in the exchange market (or elsewhere, for that matter), large trades by a few alert dealers would immediately force prices back into line. The original quotes would not be equilibrium quotes. In equilibrium, the arbitrage argument says that you cannot make money without investing capital and without taking risk. Graphically, any empty space between the two quotes would correspond to an arbitrage profit. Thus, the no-arbitrage condition says that any two banks' quotes should not be separated by empty space; that is, they should overlap by at least one point, like the quotes X' and Y in Figure 3.10.

3.3.2 Shopping Around across Competing Market Makers

Shopping-around activity implies that small differences like those between the pair (X', Y) in Figure 3.10 will not persist for very long. Rather, the two quotes will sometimes be the same, and if at other times one bank is more expensive then

this would say very little about what the situation will be five minutes later. To see this, suppose that bank X' quotes INR/NZD 20.55–20.63, while bank Y quotes INR/NZD 20.60–20.68. In such a situation, all buyers of NZD will, of course, prefer to deal with bank X', which has the lower ask rate (20.63 instead of 20.68), while all sellers will now deal with bank Y, which has the better bid rate (20.60 instead of 20.55). It is conceivable that these banks actually want this to happen—for instance if bank X' has an excess of foreign currency (long), and bank Y is short forex and wants to replenish its FC inventory. But we would not expect this to be a long-run phenomenon. It is true that very often a bank may want one type of transaction only, but situations like that must change very rapidly because otherwise that bank's position would become unacceptably large and risky.

Example 3.11

Suppose you see five banks quoting EUR against USD, as follows:

Citibank	USD/EUR	1.3450-52
Bank of America	USD/EUR	1.3450-52
Continental Bank	USD/EUR	1.3451-53
Deutsche Bank	USD/EUR	1.3450-52
Banca da Roma	USD/EUR	1.3449-51

Q. Which bank(s) is (are) keen on buying EUR? keen on selling EUR? not interested in dealing?
A. Continental, with its high bid, is quite attractive to sellers, so this trader clearly wants to buy—for example to fill a short position or because she expects a rise. Roma, in contrast, judging by its low ask, is quite attractive to buyers, so their trader clearly wants to sell—maybe to move an unwanted long position, or in anticipation of a fall in the rate. The others are just twiddling thumbs: as things stand, they are unwilling to match Continental's or Roma's rates, and they hope that things will be better soon.

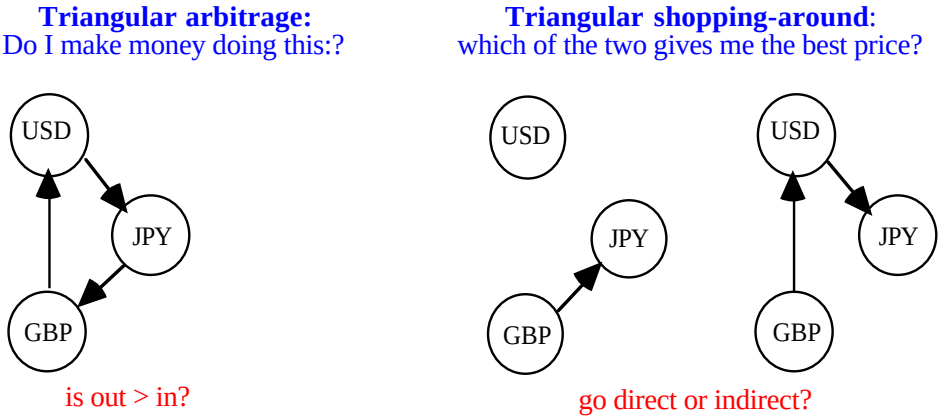
Q. Why does Continental rise both its bid and its ask, rather than just its bid?
A. Apparently it wants not just to attract sellers but also to scare off buyers. Similarly, Roma not just fancies buyers, but does not want any sellers at all.

Q. If we would look at these banks' quotes every five minutes, do we always expect to see the same pattern, i.e. Continental quoting higher and Roma lower than the majority?
A. Of course not: as soon as their desired positions are reached, they will return to the fold. Thus, the top and bottom positions are picked by a particular bank for only a brief period, and move randomly across the list of banks.

3.3.3 Triangular Arbitrage

Now that we know how exchange rates are quoted and what arbitrage means, let us look at the relationships that exist between spot rates quoted in various currencies.

Figure 3.11: **Triangular arbitrage and triangular shopping around**



The forces that support these linkages are again arbitrage and shopping around. For our purposes, we can ignore the many market makers: when we talk about bid and ask, we now mean the *market quote*, that is, the best bid across all market makers, and the best ask. The new issue is how these market quotes in various currencies are linked.

- Someone engaging in triangular *arbitrage* tries to make money by sequentially buying and selling various currencies, ending with the original currency. For instance, you could convert AUD into USD, and then immediately convert the USD into GBP and the GBP back into AUD, with the hope of ending up with more AUD than you started out with. The no-arbitrage condition says that you should not make a profit from such activities. Actually, when there are transactions costs or commissions, you are likely to end up with a loss. The potential loss is due to commissions, notably the bid-ask spread. Thus, in this context, arbitrage implies that the set of exchange rates quoted against various base currencies should be such that you cannot make any risk-free instantaneous profits after paying transactions costs.

- *Shopping around* is the search for the best way to achieve a desired conversion. For instance, an Australian investor who wants to buy GBP may buy directly, or may first convert AUD into USD and then convert these USD into GBP. Shopping around implies that the direct AUD/GBP market can survive only if its quotes are no worse than the implied rates from the indirect transaction.

In the case of perfect markets, the regular arbitrage and shopping-around arguments lead to the same conclusion. We illustrate this in the following example.

Example 3.12

Suppose one GBP buys USD 1.5, while one USD buys AUD 1.6; therefore, if we directly

convert GBP into Aussies, one GBP should buy $1.5 \times 1.6 = 2.4$ AUD. With this AUD/GBP rate and assuming a zero spread,

- nobody can make a free-lunch profit by any sequence of transactions, and
- everyone is indifferent between direct conversions between two currencies and indirect, triangular transactions.

Below, we see what the implications of arbitrage and shopping around are when there are bid-ask spreads. In order to simplify matters, we shall first show how to compute the implied rates from an indirect route. We shall call these implied rates the *synthetic* rates. Having identified these synthetic rates, we can then invoke the same mechanisms that enforce the Law of One Price as when we studied the relationship between the quotes made by various market makers.

Computing Synthetic Cross-Rates

In general, a synthetic version of a contract is a combination of two or more other transactions that achieves the same objective as the original contract. That is, the combination of the two or more contracts *replicates* the outcome of the original contract. We shall use the notion of replication repeatedly in this textbook. For now, consider a simple spot transaction: a Japanese investor wants to convert JPY into GBP.

- The investor can use the direct market and buy GBP against JPY. We will call this the original contract.
- Alternatively, the investor can first buy USD with JPY, and then immediately exchange the USD for GBP. This is a combination of two contracts. It replicates the original contract since, by combining the two transactions, the investor initially pays JPY, and ultimately ends up with GBP. Thus, this is a synthetic way of achieving the original transaction.

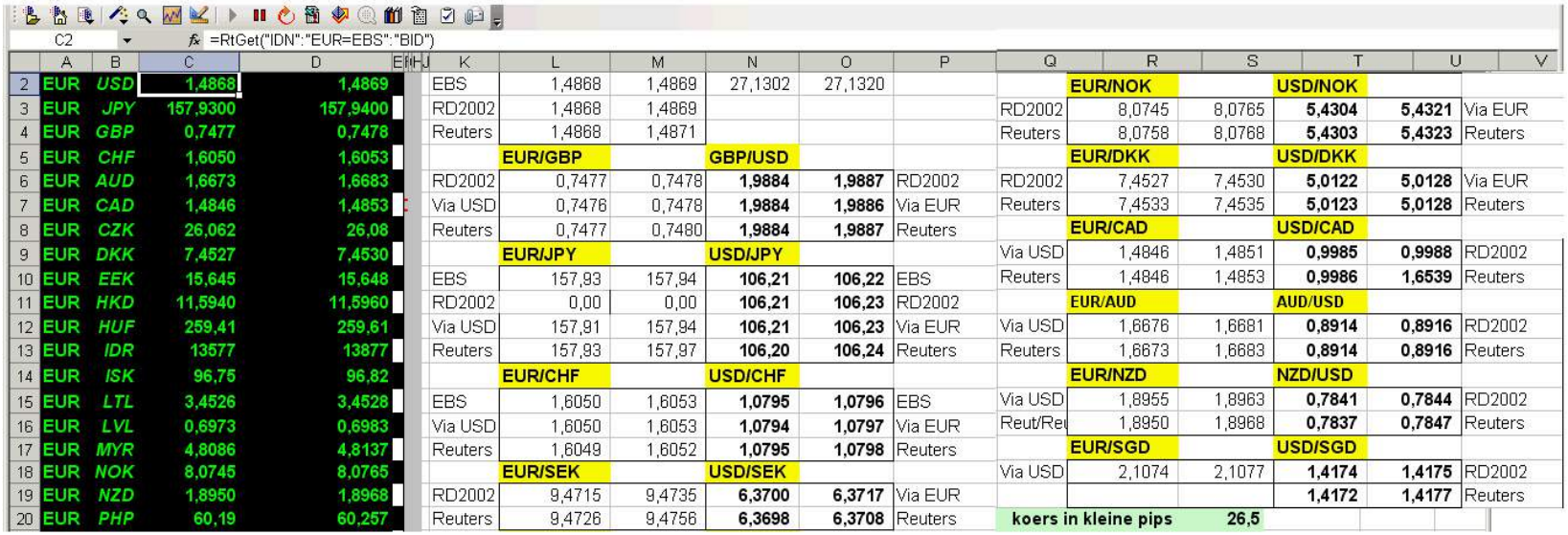
Note that the synthetic contract may be the more efficient way to deal, since the USD market has a lot of volume (or depth) in every country, and therefore has smaller spreads. (This is why the USD is involved in 90 percent of the trades). Let us see how the synthetic JPY/GBP rates can be computed.

Example 3.13

What are the synthetic JPY/GBP rates, bid and ask, if the quotes are JPY/USD 101.07 - 101.20 and USD/GBP 1.3840 -1.3850?

Step 1: multiply or divide? The dimension of the rate we are looking for is JPY/GBP. Because the dimensions of the two quotes given to us are USD/GBP and

Figure 3.12: **A Dealer's Shopping-Around Spreadsheet**



C2 =RtGet("IDN":"EUR=EBS":"BID")

	A	B	C	D	K	L	M	N	O	P	Q	R	S	T	U	V
2	EUR	USD	1,4868	1,4869	EBS	1,4868	1,4869	27,1302	27,1320			EUR/NOK		USD/NOK		
3	EUR	JPY	157,9300	157,9400	RD2002	1,4868	1,4869				RD2002	8,0745	8,0765	5,4304	5,4321	Via EUR
4	EUR	GBP	0,7477	0,7478	Reuters	1,4868	1,4871				Reuters	8,0758	8,0768	5,4303	5,4323	Reuters
5	EUR	CHF	1,6050	1,6053		EUR/GBP		GBP/USD				EUR/DKK		USD/DKK		
6	EUR	AUD	1,6673	1,6683	RD2002	0,7477	0,7478	1,9884	1,9887	RD2002	RD2002	7,4527	7,4530	5,0122	5,0128	Via EUR
7	EUR	CAD	1,4846	1,4853	Via USD	0,7476	0,7478	1,9884	1,9886	Via EUR	Reuters	7,4533	7,4535	5,0123	5,0128	Reuters
8	EUR	CZK	26,062	26,08	Reuters	0,7477	0,7480	1,9884	1,9887	Reuters		EUR/CAD		USD/CAD		
9	EUR	DKK	7,4527	7,4530		EUR/JPY		USD/JPY			Via USD	1,4846	1,4851	0,9985	0,9988	RD2002
10	EUR	EEK	15,645	15,648	EBS	157,93	157,94	106,21	106,22	EBS	Reuters	1,4846	1,4853	0,9986	1,6539	Reuters
11	EUR	HKD	11,5940	11,5960	RD2002	0,00	0,00	106,21	106,23	RD2002		EUR/AUD		AUD/USD		
12	EUR	HUF	259,41	259,61	Via USD	157,91	157,94	106,21	106,23	Via EUR	Via USD	1,6676	1,6681	0,8914	0,8916	RD2002
13	EUR	IDR	13577	13877	Reuters	157,93	157,97	106,20	106,24	Reuters	Reuters	1,6673	1,6683	0,8914	0,8916	Reuters
14	EUR	ISK	96,75	96,82		EUR/CHF		USD/CHF				EUR/NZD		NZD/USD		
15	EUR	LTL	3,4526	3,4528	EBS	1,6050	1,6053	1,0795	1,0796	EBS	Via USD	1,8955	1,8963	0,7841	0,7844	RD2002
16	EUR	LVL	0,6973	0,6983	Via USD	1,6050	1,6053	1,0794	1,0797	Via EUR	Reut/Reu	1,8950	1,8968	0,7837	0,7847	Reuters
17	EUR	MYR	4,8086	4,8137	Reuters	1,6049	1,6052	1,0795	1,0798	Reuters		EUR/SGD		USD/SGD		
18	EUR	NOK	8,0745	8,0765		EUR/SEK		USD/SEK			Via USD	2,1074	2,1077	1,4174	1,4175	RD2002
19	EUR	NZD	1,8950	1,8968	RD2002	9,4715	9,4735	6,3700	6,3717	Via EUR				1,4172	1,4177	Reuters
20	EUR	PHP	60,19	60,257	Reuters	9,4726	9,4756	6,3698	6,3708	Reuters	koers in kleine pips		26,5			

Key Courtesy of Paul Goossens, dealer at KBC Brussels. Paul's spreadsheet shows the best quotes from EBS's broking screens, from Reuters Dealing 2002, and the indirect quotes (via USD or EUR). The latter are obviously rounded. Check how the indirect quotes are always wider at one side at least. (With only two pips between the best direct quotes, and with rounding of the synthetic quotes, one side must always seem to match.) The wider quotes labeled Reuters are the indicative, non-binding ones from the `Reuters FX/FX` pages; they mean nothing except that that some banks are willing to quote. See how Paul's sheet gets the EUR/USD quote from EBS into the black&green part of the spreadsheet. Cell 1 is selected; spot the underlying command `=RtGet(''IDN'':''EUR=EBS'':''BID'')` in the `enter function` box above the spreadsheet. From the imported data in the black part, synthetic rates are computed.

JPY/USD, the way to obtain the synthetic rate is to multiply the rates, as follows:

$$[\text{JPY/GBP }] = [\text{JPY/USD }] \times [\text{USD/GBP }] \tag{3.5}$$

Note that on the right-hand side of the equation, the USD in the denominator of the first quote cancels out with the USD in the numerator of the second quote, leaving us with the desired JPY/GBP number.

Step 2: bids or asks? The first quote is the natural quote for a Japanese agent, the second one takes the USD as the base. Consider the synthetic ask (relevant for buying GBP from a JPY position). Starting from JPY we buy USD, so we need the ask; and with the USD we buy GBP, so we again need ask. Thus,

$$\begin{aligned} \textit{Synthetic } S^{\text{JPY/GBP}}_{t,ask} &= S^{\text{JPY/USD}}_{t,ask} \times S^{\text{USD/GBP}}_{t,ask} \\ &= 101.20 \times 1.3850 = 140.16 \end{aligned} \tag{3.6}$$

By a similar argument, we can obtain the rate at which we can synthetically sell GBP into USD and these into JPY:

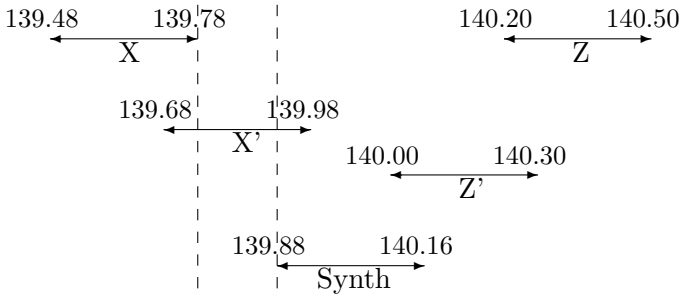
$$\begin{aligned} \textit{Synthetic } S^{\text{JPY/GBP}}_{t,bid} &= S^{\text{JPY/USD}}_{t,bid} \times S^{\text{USD/GBP}}_{t,bid} \\ &= 101.07 \times 1.3840 = 139.88 \end{aligned} \tag{3.7}$$

This example is the first instance of the Law of the Worst Possible Combination or the Rip-Off Rule. You already know that for any single transaction, the bank gives you the worst rate from your point of view (this is how the bank makes money). It follows that if you make a sequence of transactions, you will inevitably get the worst possible cumulative outcome. This Law of the Worst Possible Combination is the first Fundamental Law of Real-world Capital Markets. In our example, this law works as follows:

- Note that we are computing a product. The synthetic ask rate for the GBP (the higher rate, the one at which you buy) turns out to be the highest possible product of the two exchange rates: we multiply the two high rates, ask times ask. Note finally that, if the purpose is to buy forex, then a high rate is also an unfavorable rate. In short, we buy at the worst rate, the highest possible combined rate.
- We see that, likewise, the synthetic bid rate for the GBP (the lower rate, the one at which you sell) turns out to be the lowest possible product of the two exchange rates: we multiply the two low rates, bid times bid. Note also that, if the purpose is to sell forex, then a low rate is also an unfavorable rate. In short, we sell at the worst rate, the lowest possible combined rate.

Let us look at another example. The data are the same except that the British quotes now are direct not indirect.

Figure 3.13: **Triangular Arbitrage and Shopping-around**



DoItYourself problem 3.1

The JPY/GBP synthetic bid and ask rates, if the quotes are

JPY/USD 101.07 - 101.20 and
GBP/USD 0.72202 - .72254,

are

$$Synth\ S^{\text{JPY/GBP}}_{t,bid} = \frac{S^{\text{JPY/USD}}_{t,bid}}{S^{\text{GBP/USD}}_{t,ask}} = 139.88\,,\ Synth\ S^{\text{JPY/GBP}}_{t,ask} = \frac{S^{\text{JPY/USD}}_{t,ask}}{S^{\text{GBP/USD}}_{t,bid}} = 140.16. \tag{3.8}$$

- Derive this solution from the previous one, invoking our earlier results on inverse rates, equations (3.3) and (3.4).
- Verify that you get the above answer also if you first think of the dimensions and then apply the Law of the Worst Possible Combination.

Triangular Arbitrage with Transactions Costs

Now that we understand synthetic quotes, we can derive bounds imposed by arbitrage and shopping around on quotes in the wholesale market. Just think of the direct quotes as the quotes from bank X, and think of the synthetic quotes as the quotes from bank Y.

- *Arbitrage* then says that the two bid-ask quotes should overlap by at least one point; otherwise, you can buy cheap in the direct market and sell at a profit in the synthetic market or vice versa.
- *Shopping around* implies that if a bank skews its quotes so as to be (very) attractive at (only) one side, then it will attract a lot of business very fast; thus, this skewing cannot be persistent. But when we talk about market

quotes (the best bid, and the best ask, across all market makers) rather than the quotes by an individual dealer, the force is even stronger. Individually, a market maker may very well want to make one of its quotes unappealing for some time, as we saw. But if there are many market makers it would be quite unlikely that, across all market makers, even the best direct quote would still be unappealing against the synthetic one, for that would mean that among all the competing market makers there is not a single one that is interested in that particular type of deal. Thus, instances where a direct quote is dominated by a synthetic one at one side should be rare and short-lived, and the more so the higher the number of market makers.

- The above assumes that the direct market has enough volume. Indeed, with a very thin market, the spread required to make market-making sustainable may be too wide to allow the direct market to compete on both sides with the synthetic market via a heavily-traded vehicle currency (like the USD or the EUR). The volume and depth of the wholesale market for dollars relative to almost any other currency is so large (and the spreads, therefore, so small) that a substantial part of the nondollar transactions are, in fact, still executed by way of the dollar. Direct cross-deals have emerged as of the mid 1980s only, and are still confined to heavy-volume currency pairs.

As a final note, in the retail markets most customers have no direct access to cross rates, and bank clerks occasionally compute cross rates even where the actual transaction could be executed very differently. A Japanese bank, for instance, would post quotes for JPY/GBP and JPY/EUR rates for its retail customers, but typically not for GBP/EUR. Should a retail customer sell EUR and buy GBP, the clerk would actually compute the synthetic rates we just derived, as if the customer first went from EUR to JPY and then to GBP, even if in the bank's trading room the actual conversion may be done directly from EUR into GBP. Unless you have an account with a Euroland or UK bank, or enough clout with your home bank, you would have little choice but to accept the large spread implied by such synthetic rates.

This finishes our tour of the workings of the exchange markets. We continue the chapter with some wise advice on the merits and shortcomings of using exchange rates to translate foreign amounts of money. This brings us to the twin concepts of "PPP" and "real" exchange rates, key issues to understand the relevance of currency risk.

3.4 Translating FC Figures: Nominal rates, PPP rates, and Deviations from PPP

Obviously, when you exchange a FC amount into HC or *vice versa*, you will use the exchange rate relevant at the moment. But actual transactions like this are not the sole conceivable purpose for such a conversion; rather, the purpose may just be

translation, that is, to have an idea what a FC amount means in a unit that you are more familiar with, the HC. For instance, if a resident of Vanuatu tells you she's making 1m Vatus a month, most people would not have a clue whether they should be impressed or not. In a case like this we don't want to actually exchange any Vatus into our own HC; we'd simply like to translate a FC number into a (to us) more meaningful unit.

The most commonly used solution is to resort to the market exchange rate to make the translation. The result is an improvement on the FC amount in the sense that you know what you would be able to do with this converted amount if you consumed it here, at home. But your objective may be to have a feel for what the FC amount would mean to a resident of the foreign country, that is, if the money is consumed there, not here. Both questions—the purchasing power of some amount of money in your home country, and the purchasing power abroad—provide the same answer if prices abroad and at home are on average the same once they have been converted into the same currency. This situation is known as (Absolute) Purchasing Power parity (APPP). As we will illustrate below, APPP does not hold in reality, with deviations becoming more important the more different the two countries are in terms of location or economic development.

3.4.1 The PPP rate

To have a more reliable feel for what a given amount of foreign money really means locally, one needs for each country a number called the price level, which we denote by Π (at home, and in HC), and Π^* (abroad, and in FC), respectively. A price level is an absolute amount of currency—not an index number—needed to buy a standard consumption bundle. Computing price levels for different countries makes sense only if the consumption bundle whose cost is being measured is the same across countries. In a simple economy where fast food would be the only commodity, the bundle may be one soda, one burger, one fries (medium), a salad and a coffee—let's call this the BigMeal. We simply jot down the prices of the components abroad and at home, and tot them up into price levels for BigMeals.

Any differences in price levels, after conversion into a common currency, would make a simple conversion of a FC amount into the HC rather misleading if translated price levels are very diffferent:

Example 3.14

You often chat with a friend living in the Republic of Freedonia where, since the presidency of Groucho Marx, the currency is the Freedonian Crown (FDK). Let S_t = USD/FDK 0.010. You earn USD 50 per unit of time, your Freedonian friend 2000 FDK. What does that income really mean if the standard consumption bundle, our BigMeal, costs USD 5 here and FDK 250 in Freedonia?

- At the spot rate of USD/FDK 0.010, your friend seems to earn only $2000 \times 0,010$ = USD 20, suggesting that she is 60 percent worse off than you.

- But this ignores price differences. What you "really" earn is $50/5 = 10$ BigMeals, while your friend makes $2000/250 = 8$ BigMeals. That is, your friend is "really" almost as well off as you are.

What's the PPP rate?

To buy 8 BigMeals at home, you would need $8 \times 5 =$ USD 40. So one way to summarize the situation is that FDK 2000 means as much to your friend abroad as USD 40 means here, to you. The USD 40 is called the translation of FDK 2000 using the Purchasing Power Parity rate rather than the nominal rate, and the implied PPP rate is the $40/2000 = 0.020$ USD per FDK, the ratio of the two price levels.

Let's generalize. Suppose you want to have a feel for what a FC amount Y^* "really" means to a foreigner. The question can be made more precise as follows: Give me a HC amount $\hat{Y}$ such that its purchasing power here, $\hat{Y}/\Pi_t$, equals the purchasing power abroad of the original amount, Y^*/Π_t^*:

$$\begin{aligned} \text{Find } \hat{Y} \text{ such that } \frac{\hat{Y}}{\Pi_t} &= \frac{Y^*}{\Pi_t^*} \\ \Rightarrow \hat{Y} &= \frac{\Pi_t}{\Pi_t^*} Y^* \qquad (3.9) \\ &= \hat{S}_t^{\text{PPP}} Y^*, \text{ where } \hat{S}_t^{\text{PPP}} \stackrel{\text{def}}{=} \frac{\Pi_t}{\Pi_t^*} \qquad (3.10) \end{aligned}$$

So we can always compute the PPP rate as the ratio of the two price levels. For example, your friend's foreign amount (FDK 2000) could have been translated at the PPP rate, $5/250 = 0.020$, which would have told you immediately that her income buys as much (in Freedonia) as USD 40 buys here.

Example 3.15

End 2006, the CIA Factbook (http://www.cia.gov/cia/publications/factbook/geos/rs.html) assessed Russia's 2005 GDP at 1.589 USD trillion using the PPP rate, and at 740.7 billion using the nominal official rate. What is the explanation: are prices lower in Russia than in the US, or is it the inverse?

For China, the then figures were (purchasing power parity:) USD 8.883 trillion and (official exchange rate:) USD 2.225 trillion), a ratio of about four to one instead of Russia's two to one. Which country, then, has the lower price level?

DoItYourself problem 3.2

Check that the PPP rate has dimension HC/FC.

The IMF and the World Bank, for instance, often use PPP rates rather than the regular ("nominal") rate to translate foreign GDP's or incomes or government

Table 3.4: **PPP rates based in Big-Mac prices from *The Economist***

	curren-cy	local price	actual value of $	PPP rate of $	real rate of $	actual value in $	PPP rate in $	real rate in $
China	yuan	10.5	8.03	3.39	2.371	0.125	0.295	0.422
Macau	pacata	11.1	7.99	3.58	2.231	0.125	0.279	0.448
Malaysia	ringgit	5.5	3.63	1.77	2.046	0.275	0.564	0.489
Hong Kong	dollar	12	7.75	3.87	2.002	0.129	0.258	0.499
Indonesia	rupia	14600	9325	4709.68	1.980	0.000	0.000	0.505
Philippines	peso	85	52.6	27.42	1.918	0.019	0.036	0.521
Paraguay	guarani	9000	5505	2903.23	1.896	0.000	0.000	0.527
Egypt	pound	9.5	5.77	3.06	1.883	0.173	0.326	0.531
Ukraine	hryvna	8.5	5.05	2.74	1.842	0.198	0.365	0.543
Moldava	leu	23	13.2	7.42	1.779	0.076	0.135	0.562
Uruguay	peso	42.3	23.9	13.65	1.752	0.042	0.073	0.571
Russia	ruble	48	27.1	15.48	1.750	0.037	0.065	0.571
Dominican Rep	peso	60	32.6	19.35	1.684	0.031	0.052	0.594
Sri Lanka	rupee	190	103	61.29	1.681	0.010	0.016	0.595
Honduras	lempira	35.95	18.9	11.60	1.630	0.053	0.086	0.614
Bulgaria	lev	2.99	1.54	0.96	1.597	0.649	1.037	0.626
Slovakia	koruna	58	29.5	18.71	1.577	0.034	0.053	0.634
Poland	zloty	6.5	3.1	2.10	1.478	0.323	0.477	0.676
Thailand	baht	60	28.4	19.35	1.467	0.035	0.052	0.682
South Africa	rand	13.95	6.6	4.50	1.467	0.152	0.222	0.682
Pakistan	rupee	130	60.1	41.94	1.433	0.017	0.024	0.698
Venezuela	bolivar	5701	2630	1839.03	1.430	0.000	0.001	0.699
Costa Rica	colon	1130	510	364.52	1.399	0.002	0.003	0.715
Japan	yen	250	112	80.65	1.389	0.009	0.012	0.720
Singapore	dollar	3.6	1.59	1.16	1.369	0.629	0.861	0.730
Guatemala	quetzal	17.25	7.59	5.56	1.364	0.132	0.180	0.733
Argentina	peso	7	3.06	2.26	1.355	0.327	0.443	0.738
Georgia	lari	4.15	1.8	1.34	1.345	0.556	0.747	0.744
Taiwan	dollar	75	32.1	24.19	1.327	0.031	0.041	0.754
Estonia	kroon	29.5	12.3	9.52	1.293	0.081	0.105	0.774
Saudi Arabia	riyal	9	3.75	2.90	1.292	0.267	0.344	0.774
Lithuania	litas	6.5	2.69	2.10	1.283	0.372	0.477	0.779
Australia	dollar	3.25	1.33	1.05	1.269	0.752	0.954	0.788
UAE	dirham	9	3.67	2.90	1.264	0.272	0.344	0.791
Latvia	lats	1.35	0.55	0.44	1.263	1.818	2.296	0.792
Mexico	peso	29	11.3	9.35	1.208	0.088	0.107	0.828
Colombia	peso	6500	2504	2096.77	1.194	0.000	0.000	0.837
Croatia	kuna	15	5.72	4.84	1.182	0.175	0.207	0.846
South Korea	won	2500	952	806.45	1.180	0.001	0.001	0.847
Czech Rep	koruna	59.05	22.1	19.05	1.160	0.045	0.052	0.862
Fiju	dollar	4.65	1.73	1.50	1.153	0.578	0.667	0.867
Hungary	forint	560	206	180.65	1.140	0.005	0.006	0.877
Turkey	lire	4.2	1.54	1.35	1.137	0.649	0.738	0.880
New Zealand	dollar	4.45	1.62	1.44	1.129	0.617	0.697	0.886
Slovenia	tolar	520	189	167.74	1.127	0.005	0.006	0.888
Aruba	florin	4.95	1.79	1.60	1.121	0.559	0.626	0.892
Brazil	real	6.4	2.3	2.06	1.114	0.435	0.484	0.898
Morocco	dirham	24.5	8.71	7.90	1.102	0.115	0.127	0.907
Peru	new sol	9.5	3.26	3.06	1.064	0.307	0.326	0.940
Chile	peso	1560	530	503.23	1.053	0.002	0.002	0.949
United states	dollar	3.1	1	1.00	1.000	1.000	1.000	1.000
Canada	dollar	3.52	1.12	1.14	0.986	0.893	0.881	1.014
Britain	pound	1.94	0.532	0.63	0.850	1.880	1.598	1.176
Euroland	euro	2.94	0.781	0.95	0.824	1.280	1.054	1.214
Sweden	krona	33	7.28	10.65	0.684	0.137	0.094	1.462
Denmark	krone	27.75	5.82	8.95	0.650	0.172	0.112	1.538
Switzerland	franc	6.3	1.21	2.03	0.595	0.826	0.492	1.680
Iceland	kronur	459	72	148.06	0.486	0.014	0.007	2.056
Norway	kroner	43	6.1	13.87	0.440	0.164	0.072	2.274

Source Based on data from *The Economist*, May 26, 2006

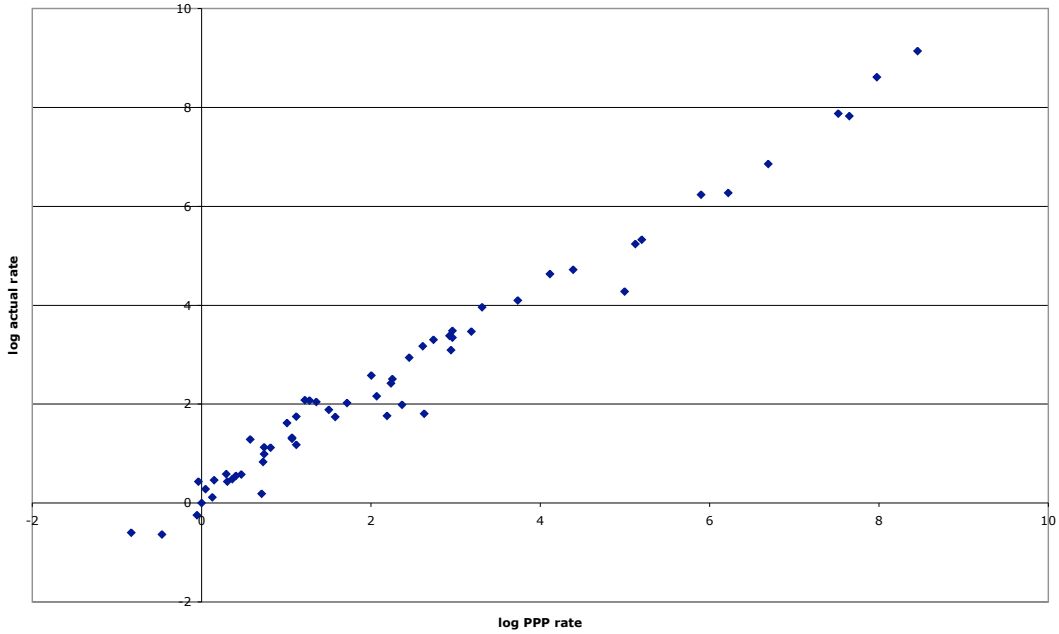
budgets. Also newspapers or magazines start adopting this approach. Lastly, the PPP rate also serves as a benchmark for the nominal rate. Many economists feel that, in the long run, the nominal rate for two similar economies should loosely fluctuate around the PPP rate, and never wander off very far above or below it. Let's see how well this theory fares, empirically.

PPP in reality

In Table 3.4 we take *The Economist*'s favorite consumption bundle, the Big Mac,[17] and we compute PPP rates for 59 countries—once in USD (a New Yorker should get 0.295 dollars to be as happy as a Beijinger with one extra yuan) and once in non-US currency (a Beijinger should get 3.39 yuan to be as happy as a New Yorker with with one extra dollar). You see that countries where the Mac has a high local price have, of course, low PPP rates but also tend to have low actual exchange rates. Figure 3.14 shows this graphically. To "shrink" the outliers and give the smaller numbers more space we plot the log of the actual against the log of the PPP rate.

[17] Based on data from *The Economist*, May 26, 2006

Figure 3.14: **Log PPP *v* log actual rates, HC/USD**



Source Based on data from *The Economist*, May 26, 2006

(This explains why there are negative rates: numbers below unit produce negative logs). There obviously is a very strong link.

DoItYourself problem 3.3

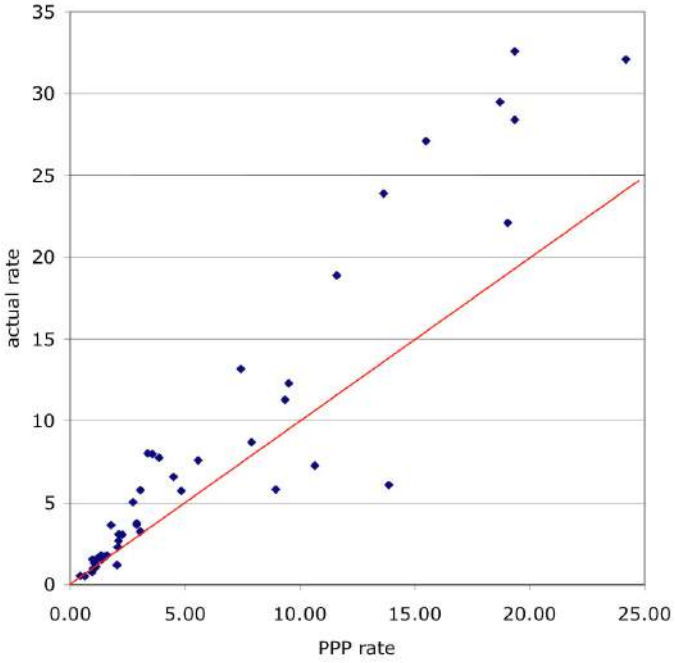
Knowing that the BigMac costs 3.10 in the US and 155 in Freedonia, and that the spot rate is 100 Crowns per dollar, complete Freedonia's PPP rates in the table:

	curren-cy	local price	actual value of $	PPP rate of $	real rate of $	actual value in $	PPP rate in $	real rate in $
Freedonia	korona	155	100					

.

But a closer look at the table reveals big relative deviations, which are hard to spot from a log graph dominated by outliers. Kicking out the 20 highest cases so as to be able to forego logs, this time, we get Figure 3.15. Note how the observations tend to be above the equality line (where actual = PPP): the dollar tends to be too expensive, by BigMac PPP standards. Yet there are also important deviations below the 45-degree line, where the slope of the ray through the dot is even below 0.5 in one case. The slope of this ray is called the *real exchange rate*, to which we now turn.

Figure 3.15: **PPP *v* actual rates, HC/USD**



Source Based on data from *The Economist*, May 26, 2006

3.4.2 Commodity Price Parity

A concept used in textbooks is Commodity Price Parity (CPP). It is said to hold when translated prices for an individual good are equalized across two countries:

$$\text{CPP holds if } P_{j,t} = S_t \times P^*_{j,t}, \tag{3.11}$$

with j referring to an individual good, and P_j (P^*_j) referring to its price at home, in HC (abroad, in FC). In fact, all the Big Mac evidence shown thus far is about CPP rather than PPP, a distinction that *The Economist* tends to gloss over.

CPP would hold if trading were costless and instantaneous. Obviously, in reality it does not work across the board; for commodities it is not too bad an approximation (within the bounds created by transportation costs and the like), but for consumer goods it is essentially a joke.

PPP in the true sense—*i.e.* for a bundle of goods—would clearly hold if CPP held for every individual good, or if deviations from CPP washed out after averaging across many goods. As we have seen, this is not really the case; apparently, too many deviations from CPP turn out to be in the same direction, suggesting there is a common force behind them. Forget CPP.

3.4.3 The Real Exchange Rate and (Deviations from) Absolute PPP

The real exchange rate (RER) is a measure of how far the nominal rate differs from the PPP one: it simply is the nominal exchange rate divided by the PPP counterpart.

Example 3.16

In our Freedonian story, the nominal rate was 0.010 USD/FDK while the PPP rate was 0.020 USD/FDK; thus, the real rate was 0.5—a large deviation from unity, but not uncommon between two very different economies.

The real rate is a dimensionless number—[HC/FC] divided by [HC/FC]. In a way, it simply tells us what the ratio is of the *translated* price levels:

$$RER_t \stackrel{\text{def}}{=} \frac{S_t}{\hat{S}_t^{\text{PPP}}} \tag{3.12}$$

$$= \frac{S_t \times \Pi_t^*}{\Pi_t}, \text{ from (3.10).} \tag{3.13}$$

Again, in the example one can find the RER for the FDK against the USD by translating into USD the foreign price of the BigMeal, FDK $250 \times 0.010 =$ USD 2.5, and divide it by the domestic price level, 5, which gets us $2.5/5 = 0.5$. Thus, the RER rate tells you how much cheaper (if RER < 1) or more expensive (if RER > 1) the foreign country is. A country with a below-unity real rate would be a nice place to spend your domestic income, or could be an attractive base to export from, but may not be the best place to export to. These are very different questions than the one answered by the PPP rate.

Obviously, if the real rate equals unity, both countries have the same price level. If that is true, Absolute PPP is said to hold:

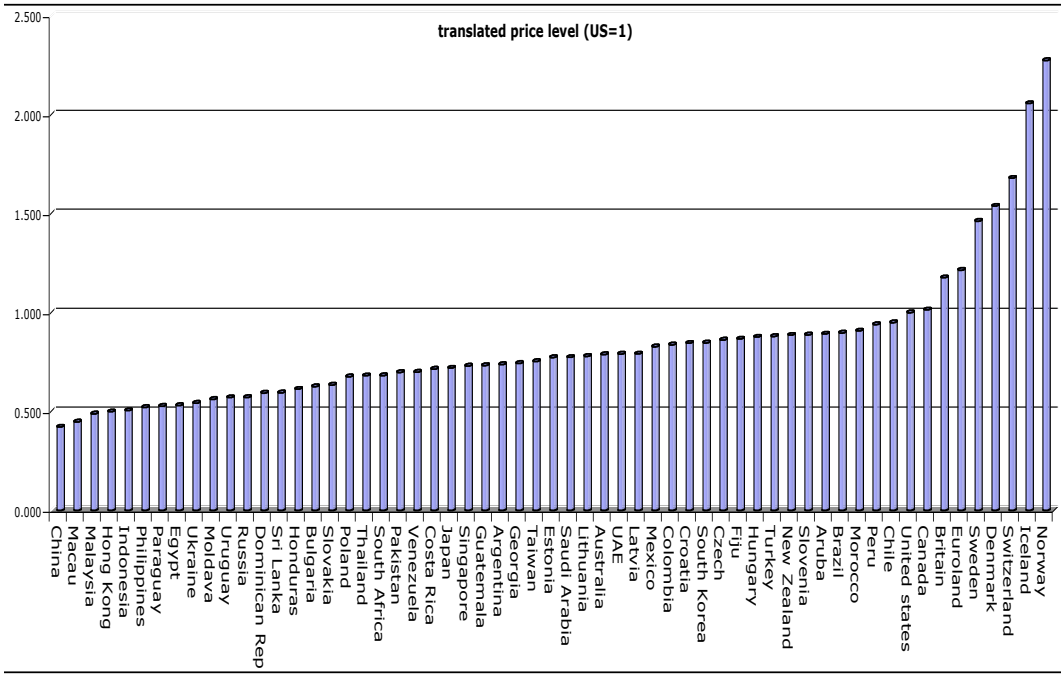
$$\text{Absolute PPP holds if } RER_t = 1 \Leftrightarrow S_t = S_t^{\text{PPP}} \Leftrightarrow S_t \times \Pi_t^* = \Pi_t \tag{3.14}$$

In Figure 3.16, and in Table 3.4 the countries have been ranked on the basis of the real rate. Two observations stand out. First, there is a five-to-one ratio between the most and least expensive countries, Norway and China. So deviations from PPP are big. Second, there is a system to it, to some extent: undervalued currencies tend to be developing ones, and overvalued ones developed. (The fact that thus USD is not top is anomalous, in this view. The long-lasting deficit in its CA may be one reason). The (imperfect but strong) relation between real rate and degree of economic development is discussed in Chapter 10.

DoItYourself problem 3.4

Norway is most expensive. Identify the dot, in Figure 3.15, that corresponds to Norway.

Figure 3.16: **Real rates based on Big-Mac prices from *The Economist***



Source Based on data from *The Economist*, May 26, 2006

3.4.4 The Change in the Real Rate and (deviations from) Relative PPP

For most of the time since the 80s, Japan has had a real rate above unity: it was a more expensive place to spend a dollar than the US or Europe. Sometimes one would be interested in whether the country's situation has worsened or improved. That is, has the real rate increased or decreased (as distinct from the issue of whether its level is above unity or not)?

To measure this, one can simply compute the RER's percentage change. Not surprisingly, the percentage change in the RER is determined by the percentage changes in the spot rate and the price levels—the inflation rates:

Example 3.17

Q. Suppose that 5 years ago the FDK traded at USD/FDK 0.012, and the price levels were USD 4 in the US and FDK 250 abroad. (So, with current price levels being 5 and 250, respectively, inflation was 25 percent in the US, and zero in Freedonia.) Recalling that the current RER is $250 \times 0.010/5 = 0.5$, how much did the RER change since then?

A. The old RER was $250 \times 0.012/4 = 0.75$; so the rate changed by $(0.50 - 0.75)/0.75 = -0.33$, that is, minus 33 percent. There was real depreciation of the Crown—that is, Freedonia became cheaper over time—because the FDK went down *and* because

inflation in Freedonia was lower than US.

Below, we first show the general relation between the percentage change in the RER and the changes in the nominal rate, and then a first-order approximation that is occasionally used:

$$\begin{aligned} \text{percentage change in the RER} &= (1+s_{t_0,t})\frac{1+infl^*_{t_0,t}}{1+infl_{t_0,t}}-1 && (3.15)\\ &\approx s_{t_0,t}+[infl^*_{t_0,t}-infl_{t_0,t}] && (3.16)\end{aligned}$$

where $s_{t_0,t}$ is the simple percentage change in the spot rate S between times t_0 and t while $infl_{t_0,t}$ and $infl^*_{t_0,t}$ denote inflation at home and abroad, respectively, over the same time window. The first-order approximation works well if both inflation rates are low. This is not the case in our Freedonian example:

Example 3.18

In our above story, foreign inflation was zero, US inflation 25 percent, and the exchange rate changed by minus one-sixth; so the RER changes by

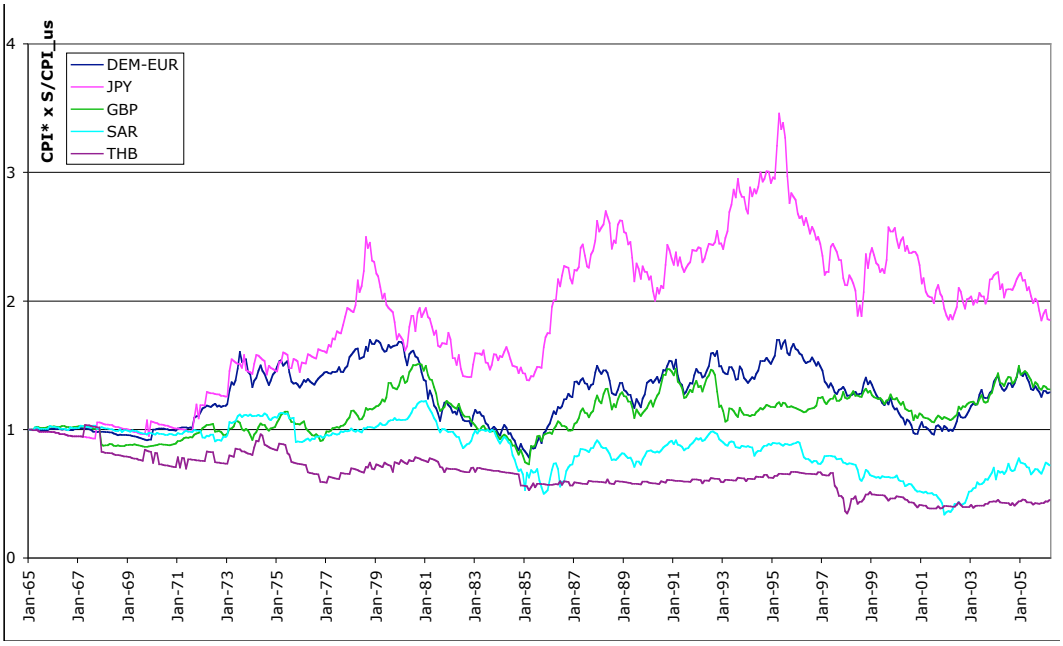
$$(1-1/6)\frac{1+0.00}{1+0.25}-1=0.66667-1=-1/3,$$

as computed directly before. In contrast, the first-order approximation would have predicted a change of –1/6 – 0.25 = –41.67 percent rather than –33.33 percent. The error is nontrivial because in this example the exchange-rate change and one inflation rate, the US one, are far from zero.

If the RER is constant—whatever the level— then Relative PPP (RPPP) is said to hold; and the percentage change in the RER is a standard measure of deviations from RPPP. An RPPP deviation is most often resorted to if the RER itself cannot be computed because price-level data are missing. If, indeed, absolute price levels for identical bundles are not available, there is no way to compute which of the two countries is the cheaper one. But one can still have an idea whether the RER went up or down if one estimates the inflation rates from the standard Consumption Price Indices (CPI's) rather than the price levels. A CPI is a relative number vis-a-vis a base period, and the consumption bundle is typically tailored to the country's own consumption pattern rather than being a common, internationally representative bundle of goods. Still, in most cases this makes little difference to the inflation rates.

The RPPP rate relative to some chosen base period t_0 is the level of the current

Figure 3.17: **[Actual Rate]/[RPPP Rate] against the usd, 1965=1.00**



Source Underlying data are from Datastream

rate that keeps the RER at the same level as in the base period:

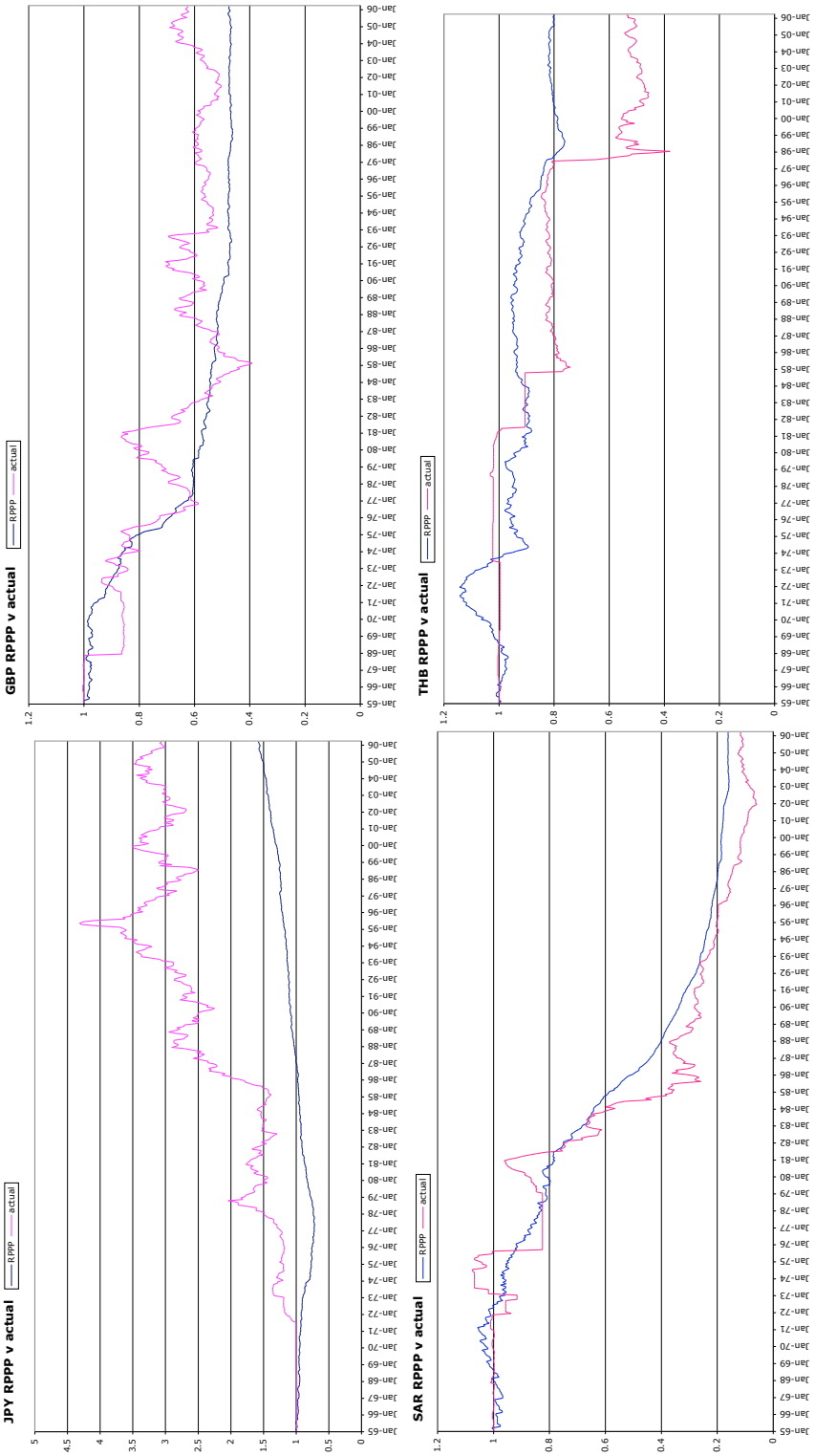
$$[\text{RPPP rate vis-a-vis } t_0] = S_t^{RPPP,t_0} = S_{t_0}\frac{1+infl_{t_0,t}}{1+infl^*_{t_0,t}}; \tag{3.17}$$

$$\begin{aligned}\text{Relative Real Rate vis-a-vis } t_0 &= \frac{S_t}{S_t^{RPPP,t_0}},\\ &= \frac{S_t}{S_{t_0}}\frac{1+infl^*_{t_0,t}}{1+infl_{t_0,t}},\end{aligned} \tag{3.18}$$

which is unity plus the change in the real rate except that we use each country's CPI inflation (or some similar index) rather than the change in the absolute price of an internationally common basket. In pre-EUR days, the EC or EU ministers of EMR[18] countries used the RPPP norm when devaluations were negotiated. They went back to the time of the last re-alignment, and corrected that base-period level for the accumulated inflation differential since then, as in Equation [3.17]. But the main use of the RPPP for business is that it tells us whether a country has become cheaper, or more expensive, relative to another one. Cheapening countries are good if they are your production centers or your favorite holiday resort, but bad if they are the

[18]Exchange Rate Mechanism—the arrangement that kept members' crossrates stable. See Chapter 2.

Figure 3.18: **RPPP v actual rates against usd, 1965=1.00**



Source Underlying data are from Datastream

markets where you sell your output.

For this reason, deviations from RPPP are important. Are they large? Figure 3.17 shows time-series data, taking Jan 1965 as the base period, on relative real rates against USD, for the DEM-EUR, JPY, GBP, SAR, and THB. We note four facts.

- First, there are huge swings in the medium run, with the real rate appreciating by 50% and then going back—and occasionally even doubling or halving— in a matter of years not decades. Imagine you being caught in this as an exporter.

- Second, in the short run there is lots of inertia: once the rate is above its mean, it tends to stay there for years. Statistical analysis shows that the average half life is three to five years, meaning that it takes three to five years, on average, for a deviation to shrink to half its original size. Thus, when you get into a bad patch, you can expect that this will be a matter of years rather than weeks or months.

- Third, when we look at the RPPP rates and the actual ones separately (Figure 3.18), we see that, almost always, in the short run most of the variation in the real rate stems from the nominal rate; the RPPP rate is usually smooth relative to the actual, except of course under a fixed-exchange-rate regime (see graphs) and in hyperinflation cases (not shown). The fall, rise, & fall of the USD against the DEM under presidents Carter and Reagan had nothing to do with inflation. In a way, that's good, because there are good hedge instruments against swings in nominal rates. Hedging nominal rates, in the short run, almost stabilizes the real rate too.

- Even though deviations between actual and RPPP rates are huge, there often does seem to be a link, in the long run. As a result, the long-run variability of the inflation-corrected rate is somewhat lower than that in the nominal rate.

- A last fact, impossible to infer from the graphs but to be substantiated in Chapter 10, is that changes in both nominal and real exchange rates seem hard to predict.

Should you care? If exchange risk would just lead to capitals gains and losses on assets or liabilities denominated in FC, most (but not all) firms would be able to shrug it off as a nuisance, perhaps, but no more than that. However, there is more: real-rate moves may also make your production sites incompetitive or your export markets unprofitable, and it is harder for a firm to just shrug this off. Another implication worth mentioning is that when two investors from different countries hold the same asset, they will nevertheless realize different real returns if the real exchange rate is changing—which it does all the time. Thus, exchange risk undermines one of the basic assumptions of the CAPM, namely that investors all agree on expected returns and risks. These implications explain why exchange risk gets so much attention in this text.

3.5 CFO's Summary

In this chapter, we have seen how spot markets work. From the treasurer's point of view, one immediately interesting aspect is the possibility for arbitrage and shopping around.

- Arbitrage consists of buying and immediately reselling (or vice versa), thus taking no risk and engaging no capital. One could try to do this across market makers (for one particular exchange rate) or in a triangular way. In practice, the likelihood of corporate treasurers finding such a riskless profit opportunity is tiny. Arbitrage by traders in the wholesale market eliminates this possibility almost as quickly as it arises. In addition, most firms deal in the retail market, where spreads are relatively wide.

- Shopping around consists of finding the best route for a particular transaction. In contrast to arbitrage, shopping around may work—not in the sense of creating large profits, but in the sense of saving on commissions or getting marginally better rates. It is generally worth calling a few banks for the best rate when you need to make a large transaction. And it may pay to compute a triangular cross rate, especially through routes that involve heavily traded currencies like the USD or the EUR. Doing such a computation could enable corporate treasurers to find cheaper routes for undertaking transactions as compared to direct routes.

The spot rate is, by definition, the right number to use if you need to do an actual transaction. But for other purposes, other exchange-rate concepts are quite useful:

- The PPP rate is the ratio of the two price levels. Translating foreign income numbers or investment budgets at this rate tells you what the foreign figures really mean to locals—but expressed in terms that are familiar to you.

- The *real exchange rate* (or the deviation from Absolute PPP) is the ratio of the *translated* price levels. It tells you which country is more expensive. This is relevant if you want to evaluate a country as a destination for exports, or a source of imports, or a place to live or produce.

- Both the above concepts require data on price levels, which are not available for all countries. Often one makes do with the *deviation from RPPP* relative to a given base period, which estimates to what extent the real exchange rate has changed since then.

There is a clear, but imperfect relation between actual rates and PPP rates: countries that have gone through high-inflation episodes and, thus, ended up with high nominal prices for all goods, pay high nominal prices for currencies too. But the relation is far from one-to-one: real rates can be five to one (Norway against China,

for instance, in the BigMac data set). Also, there is a lot of variability over time, making countries more attractive or unattractive as production centers or markets. Most of that variability comes from the nominal exchange rate: inflation contributes little, except for hyper-inflation episodes (with inflation rates measured in 100s or 1000s per month). Thus, currency risk affects contractual cash flows fixed in FC but also the operations of a firm. It even messes up the CAPM because real exchange risk means that investors from different countries no longer perceive asset returns and risks in the same way.

What are the implications for the CFO? You should remember, first, that variations in the real exchange rate are long-memory events and can be vast. So they can have a big impact on how and where you should produce, and may even force you to change your fundamental strategy. All this comes on top of a shorter-run effect, of course: variations in exchange rates cause capital gains and losses on FC-denominated contractual claims and liabilities.

Your instinctive reaction may be that the firm should try to reduce the impact of these changes. This may be too fast, though: we first need to determine whether any such "hedging" policy really adds value. To be able to answer this question, we need to understand how the hedge instruments work: forwards, futures, swaps, and options. A good knowledge of these derivatives is, of course, also required to make an informed choice among the available hedge instruments. This is what the remainder of Part II is about. We begin with forward markets.

References

Grabbe, O., 1995. International Financial Markets, 3rd Edition, New York: Elsevier

Deardorff , a. V., 1979. One-Way Arbitrage and Its Implications for the Foreign Exchange Markets. The Journal of Political Economy, Vol. 87 Issue 2, p351-65

3.6 TekNotes

Technical Note 3.1 What's wrong with the FC/HC convention, in a textbook?

In the text just below Example 3.2 we claimed that using the FC/HC convention would mean all the familiar formulas from Finance would have to be abandoned. Here's this message in math. Let r^* denote the risk-free interest rate earned on FC, and $\tilde{S}_1$ the (random) future value, in HC of one unit of FC. If you buy one unit of FC, you'll have $1 + r^*$ of them next period, worth $\tilde{S}_1(1 + r^*)$ in HC. Standard finance theory then says that the current price, S_0, should be the future value discounted at a rate $\mathrm{E}(\tilde{r}_S)$ that takes into account this risk of $\tilde{S}_1$:

$$S_0 = \frac{\mathrm{E}(\tilde{S}_1)(1 + r^*)}{1 + \mathrm{E}(\tilde{r}_S)}. \tag{3.19}$$

This looks quite normal and well behaved. Now look at what would happen if we had used the inverse rate, $X := S^{-1}$, and if we wanted a theory about how X_0 is set. First substitute $X = S^{-1}$ into the equation and then solve for X_0:

$$1/X_0 = \frac{\mathrm{E}(1/\tilde{X}_1)(1 + r^*)}{1 + \mathrm{E}(\tilde{r}_S)} \Rightarrow X_0 = \frac{1 + \mathrm{E}(\tilde{r}_S)}{\mathrm{E}(1/\tilde{X}_1)(1 + r^*)}.$$

All connection with finance is gone. The discount rate is on top (?!), and the expectation is below, and the expectation is about the inverse of X. Clearly, this makes no sense in a finance textbook.

3.7 Test Your Understanding

3.7.1 Quiz Questions

1. Using the following vocabulary, complete the text: forward; market maker or broker; shopping around; spot; arbitrage; retail; wholesale.

   "When trading on the foreign exchange markets, the Bank of Brownsville deals with a (a) on the (b) tier, while an individual uses the (c) tier. If the bank must immediately deliver EUR 2 million to a customer, it purchases them on the (d) market. However, if a customer needs the EUR in three months, the bank buys them on the (e) market. In order to purchase the EUR as cheaply as possible, the bank will look at all quotes it is offered to see if there is an opportunity for (f). If the bank finds that the quotes of two market makers are completely incompatible, it can also make a risk-free profit using (g)."

2. From a Canadian's point of view, which of each pair of quotes is the direct quote? Which is the indirect quote?

   (a) CAD/GBP 2.31; GBP/CAD 0.43

   (b) USD/CAD 0.84; CAD/USD 1.18

   (c) CAD/EUR 1.54; EUR/CAD 0.65

3. You are given the following spot quote: EUR/GBP 1.5015-1.5040

   (a) The above quote is for which currency?

   (b) What is the bid price for EUR in terms of GBP?

4. You read in your newspaper that yesterday's spot quote was CAD/GBP 2.3134-2.3180.

   (a) This is a quote for which currency?

   (b) What is the ask rate for CAD?

   (c) What is the bid rate for GBP?

5. A bank quotes the following rates. Compute the EUR/JPY bid cross-rate (that is, the bank's rate for buying JPY).

	Bid	Ask
EUR/CAD	0.64	0.645
CAD/JPY	0.01	0.012

6. A bank quotes the following rates: CHF/USD 2.5110-2.5140 and JPY/USD 245–246. What is the minimum JPY/CHF bid and the maximum ask cross rate that the bank would quote?

7. A bank is currently quoting the spot rates of EUR/USD 1.3043-1.3053 and NOK/USD 6.15-6.30. What is the lower bound on the bank's bid rate for the NOK in terms of EUR?

8. Suppose that an umbrella costs USD 20 in Atlanta, and the USD/CAD exchange is 0.84. How many CAD do you need to buy the umbrella in Atlanta?

9. Given the bid-ask quotes for JPY/GBP 220-240, at what rate will:

   (a) Mr. Smith purchase GBP?

   (b) Mr. Brown sell GBP?

   (c) Mrs. Green purchase JPY?

   (d) Mrs. Jones sell JPY?

True or false? Indicate the correct statement(s).

1. CPP says that you can make a risk-free profit by buying and selling goods across countries.

2. CPP implies causality. It states that foreign prices are determined by domestic prices and other factors such as production costs, competitive conditions, money supplies, and inflation rates.

3. In order for a firm not to be affected by real exchange risk, CPP must hold not only for the goods a firm produces but also for all production inputs, and for the prices of complementary and substitute goods.

4. The equilibrium exchange rate suggested by the Absolute Purchasing Power Parity hypothesis depends on the relative relationship between the prices of a representative consumption bundle in the currencies of two countries.

5. Your purchasing power is the number of representative consumption bundles that you can buy.

6. The real effective exchange rate is the price of an average foreign consumption bundle in units of domestic currency.

7. Relative PPP shows how a consumer's purchasing power changes over time.

8. Absolute PPP may hold even when Relative PPP does not because absolute PPP looks at levels at a specific point in time, and levels are always comparable regardless of the composition of the consumption bundle.

9. Given the empirical evidence on the correlation between the nominal and real exchange rate, it is possible to use the nominal financial instruments to hedge real exchange risk.

10. Purchasing Power Parity is based on the idea that the demand for a country's currency is derived from the demand for that country's goods as well as the currency itself.

Multiple-Choice Questions Choose the correct answer(s).

1. CPP may not hold because:
   (a) the prices for individual goods are sticky.
   (b) transaction costs increase the bounds on deviations from CPP, making it more difficult to arbitrage away price differences.
   (c) quotas and voluntary export restraints limit the ability to arbitrage across goods markets.
   (d) parallel imports lead to two different prices for the same good.
   (e) the prices of tradable goods fluctuate too much, which makes it difficult to take advantage of arbitrage opportunities.
2. Absolute Purchasing Power Parity may not hold when:
   (a) the prices of individual goods in the consumption bundle consistently deviate from CPP across two countries.
   (b) the consumption bundles of different countries are not the same.
   (c) the prices for individual goods are sticky.
   (d) there are tariffs, quotas, and voluntary export restraints.
   (e) competition is perfect.
3. Relative Purchasing Power Parity is relevant because:
   (a) empirical tests have shown that Absolute PPP is always violated, while Relative PPP is a good predictor of short-term exchange rate exposure.
   (b) consumption bundles are not always comparable across countries.
   (c) price levels are not stationary over time.
   (d) investors care about the real return on their international portfolio investments.
   (e) investors care about the nominal return on their international portfolio investments.

3.7.2 Applications

1. You have just graduated from the University of Florida and are leaving on a whirlwind tour to see some friends. You wish to spend USD 1,000 each in Germany, New Zealand, and Great Britain (USD 3,000 in total). Your bank offers you the following bid-ask quotes: USD/EUR 1.304-1.305, USD/NZD 0.67-0.69, and USD/GBP 1.90-1.95.

(a) If you accept these quotes, how many EUR, NZD, and GBP do you have at departure?

(b) If you return with EUR 300, NZD 1,000, and GBP 75, and the exchange rates are unchanged, how many USD do you have?

(c) Suppose that instead of selling your remaining EUR 300 once you return home, you want to sell them in Great Britain. At the train station, you are offered GBP/EUR 0.66-0.68, while a bank three blocks from the station offers GBP/EUR 0.665-0.675. At what rate are you willing to sell your EUR 300? How many GBP will you receive?

2. Abitibi Bank quotes JPY/EUR 155-165, and Bathurst Bank quotes EUR/JPY 0.0059-0.0063.

(a) Are these quotes identical?

(b) If not, is there a possibility for shopping around or arbitrage?

(c) If there is an arbitrage opportunity, how would you profit from it?

The following spot rates against the GBP are taken from the Financial Times of Friday, February 2, 2007. Use the quotes to answer the questions in Exercises 3 through 5.

Country	Code	midpoint	change	spread
Czech Rep	CZJ	42.7945	+0.1868	616–273
Denmark	DKK	11.30929	+0.0289	065–119
Euro	EUR	1.5172	+0.0039	168–175
Norway	NOK	12.3321	+0.0394	263–379
Russia	RUB	52.1528	– 0.0368	376–679
Switzerland	CHF	2.4531	+0.0040	522–540
Turkey	YTL	2.7656	–0.0050	614–698

Note: Bid-ask spreads show only the last three decimal places. When the ask seems to be smaller then the bid, add 1000.

3. What are the bid-ask quotes for:

(a) CZJ/GBP?

(b) DKK/GBP?

(c) EUR/GBP?

(d) NOK/GBP?

4. What are the bid-ask quotes for:

(a) GBP/CZJ?

(b) GBP/DKK?

(c) GBP/EUR?

(d) GBP/NOK?

5. What are the cross bid-ask rates for:

   (a) RUB/CHF?
   (b) NOK/YTL?
   (c) DKK/EUR?
   (d) CZJ/CHF?

6. In Figure 2.8 I showed plots of the gold price and mentioned that, if we had corrected for inflation, then the 1980 price would be seen to be much above the current peak: obviously, the small percentage price rise of gold, between 1980 and 2007, must have been way below the percentage rise of the USCPI.

   (a) In the above we presumably use USCPI rate to deflate the USD prices. But is this result generalizable to all countries—is this conclusion necessarily also valid for Japanese or German investors? Why (not)?
   (b) If you think the result does not necessarily hold true elsewhere, what would you bet w.r.t. a hyper-inflator like Zimbabwe?: if inflation is much higher, then the real price of gold must have fallen even more—no?
   (c) What would guarantee identical real price paths in all countries: APPP, RPPP, or what?

