Exchange Rates
Revised: January 9, 2008

Exchange rates (currency prices) are a central element of most international transactions. When Heineken sells beer in the US, its euro profits depend on its euro costs of production, its dollar revenues in the US, and the dollar-euro exchange rate. When a Liverpool resident purchases a yen-denominated asset, her return (in pounds sterling) depends on the asset’s yen yield and the change in the pound-yen exchange rate. The level and change of exchange rates are therefore important aspects of international business. In this note we review some of the properties of exchange rates and describe the policy regimes that countries adopt toward them.

Terminology

There is an enormous amount of jargon associated with this subject. You’ll run across references to:

- Exchange rate conventions. We will typically express exchange rates as local currency prices of one unit of foreign currency. In the US, we might refer to the dollar price of one euro. In currency markets, the conventions vary, so we’ll stick with this one. It has the somewhat strange feature that an increase in the exchange rate is a decline in the relative value of the home currency, but remember that it’s an increase in the value of the foreign currency. As a rule of thumb, remember that we quote prices in dollars (or whatever our local currency is). Changes in exchange rates also have their own names. We refer to a decrease in the value of a currency as a *depreciation* and an increase as an *appreciation*. In fixed exchange rate regimes, where the changes reflect policy, the analogous terms are *devaluation* and *revaluation*.

- Real exchange rates. You’ll see this term, too, but what does it mean? (What’s an imaginary exchange rate?) By convention, the real exchange rate between (say) the US and Europe is the relative price of a basket of goods. If $P$ is the US CPI in dollars, $P^*$ is the European CPI in euros, and $e$ is the dollar price of one euro (the *nominal* exchange rate), then the (CPI-based) *real exchange rate* between the US and the Euro Zone is

$$\text{real exchange rate} = e \frac{P^*}{P},$$

the ratio of the price of Euro goods to US goods, with both expressed in the same units (here dollars). (Note: asterisks are commonly used to denote foreign values).
- Parity relations. We generally think that trade will tend to reduce differences in prices and returns across countries. Parity relations are based on the assumption that differences are eliminated altogether. It’s an extreme assumption, to be sure, but a useful benchmark nevertheless. *Purchasing power parity* is the theory that prices of baskets of goods are equal across countries: $P = eP^*$ (or real exchange rate = 1). This works for some specific goods (think of gold), but anyone who takes a vacation abroad realizes that it is at best a crude approximation for broad categories of goods (hotels, restaurant meals, etc). *Interest rate parity* is the assumption that returns are equal for comparable investments in different currencies — think of US and Japanese treasury bills, or dollar- and yen-denominated eurocurrency deposits at major banks.

You’ll see each of these terms in the coming pages.

**Properties of exchange rates**

After years of study, economists have discovered that exchange rates are largely unpredictable, and often hard to explain even after the fact. Since movements in major currencies are relatively large, this adds an element of randomness to international business. For example, if the dollar falls, US exporters typically report higher earnings, because the dollar value of foreign revenue goes up. And vice versa. Some firms choose to hedge exchange rate movements for this reason.

You can get a sense of recent dollar movements from Figure 1, which plots the price of one dollar expressed in Australian dollars, British pounds, Canadian dollars, euros, yen, and yuan, respectively. (Inverses of dollar exchange rates, in other words). They are constructed as indexes, with the January 2001 values set equal to 100. You can see that the dollar-euro rate fluctuates quite a bit; over the last five years, it’s ranged from 70 to 110. This reflects, to a large extent, the approaches taken by the US and the European central banks: they let their currencies float freely. The yen, the Canadian dollar, and the Australian dollar are similar. The yuan, however, is fixed by the Chinese central bank at a value of about 8 yuan per dollar. More on this later.

**Purchasing power parity**

The bottom line is that exchange rates are puzzling, but let’s try to think about how they should behave. One line of attack is based on prices of goods: that exchange rates adjust to equate prices across countries. The logic is arbitrage: if a good is cheaper in one country than another, then people would buy in the cheap country and sell in the other, taking a profit on the way. This process will tend to eliminate the difference in prices.
Consider wine. Suppose a bottle of (some specific) wine costs $p = 26$ dollars in New York, and $p^* = 20$ euros in Paris. Are the prices the same? If the exchange rate is $e = 1.3$ dollars per euro, then the New York and Paris prices are the same once we express them in the same units. More generally, we might say that

\[ p = ep^*. \]

We refer to this relation as the law of one price: that a product should sell for the same price in two locations. An even better example might be gold, which sells for pretty much the same price in New York, London, and Tokyo.

If the law of one price works for some products, there are many more for which restrictions on trade (tariffs or quotas) or transportation costs prevent arbitrage. Agricultural products, for example, are protected in many countries, leading to substantial differences across countries in the prices of such basic commodities as rice, wheat, and sugar. Cement faces substantial shipping costs, even within countries. Many services (haircuts, dry cleaning, medical and legal services) are inherently difficult to trade, and often protected by regulation as well.

*The Economist*, with its usual flair for combining insight with entertainment, computes dollar prices of the Big Mac around the world. In January 2006, it reports averages of $3.15 in the US, $3.55 in the Euro Zone, $2.19 in Japan, $1.55 in Argentina, and $1.30 in China. The prices differences are not only large, they vary widely over time. In April 2000, the prices were $2.50 in
the US, $2.78 in Japan, and $2.50 in Argentina, implying much higher relative prices in Japan and Argentina. The problem with the Big Mac is that it is not really a tradable good, because it is perishable. For this reason, we do not expect the Law of One Price to hold.

Optional. Even if the burger is not tradable, if the inputs (beef, veggies, and labor) were, then we would expect that eventually the Law of One Price would hold. Consider the labor input. Many of MacDonald’s employees in the US are paid the minimum wage, while in France they get higher salaries and benefits. This implies that the labor cost of producing a Big Mac is higher in France. This probably means higher burger prices in Paris than in New York. If the workforce was freely mobile, people would move from the US to France to benefit from the higher wages, which would tend to eliminate the difference in labor costs. Since labor is not mobile across countries, we would not be surprised to see a difference in labor costs or prices of Big Macs.

Despite such modest encouragement, the first-cut theory of exchange rates is based on an application of law-of-one-price logic to broad baskets of goods. The so-called theory of purchasing power parity (PPP) is that local and foreign price indexes (\( P \) and \( P^* \), say) are linked through the exchange rate: \( P \approx eP^* \) or

\[
\text{real exchange rate} = \frac{P^*}{P} \approx 1. \tag{2}
\]

The approximation symbol suggests that we don’t expect this to be perfect. In the most common applications, the price indexes are CPIs and we refer to the measure of the real exchange rate as CPI-based. If this doesn’t work for specific goods, why might we expect it to hold for average prices of goods? One reason is that, for any pair of countries, there tend to be as many products that are ‘overpriced’ as there are products that are ‘underpriced’. When we average, many of these deviations cancel out. Another reason is that, as an empirical matter, deviations from PPP tend to average out over time. Sometimes prices are higher in Paris, sometimes higher in New York, but on average prices are roughly comparable. Prices are lower, on average, in countries with lower GDP per capita, but here, too, large fluctuations in the real exchange rate tend to disappear with time.

Real exchange rates computed this way are often used to judge whether a currency’s price is reasonable. If the prices are lower at home than abroad (\( P < eP^* \)), we say the (home) currency is undervalued, and if prices are higher at home (\( P > eP^* \)), we say the currency is overvalued. [If this seems mysterious to you, apply it to the problem of taking a vacation in Paris or Mexico City]. We can do the same thing with the Big Mac index. We saw earlier that Big Macs were cheaper in the US than the Euro Zone, so we might say that the dollar in undervalued relative to the euro. Big Macs are even cheaper in Japan, so the yen is undervalued relative to both the dollar and the euro. Over time, we might expect most of these ‘misvaluations’ to decline. Experience suggests, however, that any such adjustment will take years. Our best estimates are that half the mispricing will disappear in 2-5 years. We can do the same thing with CPIs, with one difference: since CPI are indexes, we don’t know the absolute prices. The standard approach is to find the mean value...
of the real exchange rate (or its logarithm) and judge under- or overvaluation by comparing the real exchange rate to its mean, rather than one.

At the risk of trying your patience, we’ll conclude this section by describing PPP in growth rates. PPP implies that the exchange rate is the ratio of price indexes: \( e \approx \frac{P}{P^*} \). If we take logarithms and first-difference, we have

\[
\Delta \log(e_t) \equiv \log(e_t) - \log(e_{t-1}) \approx [\log(P_t) - \log(P_{t-1})] - [\log(P^*_t) - \log(P^*_{t-1})]
\]

or

\[
\Delta \log(e_t) \approx \pi_t - \pi^*_t,
\]

where \( \pi \) and \( \pi^* \) are the home and foreign inflation rates and \( \Delta \log(e_t) \) is the rate of depreciation of the home currency. In words: PPP implies that rate of change in the exchange rate should be equal to the difference in inflation rates.

Does this work? It turns out that the relation tends to hold in the long-run, but not in the short run, in the sense that there are plenty of deviations from it. For example, let’s consider the case of the exchange rate between the Venezuelan Bolivar and the US dollar. Between January 1985 and January 2006, Venezuela’s average annual inflation rate was 30%, as opposed to the US’s 2.9%. In the same period, the Bolivar depreciated at the average yearly rate of 27.9%, i.e. only .8% more than implied by the PPP condition. In the short-run, however, deviations from PPP are the norm. Figure 2 shows that this has definitely been the case for the Bolivar: there have been plenty of periods in which exchange rate depreciation did not track closely the inflation differential with the United States. In some instances, in particular in the late 80s, the deviations were due to the central bank’s attempt to keep the exchange rate constant. In other cases (the early 90s for example), the deviations had probably nothing to do with central bank interventions. In developed countries, it’s not unusual to see deviations of the real exchange rate from one of 30-40% in either direction. Figure 3 shows this for the dollar-euro. In recent years the US dollar has depreciated against the euro despite similar inflation rates. This picture is typical of developed countries: inflation differentials are relatively small, so changes in the real and nominal exchange rates are almost equal. These deviations from PPP tend to disappear with time, but as we saw earlier, they go away slowly.

**Interest rate parity**

Exchange rates also play a role in interest rate differences across countries. In June 2004, for example, 3-month eurodollar deposits paid interest rates of 1.40% in US dollars, 4.78% in British pounds, 5.48% in Australian dollars, and 2.12% in euros. If international capital markets are so
closely connected, why do we see such differences? The answer is that these returns are expressed in different currencies, so they’re not directly comparable.

Let’s think about how prices of currencies show up in interest rate differentials. We’ll start with a relation called covered interest parity, which says that interest rates denominated in different currencies are the same once you ‘cover’ yourself against possible currency changes. The argument follows the standard logic of arbitrage used endlessly in finance. Let’s compare two equivalent strategies for investing one US dollar for 3 months. The first strategy is to invest one dollar in a 3-month euro-dollar deposit (with the stress on ‘dollar’). After three months that leaves me with 

\[(1 + \frac{i}{4})\] dollars, where \(i\) is the dollar rate of interest expressed as an annual rate.

What if we invested one dollar in euro-denominated instruments? Here we need several steps to express the return in dollars and make it comparable to the first strategy. Step one is to convert the dollar to euros, leaving us with \(1/e\) euros (\(e\) is the spot exchange rate – the dollar price of one euro). Step two is to invest this money in a 3-month euro deposit, earning the annualized rate of return \(i^*\). That leaves us with \((1 + \frac{i^*}{4})/e\) euros after three months. We could convert it at the spot rate prevailing three months from now, but that exposes us to the risk that the euro will fall.

An alternative is to sell euros forward at price \(f\). In three months, we will have \((1 + \frac{i^*}{4})/e\) euros that we want to convert back to dollars. With a three-month forward contract, we arrange now to convert them at the forward rate \(f\) expressed, like \(e\), as dollars per euro. This strategy leaves us
with \((1 + i^*/4)f/e\) dollars after three months.

Thus we have two relatively riskless strategies, one yielding \((1 + i/4)\), the other yielding \((1 + i^*/4)f/e\). Which is better? Well, if either strategy had a higher payoff, you could short one and go long the other, earning extra interest with no risk. Arbitrage will tend to drive the two together:

\[
(1 + i/4) = (1 + i^*/4)f/e.
\]  

(3)

We call (3) covered interest parity. Currency traders assure us that covered interest parity is an extremely good approximation in the data. The only difference between the left and right sides is a bid-ask spread, which averages less than 0.05% for major currencies.

A related issue is whether international differences in interest rates reflect differences in expected depreciation rates. Does the high rate on Australian dollars (AUD) reflect the market’s assessment that the AUD will fall in value relative to (say) the euro? To see how this works, suppose we converted the proceeds of our foreign investment back to local currency at the exchange rate prevailing in 3 months. Our return would then be

\[
(1 + i^*/4)e_3/e,
\]

where \(e_3\) is the spot exchange rate 3 months in the future. This investment is risky, since we don’t know what the future exchange rate will be, but we might expect it to have a similar expected
return to a local investment. That is,

\[(1 + i/4) = (1 + i^*/4)E(e_3)/e,\]

where \(E(e_3)\) is our current expectation of the exchange rate in 3 months. This relation is an application of the expectations hypothesis to currency prices (the forward rate equals the expected future spot rate) that is commonly referred to as uncovered interest parity.

In fact, uncovered interest rate parity doesn’t work. It implies that high interest rate currencies depreciate, when in fact they appreciate (increase in value), making them good investments on average. If \(i > i^*\), we invest at home. If \(i < i^*\), we invest abroad, expecting to pocket not only the higher interest rate but an appreciation of the currency \((e_3 > e)\). Why this investment opportunity persists remains something of a mystery to academics and investors alike. Two fine points: (i) This feature of the data does not apply to the currencies of developing countries, where higher interest rates typically imply future depreciation; (ii) even in developed countries, forecasts of exchange rate changes based on interest differentials have an \(R^2\) of about 0.05. That’s still useful for investment purposes, but leaves most of the variance of exchange rate changes unexplained.

**Forecasting exchange rates**

Let’s summarize what we’ve learned about exchange rates:

- PPP works reasonably well over long periods of time, but has little empirical content over periods of less than a year.
- Interest rate differentials have some forecasting power, but leave most of the variance of exchange rate movements unexplained.

Can we do better than this? A little, but probably no more than that. It’s extremely hard to forecast exchange rates better than a 50-50 bet on up or down. Interest differentials do a little better, and we may be able to do better still using more complex theory or personal judgment about policy, but the state of the art on short-term exchange rate fluctuations is that it’s very hard to beat a random walk consistently.

**Exchange rate regimes**

The primary difference between currency markets and others is the direct role of the government, typically through the central bank. China, for example, has adopted a ‘fixed’ or ‘pegged’ exchange
rate, which means it follows policies that maintain an exchange rate with minimal day-to-day movement. The US, on the other hand, has a ‘flexible’ or ‘floating’ exchange rate, in which the dollar fluctuates in value against other currencies with little official influence. We say that China and the US have adopted different exchange rate ‘regimes’.

A flexible exchange rate is easy to describe — the market sets the rate — but a fixed exchange rate is not. Could a central bank simply announce a rate? No! I could claim, for example, that my apartment was worth $10m, but if no one is willing to buy it for that price the statement is meaningless. For the same reason, a central bank must back up its claim to fix the exchange rate by buying and selling as much foreign currency as people want at the stated price.

Let’s think through how this might work. Suppose the New York City government decided to fix the price of beer at $2 a 6-pack (cheap even if you live outside NYC). It supports this price by buying or selling any amount at the quoted price. Can they keep the price this low? Our guess is that at this price, beermakers would not find it profitable to make any (at least not any that we’d be willing to call beer). People would then flood the government with requests for beer, which the government would not be able to meet. When the government reneged on its promise to buy or sell at $2, the price would rise above $2 to its market level, either officially or on the black market. In short, unless the government has enough beer to back up the price, the system will collapse. Alternatively, suppose the government set the price at $20. Beermakers would flood the government with beer at this price, leaving the government with a huge surplus. This is roughly what Europeans do with agriculture, where artificially high prices have left the EU with ‘mountains of butter,’ ‘lakes of wine’ and so on. The point is that the government can only fix a price if it is willing and able to buy and sell at that price.

The same logic applies to currencies. If the People’s Bank of China were to support an excessively high price for the yuan, then they would be flooded with offers from traders selling yuan for (say) dollars. Its balance sheet would look something like this:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
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<tbody>
<tr>
<td>Foreign Currency Reserves</td>
<td>Monetary Base</td>
</tr>
<tr>
<td>Bonds</td>
<td>20</td>
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<td>200</td>
</tr>
</tbody>
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We made these numbers up, but they give us the right idea: the central bank has the usual liabilities, ‘money’ and government bonds, and also holds some foreign currency reserves, which you might think of (for this example) as dollars. The PBOC intervenes in the currency market by trading yuan for dollars, and vice versa, depending on market conditions. Suppose, for example, that Nike wanted to convert $2m to yuan for the purpose of building a new plant. It would do this through a Chinese bank. If the bank had no countervailing trades, it would go to the PBOC and exchange the $2m for yuan at the going rate — say 10 yuan per dollar, to make the arithmetic
simple. The PBOC’s balance sheet would then show an increase of 20m yuan worth of foreign currency and a comparable increase in its monetary base:

<table>
<thead>
<tr>
<th>Assets</th>
<th>Liabilities</th>
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<tbody>
<tr>
<td>Foreign Currency Reserves</td>
<td>40 Monetary Base 220</td>
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<tr>
<td>Bonds</td>
<td>180</td>
</tr>
</tbody>
</table>

The PBOC’s net worth is unchanged, since it has exchanged assets with equal value.

[A fine point. The PBOC’s fixed exchange rate was revalued (increased in value) in July 2005. Since then, the PBOC has chosen a midpoint each day for the exchange rate and allowed market transactions to vary up to 0.3% in either direction. In practice, the amount of variation is tiny].

The difference, then, between fixed and flexible exchange rate regimes is that the former obligates the central bank to buy and sell currencies at the stated price. As a matter of experience, fixed exchange rate system often collapse — sometimes spectacularly — when the central bank runs out of reserves. The issue: if people would prefer to buy foreign currency at the official exchange rate, the central bank may find that its supply of reserves is not enough to meet the market demand. (The market for currencies is enormous, so you need a lot of reserves.) For that reason, currency traders often look closely at central bank’s foreign currency reserves to measure their ability to maintain the rate.

In China and many other developing countries, there are often further restrictions on the ability of private agents to buy and sell currency (‘convertibility’). Citizens are sometimes prohibited from using foreign currency for domestic transactions. They may also face limits on their ability to buy foreign currency to buy foreign goods or assets. In China, for example, purchases of foreign currency are generally allowed to buy foreign goods, but not to buy foreign assets. This, of course, has an impact on the market value of the currency, making it more difficult for investors to bet for or against a change in the value of the yuan.

**Executive summary**

1. Exchange rates are prices at which one currency trades for another.

2. In the long run, exchange rates equate prices of products across countries (PPP).

3. In the short run, exchange rate movements are large but very difficult to predict.

4. Governments influence currency prices through a range of policies, including direct intervention in currency markets.
Further reading

- *The Economist’s Big Mac index* is the center of a nice web site on exchange rate data and issues.

- Deutsche Bank’s *Guide to Exchange-Rate Determination* is a terrific summary of what we know about exchange rates from a bond and currency trader’s perspective.

- The International Monetary Fund’s *Annual Report on Exchange Arrangements* is the definitive guide to exchange rate arrangements: fixed, flexible, capital controls, and so on.