The Global Economy
Class Notes

Exchange Rate Fluctuations

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Exchange rates (prices of foreign currency) 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 Tokyo resident purchases a dollar-denominated asset, her return (in yen) depends on the asset's dollar yield and the change in the dollar-yen exchange rate. The level and change of exchange rates are therefore important aspects of international business.

Nevertheless, countries in which exchange rates are determined in open markets find that short-term fluctuations are substantial, largely unpredictable, and hard to explain after the fact. That's been horribly disappointing to those of us who would like to understand them better, but it's a fact of life. From a business perspective, they're a source of random noise. Heineken profits, for example, vary with the dollar-euro rate, even if the underlying business doesn't change.

What follows is a summary of what we know about exchange rates.

Terminology

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

- Exchange rate conventions. We 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 (every currency pair has its own), but we'll try to 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. Of course, it's also 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).
- Exchange rate changes. Changes in exchange rates also have their own names. For a flexible exchange rate, we refer to a decrease in the value of a currency as a *depreciation* and an increase as an *appreciation*. For a fixed exchange rate, 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?) A nominal exchange rate is the relative price of two currencies: the number of units of currency A needed to buy one unit of currency B. The real exchange rate is the relative price of commodity or 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

$$RER \ = \ eP^*/P,$$

  the ratio of the price of EU 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 ("arbitrage") 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. *Purchasing power parity* is the theory that prices of baskets of goods are equal across countries: $P = eP^*$ (or $RER = 1$). 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, or the CPI). *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. Despite the globalization of financial markets, this doesn't work that well either.

We'll see each of these in action shortly.

Properties of exchange rates

Flexible exchange rates move around — a lot. The standard deviation of annual rates of change of currency prices is 10-12% for major currencies, more for emerging markets. That's less than the standard deviation of equity returns (the return on the S&P 500 index has a standard deviation of 16-18%) but a significant source of risk. With a standard deviation of 10%, and a normal distribution, there's a 5% chance of seeing a one-year change greater than 20% either up or down. (That's if we use the normal distribution. Since currencies have fat tails, it's really a little worse than that.)

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 renminbi, 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 renminbi, however, is fixed (or close to it) by the Chinese central bank at a value of about 8 yuan per dollar. More on this later.

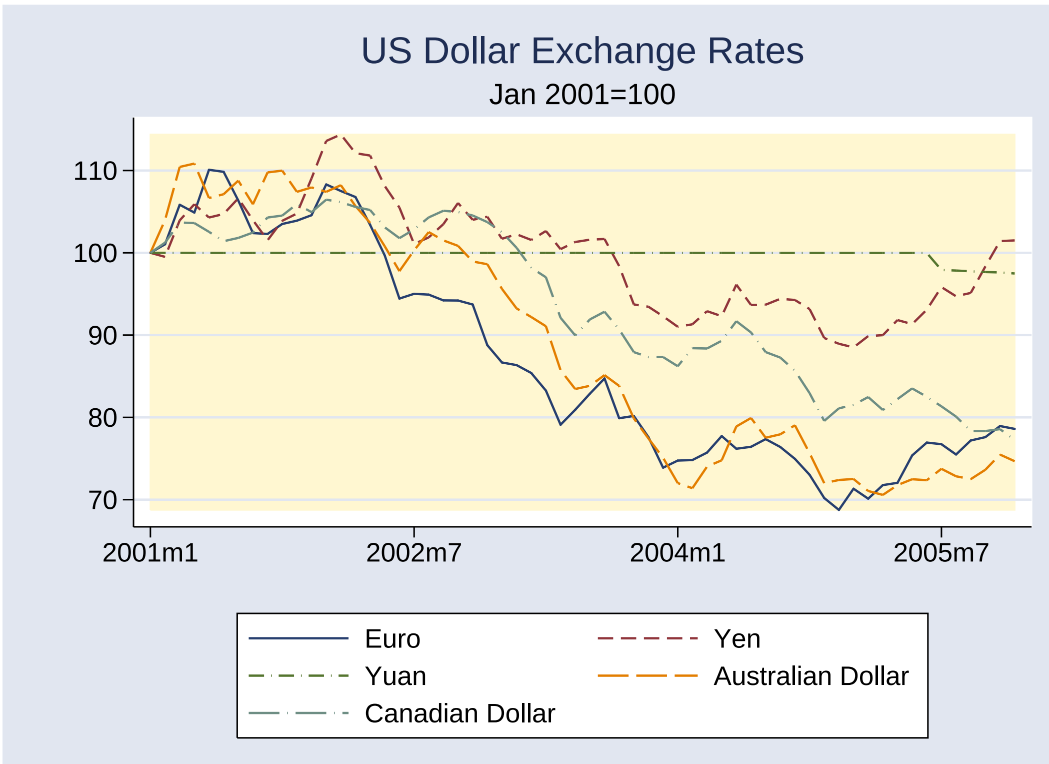

Figure 1: The US dollar against other major currencies.

Purchasing power parity

So we've seen that exchange rates move around. But can we say anything about why? We can't say much about short-term movements, but here's a theory that gives us a long-term anchor for the real exchange rate. It's a helpful benchmark.

The idea is to compare prices of goods. Suppose exchange rates adjusted 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, either through changes in the exchange rate or the prices themselves.

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

$$p \;=\; ep^*. \tag{1}$$

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), transportation costs, or other "frictions" 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. The idea is that it's the same product everywhere, so differences in prices reflect deviations from the law of one price. In January 2006, Big Mac prices were \$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 price 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. Perhaps it's no surprise that the law of one price doesn't hold: you can imagine the mess involved in trying to arbitrage price differences. But it's a good illustration of international price differences more generally.

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

$$RER \;=\; eP^*/P \;\approx\; 1. \tag{2}$$

The approximation symbol suggests that we don't expect this to be perfect. In the most common applications, the price indexes are CPIs (consumer price indexes) 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, we might see as many products that are "overpriced" as there are products that are "underpriced." When we average, these deviations could offset each other. In fact, they don't. If prices of some goods are cheaper abroad, then prices of other goods tend to be, too.

What limited success we have comes in the long run. 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. How much time do we need for this to work? At least several years. If you're thinking of going to Paris next month, there's little reason to expect that we'll be closer to PPP by then. Maybe we will, maybe we won't, it's a tossup.

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 ($RER > 1$), we say the (home) currency is *undervalued*, and if prices are higher at home ($RER < 1$), we say the currency is *overvalued*. Over- and under-valued here means relative to our theory of PPP. 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 is 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 about half the mispricing will disappear in 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.

Depreciation and inflation

We can express the same theory in growth rates, with the result that the change in the exchange rate (the depreciation of the currency) should equal the difference in the two inflation rates. Simply put, if one country has a higher inflation rate than another, then we would expect its currency to fall in value by the difference. That's not true over short periods of time, but the basic idea is right. Countries with high inflation rates also find that their currencies fall in value.

Here's how that works. The PPP relation equation (2), implies

$$e_t = P_t / P^*_t .$$

(Feel free to put $\approx$ here if you prefer.) If we take (natural) logs both sides, we have

$$\log e_t = \log P_t - \log P^*_t .$$

If we take the same equation at two different dates, we have

$$\begin{aligned} \log e_{t+1} - \log e_t &= (\log P_{t+1} - \log P_t) - (\log P^*_{t+1} - \log P^*_t) \\ &= \pi_{t+1} - \pi^*_{t+1} . \end{aligned}$$

In words: the depreciation rate equals the difference in the inflation rates. It's simply PPP in growth rates.

Does this work? It's pretty good for long-run averages (5-10 years or more), but like everything we know about exchange rates, not very useful for short-term movements outside very very high inflation situations.

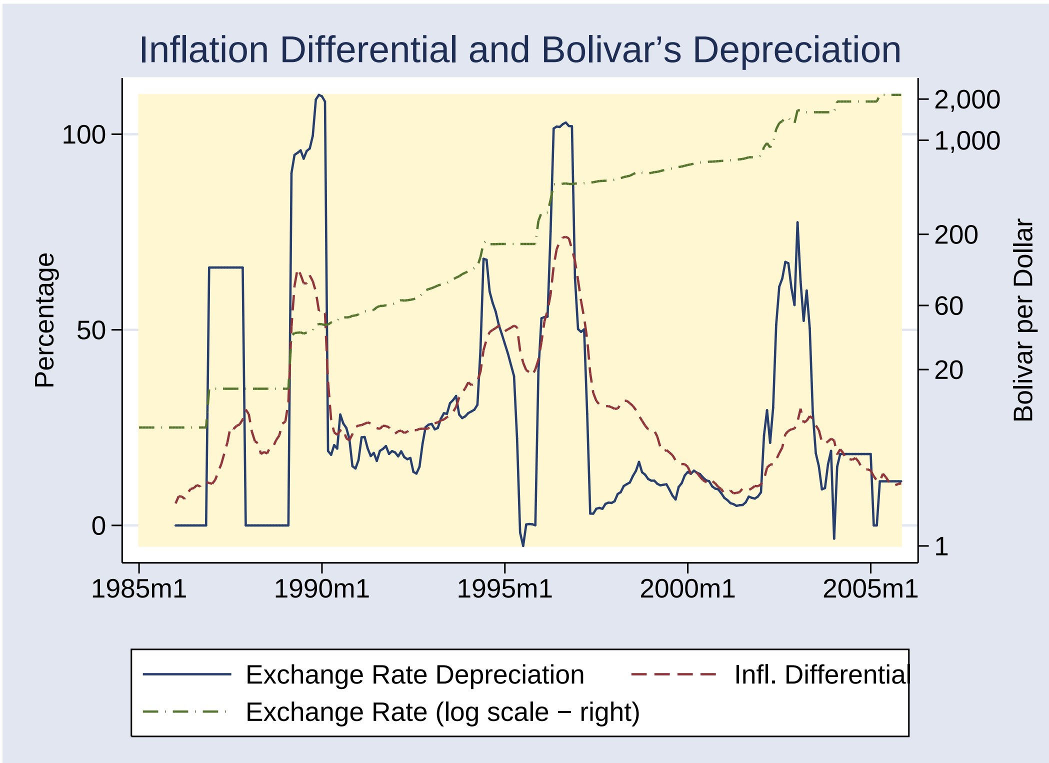

Figure 2: Venezuela: Bolivar depreciation and inflation differential.

By way of example, consider 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 80's, 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, inflation differentials are typically small, so they don't give us much insight into the relatively large movements in exchange rates.

Interest rate parity and the carry trade (skim only)

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 us with $(1+i/4)$ 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 $(1 + i^*/4)/e$ 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 $(1+i^*/4)/e$ 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:

$$(1 + i/4) \;=\; (1 + i^*/4)f/e. \tag{3}$$

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 Aussie 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,

$$(1 + i/4) \;=\; (1 + i^*/4)E(e_3)/e, \tag{4}$$

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) on average, making them good (if risky) investments. 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 ($e_3 > e$). That's the essence of what is called the "carry trade." 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. That is, uncovered interest parity works better here. (ii) Even in developed countries, forecasts of exchange rate changes based on interest differentials have an R^2 of 0.05 or less. That's still useful for investment purposes, but leaves most of the variance of exchange rate changes unexplained.

Predicting exchange rates

Let's summarize what we've learned about movements in exchange rates:

- PPP works reasonably well over long periods of time, but has little empirical content over periods of less than a few years, and virtually none over periods under a year.

- Interest rate differentials have some forecasting power, with high interest rate currency increasing in value on average, the they 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, but only a little. The R^2 are less than 0.05. We may be able to do better still using more complex theory or personal judgment about policy, but years of failure suggest that it's very hard to beat a random walk consistently.

Executive summary

1. In the long run, exchange rates tend to equalize prices of products across countries (PPP).

2. In the short run, exchange rate movements are large and unpredictable.

Review questions

1. Forecasting the euro. Right now, the euro is "overvalued" in PPP terms relative to the dollar (goods are more expensive in Europe) and Euro Zone short-term interest rates remain 2-3% above US interest rates. Given these facts, how would you expect the euro/dollar exchange rate to change over the next 6 months? 6 years? How good is each of these informed guesses?

   Answer. Purchasing power parity is a long-run "anchor" for the exchange rate: if prices of goods and services in the Euro Zone are higher than those in the US, when expressed in a common currency, we'd expect the euro to fall in value relative to the dollar — eventually. This is pretty much useless over a period as short as 6 months, but has some content over 6 years. More useful in the short-run is the interest differential. Since the Euro interest rate is higher, we'd expect the euro to increase in value. Neither works all that well: an R^2 of 0.05 would be good over periods of a few months.

If you're looking for more

- 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.