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362, Winter 2006

Lecture #3: More on Exchange Rates

More on the idea that exchange rates move around 'a lot'.

1. The example at the end of lecture #2 discussed a large movement in the US-Japanese exchange rate that occurred over the period 1986-1987. The example showed how disruptive a move like that could be for business. That swing in the exchange rate was chosen because it was large, and so it was somewhat unusual. This example shows how 'normal' exchange rate fluctuations are quite disruptive too. It's another car maker example. It involves a different exchange rate, the Euro. This is another important exchange rate that you should be familiar with.

   Figure 1 displays the exchange rate, E, between the US and the Euro. The data begins in January 1999, because that's when the Euro began to circulate as a full-fledged paper currency. The convention here is the 'standard' one, with E being the number of dollars it takes to purchase a Euro ($E_{\$/\mathcal{E}}$ in the notation of the book). Note how much E moves around! It cost \$1.15 dollars to buy a Euro at the start. In a matter of about two years, the Euro had depreciated about 30 percent, with the price falling to \$0.85. Then, the Euro reversed course and appreciated by almost 50 percent from mid-2001 to late 2004! Since then, the dollar has been appreciating.

   Figure 1 emphasizes the longer-term movements in the Euro, while Figure 2 gives greater weight to the quarter-to-quarter movements. Figure 2 displays:

$$\frac{E_{t+3}}{E_t},$$

   for t = January 1999 to August 2005. Note that this ratio appears to fluctuate between 1.07 and 0.95. This means that it is not unusual for the exchange rate to jump from one quarter to the next by 5 percent, or fall by 5 percent. In the example, we'll see that even these are large and potentially disruptive movements.

   Turning to the example, it is also about a car manufacturer. This time, it's a car manufacturer selling in Europe. For the manufacturer to generate an acceptable return for shareholders, the manufacturer must on average earn 10 percent over costs. Thus, m from the example of lecture 2 must be $m = 0.10$. Suppose the dollar costs of making a car, C, are determined in advance, by contracts with workers and by contracts which specify what price parts suppliers will receive. Also, let P^{Euro} denote the price, in Euros, that the manufacturer receives for

each car from German dealers. This too is determined in advance by contract. Given the exchange rate, E, to generate enough dollars to cover costs and profits, the manufacturer must set a price that satisfies:

$$P^{Euro} \times E = (1+m)C.$$

Recall, E is Dollars per Euro. Then, if you multiply P^{Euro} (which is in Euros) by E (which is Dollars per Euro), you end up with dollars. So, $P^{Euro} \times E$ is the number of dollars the manufacturer receives when the exchange rate is E and the sale price of a car is P^{Euro}. Since P^{GER} and C are determined in advance by contract, and E is determined by broader market forces, over which the manufacturer has no control, you can think of this equation as determining m. That is,

$$m = \frac{E \times P^{Euro}}{C} - 1.$$

Suppose P^{Euro} and C are determined three months before the American manufacturer actually receives delivery of the dollars, $P^{Euro} \times E$. This creates a problem for the manufacturer at the time P^{Euro} and C are set in contract negotiations. Since they don't know what E will be, they in effect don't know what m will be. If the uncertainty in E were small, this would translate into just a little uncertainty in m, and no one would care. But, let's see how much uncertainty there is in E in practice.

Recall from Figure 2, how it is not unusual for the exchange rate to jump from one quarter to the next by 5 percent, or fall by 5 percent. Let's see how this translates into uncertainty in the car manufacturer's profit margin, m.

Imagine the following timing. Contracts are set in one quarter, and then revenues come in during the following quarter. The amount of uncertainty in next quarter's exchange rate is captured (somewhat crudely) by the following simple setup. Suppose that next period's exchange rate could be E^1, E^2 or E^3, where $E^1 = 1.05$, $E^2 = 1.00$, and $E^3 = 0.95$, with probability 1/3 each. Thus, the forecasted value of the exchange rate is ((1.05+1.00+0.95)/3=1) is 1. The example captures the notion that it would not be surprising if the actual exchange rate differed from the forecasted value by 5 percent.

Suppose P^{Euro} is set so that, given C, $m = 0.10$ if the forecasted value of the exchange rate occurs. Then, what values will m take on if $E^1 = 1.05$, $E^2 = 1.00$, or $E^3 = 0.95$? Denote the values of

m corresponding to these three possible values of E by m^1, m^2, m^3, respectively. Then, it is easy to verify[1]:

$$\begin{aligned} m^1 &= \frac{E^1}{E^2}(1+m^2)-1 = 0.155 \\ m^2 &= .10 \\ m^3 &= \frac{E^3}{E^2}(1+m^2)-1 = 0.045. \end{aligned}$$

Let's look at the impact of this uncertainty in m on profits. Total profits are $m \times C$. So, when the exchange rate appreciates from its expected value of E^2 to E^3 by 5 percent, the change in profits is:

$$\frac{m^3 \times C}{m^2 \times C} = \frac{0.045}{0.10} = 0.45.$$

That is, profits fall by 55 percent! Why is it that the profits of the American manucturer *fall* when the dollar appreciates? They fall because the American is earning Euros, and when the Dollar appreciates, the Euros the American earn fall. The point is that the 5 percent depreciation translates into a 55 percent change in profits.

Now consider the impact on profits when the dollar depreciates from its expected value of E^2 to E^1. In this case, the change in profits is:

$$\frac{m^1 \times C}{m^2 \times C} = \frac{0.155}{0.10} = 1.55.$$

The Dollar depreciation of 5 percent produces a 55 percent increase in profits! The message here is: small uncertainty in the exchange rate produce large uncertainty in profits.

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[1]To see this, note

$$\begin{aligned} P^{Euro}E^1 &= (1+m^1)C, \\ P^{Euro}E^2 &= (1+m^2)C, \\ P^{Euro}E^3 &= (1+m^3)C. \end{aligned}$$

Divide the first equation by the second, and the third by the second, to obtain:

$$\frac{E^1}{E^2} = \frac{1+m^1}{1+m^2}, \ \frac{E^3}{E^2} = \frac{1+m^3}{1+m^2}.$$

What appears in the text is a simple transformation on these equations.

In reality, the impact of the uncertainty in exchange rates is likely to be even bigger than what the previous example suggests. That's because contracts are often negotiated much further in advance than just one quarter. For example, most wage agreements extend for a year, and many contracts actually go for three years. The uncertainty in the one-year-ahead forecast of an exchange rate is roughly four times greater than the uncertainty in the one-quarter-ahead forecast. If we widened the spread in E substantially, there could be so much volatility in profits that they could actually go negative, that is, earning could be less than costs. The point is that this happens with exchange rate fluctuations that are not far from historical experience.

2. The market where traders directly exchange different currencies is called the 'spot market'. As the previous discussion suggests, business people are likely to be nervous about doing all their currency trading in the spot market when they have to make other decisions in advance. In such cases, they have an incentive to find an alternative to the spot market, which allows them reduce or eliminate the uncertainties in their cash flow arising from spot exchange rate uncertainty. Not surprisingly, the appropriate markets have come into being.

   Markets exist where people can commit today to exchanging currencies in the future at a specific rate of exchange. Thus, the manufacturer in the previous example could try and find someone who is willing to commit to giving them dollars in exchange for Euros (i.e., enter into a 'forward contract') at some mutually satisfactory rate of exchange three months from now. In this way (for a fee, of course!), the manufacturer can eliminate *all* exchange rate uncertainty. The exact exchange rate and fees traders are likely to settle on in the forward market will depend in part on how many traders there are on each side of the market and how they feel about the spot market. If one side of the market stands to lose more from the uncertainties of the spot market than the other side, then the laws of bargaining dictate that they are likely to get the worst deal. See the text for additional discussion of the issues. The key point is that for reasons not well understood, forward markets are not highly developed and are expensive to participate in. As a result, a lot of the exchange rate uncertainty described above is experienced by actual market participants.

3. Financial Assets and Rates of Return.

   Financial Asset: A Piece of paper that entitles the holder to a stream of payments in the future. The supplier of the financial asset receives an up-front payment in the form of the purchase price of the asset. In the case of a business, the future stream of payments is paid using the revenues generated by what is purchased using the up-front payment on the asset. For example, if it is a machine that is purchased, the

future stream of payments is paid using the extra receipts earned by the business as a result of the machine. Businesses issue two types of financial assets: equity or debt. In the case of debt, the purchaser of the financial asset is told precisely what the stream of payments will be in the future (unless the company goes bust!). In the case of equity, the purchaser does not know what that stream will be, since what it receives is a cut of the firm's profits.

One measure of the worth of a financial asset is its expected 'rate of return', which measures how much you get out of it, relative to what it costs. Below is a discussion of rates of return. It shows that the rate of return on an asset depends on what units you measure costs and returns. Units can be in dollars, goods, or some other currency.

(a) Nominal one-period return on a financial asset. This is the amount of money you get from holding a financial asset for one period and then selling it next period at the price prevailing then, divided by the amount of money you paid for it today, P :

$$\text{nominal return} = \frac{D + P'}{P} = 1 + R,$$

where D is the dollar payment you get from holding the asset, and R is the (net) nominal return. The asset could be a bond, in which case D is an interest payment, or a share in a corporation, in which case D would be a dividend check.

(b) Real return on a financial asset: what you get, in terms of goods, from holding an asset for one period, divided by what you give up, in goods, to acquire the asset. The goods value of \$1 is just $1/P_c$, where P_c is the price of a good. In practice, P_c is the price of a basket of goods. An example is the consumer price index, which is the price of buying a specific basket of goods (so many apples, so much bread, so much fuel oil, etc.) that government economists think resembles the mix of goods Americans actually buy.[2] So, if the price of a basket is $P_c = \$2$, then with one dollar you can buy $1/P_c = 1/2$ of one basket. Similarly, if the price of a given asset is P dollars, then that corresponds to P/P_c baskets of goods. Also, if the monetary payoff of holding the asset one period and then selling it is $D + P'$, then that payoff in terms of baskets of goods

[2]The actual level of P_c doesn't mean much, of course, since we don't know exactly how many of each the goods the government economists have in the basket. But, changes in P_c are of interest, since they indicate that the basket of goods that Americans buy has changed in cost.

is $(D+P')/P_c^{'}$ where $P_c^{'}$ is next period's price index. So, now we say what the real return on an asset is:

$$\text{real return} = \frac{(D+P')/P_c^{'}}{P/P_c} = (1+R)\frac{P_c}{P_c^{'}} = \frac{1+R}{1+\pi} \approx 1+R-\pi,$$

where R is the nominal return defined above and π is the inflation rate, $1+\pi = P_c^{'}/P_c$. The '$\approx$' means 'almost equals'. You can verify this by plugging in some (not too big!) values for R and π. So, the real rate of return on an asset is the nominal rate of return, minus the inflation rate. You can see here, that even if R is known at the time an asset is acquired (typically, it is not known - in the case of a bond, D may be known but P' is not likely to be known; in the case of equity, neither D nor P' are known), there will still be uncertainty in its rate of return stemming from uncertainty there is in π.

(c) The return on a foreign currency asset. In thinking about whether to invest in a US dollar asset or a foreign asset, it is important to get the returns in the same units. This is because, as the previous examples indicate, the units matter. So, imagine an American contemplating two assets: a US asset which has a nominal, US dollar rate of return, $R_{\$}$, and a European asset, which has a nominal return, in Euros, of $R_{€}$. As it stands now, the two assets are in different units. To compare them they have to be put in the same units. So, let's put them in US dollar units.

To acquire one unit of the European asset, the American has to pay $P^{€}$ Euros. In dollar terms, the American has to pay $E \times P^{€}$ dollars, where E denotes the number of Dollars per Euro in the spot exchange rate market (i.e., this is $E_{\$/€}$ in the notation of the book). So, the price, to an American, of the European asset, is $E \times P^{€}$ dollars. The payoff, next period, in Euros, is $D^{€} + P^{€\prime}$, which translates into $\left(D^{€} + P^{€\prime}\right) \times E'$ dollars next period. Here, E' denotes next period's exchange rate. So, the rate of return, in US dollars, on the European asset is:

$$1+R = \frac{\left(D^{€} + P^{€\prime}\right) \times E'}{P^{€} \times E} = (1+R_{€})\frac{E'}{E} \approx 1 + R_{€} + \frac{E'-E}{E},$$

In practice, E' is not known at the time the asset purchase decision is made, so it makes sense to replace E' by E^e :

$$R = R_{€} + \frac{E^e - E}{E}.$$

This says that the return, in domestic currency, on a foreign asset is the foreign denominated return on that asset, plus what you make from holding foreign currency for a while. Thus, if the foreign rate of interest is 5% and the depreciation of the domestic currency is 10%, then the return, in domestic currency units, of the foreign asset is 15%. This is actually only an approximation. But, it is a very good one. To see this, note that, from the exact formula:

$$R = (1 + R_{€})\frac{E'}{E} - 1 = 1.05 \times 1.1 - 1 = 1.155 - 1 = 0.155,$$

which is pretty close to 0.15.

When you're buying a foreign, as opposed to a domestic asset, you're really doing two things. First, you are investing in the asset itself. That is, you are earning 5% on the foreign asset. Second, you are benefiting from any depreciation that might occur in your exchange rate. For example, suppose $E' = 1.10$ and $E = 1.00$, so that the currency depreciates by 10 percent. Then, if you buy one euro with one dollar, and then turn around later and sell that euro for a dollar again, you get E' dollars back. The gross return on this transaction is the dollars you get back, E', divided by the dollars you put in, E, i.e., $E'/E = 1.10$. The net rate of return is $E'/E - 1 = 0.10$. The round trip through the foreign exchange market earns you 10%.

The above formula says that if the domestic currency depreciates, this adds to the return earned by domestic residents on financial assets in that country. Similarly, if the domestic currency depreciates, then this subtracts from the return earned by domestic residents.

4. Uncovered interest parity. Let the nominal rate of return on a US asset be denoted by $R_{\$}$. In practice, when traders decide how many dollar and euro assets to hold, they may know the values of $R_{\$}$ and $R_{€}$ (at least as long as it's one-period government bonds we're talking about, and not equity[3]), but E' is not known. Instead, they must form an

[3]The payoff of a one-period government bond occurs just in the next period. There are no more payoffs after that. So, P' for such a bond is zero, and the return on the bond is just D/P. Since P is known and so is D, the one period return on a one-period government bond is known at the time you buy it. The same is not true of a two or higher period government bond. In this case, P' is not zero, and this introduces a risk into the one period rate of return on such a bond. Although there is no risk about the payoff itself, there is risk coming in via uncertainty over how the market will value that bond in the next period.

expectation of what E' is likely to be. We denote this by E^e.

The markets for foreign exchange are extremely active and growing. In 1989 the daily volume of transactions was around $600 billion, and by 2001 that had grown to $1.2 trillion. Moreover, about 90 percent of the transactions involved the US dollar.

Some people are buying and selling because they're hoping to profit from changes in exchange rates. Others participate because they have receipts in one currency, but pay out profits in another currency. With many people trading financial assets, we would expect assets in different countries to generate similar rates of return, when denominated in the same currency units. Thus, we expect this relationship between the nominal return on US dollar assets, $R_{\$}$, and the nominal return on European assets, $R_{€}$:

$$R_{\$} = R_{€} + \frac{E^e - E}{E}.$$

In words, this expression says that if US interest rates are higher than European interest rates ($R_{\$} > R_{€}$), then the US dollar must be expected to depreciate. Similarly, if US interest rates are lower than European interest rates, then the US dollar must be expected to appreciate.

How might markets produce this equality, in practice? Suppose US interest rates were higher than the dollar returns one could earn on European assets, i.e., suppose

$$R_{\$} > R_{€} + \frac{E^e - E}{E}.$$

What would happen? Presumably, traders in Europe would sell euros and buy US dollars, to take advantage of high US returns. There would be a rush for the foreign exchange market, as traders scrambled to sell euros and acquire dollars. But, this would have the effect of causing the US dollar to appreciate, i.e., of driving E down. The lower E, assuming E^e does not change, implies a higher anticipated depreciation of the currency, restoring equality to the above relation. A similar story explains how the markets would prevent US rates from being lower than foreign rates, when denominated in dollars.

The above equality is called the Uncovered Interest Parity (UIP) relation.

5. UIP, Risk and Liquidity. The rate of return, $R = R_{€} + (E^e - E)/E$, is the 'expected' rate of return, denominated in domestic currency units, of a foreign financial asset whose foreign currency return is $R_{€}$. When

we compare R with $R_{\$}$, we are implicitly assuming that traders don't care about the risk characteristics of an asset. They only care about their expected returns. This leads to the UIP relationship, which says that expected returns on different assets should be the same. In practice, of course, traders do care about risk. An asset that is very risky may have to have a higher expected rate of return than an asset that has no risk, for traders to be willing to hold both of them.

There is another reason why focusing exclusively on expected returns oversimplifies things. Different assets have different liquidity characteristics. A highly liquid asset is one for which it is easier to find a buyer in case you need to sell it. For example, US government debt is highly liquid. The market for that is so highly developed and there are so many people in it all the time, that US government debt is as easy to dump in case you have to, as it is to dump regular currency. The IOU I gave to my colleague yesterday in exchange for lunch money is completely illiquid. So, the UIP relationship also implicitly abstracts from the different liquidity characteristics of different assets.

The upshot is that there is no reason for UIP to hold exactly. At best, it can only be expected to hold only as an approximation. Consistent with UIP, we do find that countries with low interest rates generally have an appreciating currency, at least over long periods of time. An example is Japan, whose currency has appreciated on average relative to the dollar and whose interest rates are lower than US interest rates on average. UIP tends not to hold over shorter periods of time.[4]

It is interesting to think a little more about the ways in which risk considerations creep into comparisons of different assets. Consider, for example, US and German government debt. Both are very liquid. Both are essentially risk free, when denominated in their own currencies. Still, the risk characteristics of the two types of debt, when the returns are denominated in common units, *are* different. To see this, suppose $R_{\$}$ and $R_{¢}$ are the return on US and German government debt, respectively. If the assets are held until maturity, then their risk when the returns are *denominated in their own currency*, is roughly zero. At the time you buy US government debt that you plan to hold onto until maturity, $R_{\$}$ is known for sure. The same is true for $R_{¢}$. However, what is not known at the time German government debt is purchased is its *dollar denominated* return. This is not known because the value of the exchange rate when the debt matures is not known. This is what makes German debt riskier than US debt, to an American.

[4]For a recent paper that documents this, see 'Long Horizon Uncovered Interest Rate Parity,' by Guy Meredith and Menzie Chinn. This is a November 1998 working paper available as NBER working paper 6797 at http://www.nber.org/papers/w6797. This paper uses simple econometric techniques. It is *not* required reading for the class.

Of course, the opposite is true from the perspective of a German. A German will find US government debt riskier than German government debt because the former involves exchange risk, while the latter does not.

As noted above, these issues of risk are likely in practice to prevent the UIP from holding exactly. Consider the following example. Suppose $E^e/E = 1.05$, so that a 5 percent dollar depreciation is expected. Suppose that $R_{\$} = R_{€} = 0.05$, i.e., the interest rates in both countries is five percent. Now, the uncovered interest parity relationship says that no one should be holding American denominated assets. Any American holding US government debt should sell it and buy German government debt. Why might an American hold on to US government debt anyway? The American may well agree with the assessment that E^e/E is 1.05. And, if E' turned out to equal E^e, the American would regret not having sold his or her US government debt and bought German government debt instead. But, the fact is that E' is uncertain, and therefore it could end up higher than E^e, or lower. The American may be especially concerned about the latter. For example, he or she may be worried that E'/E might turn out to be 0.95, say, where the US dollar appreciates by 5 percent. In this case, the American would *lose* money by holding German government debt.

Often, people hold government debt without planning to hold it to maturity. For example, you may want to buy 30-year government debt and only plan to hold onto it for one year. Then, even the own currency return on government debt is risky. The value of government debt that is sold before it matures is determined in the market, and is a random variable when you first buy it. Thus, there are at least two sources of risk to consider in comparing rates of return across countries: one that stems from uncertainty in the local currency denominated return and the other that stems from uncertainty in the exchange rate. Both of these forms of risk, if important enough, could lead to UIP not holding.

In particular, if there were evidence that UIP did not hold in the data, that would not constitute evidence of irrationality on the part of portfolio managers. That's because, in deriving UIP, we abstracted from risk and liquidity considerations. As it happens, UIP tends *not* to fit the data very well when we consider assets with short-term maturities. It does better on assets with longer term maturities. In developing our theory of exchange rates, we will make heavy use of UIP. This is because it probably does a good job in capturing the primary channel linking changes in interest rates and expected future exchange rates to the current exchange rate. A complete understanding of exchange rates requires also knowing how interest rate and expected exchange rate changes impact on the current exchange rate via their impact on risk. This channel is less well understood, and, in any case, well beyond

the scope of this course.

6. Covered Interest Parity. This is a relationship which does hold in the data. Let F denote the exchange rate in the forward market. This is known for sure at the time you buy German or US government debt. The return on German denominated debt, denominated in dollars, assuming the forward market is used, is

$$\frac{F(1+R_{€})}{E} \approx 1 + R_{€} + \frac{F-E}{E}.$$

The covered interest parity relation implies:

$$R_{\$} = R_{€} + \frac{F-E}{E}.$$

If this did not hold, then sure profits could be made simply by selling one of the assets and buying the other. In efficient markets, sure profits, or arbitrage opportunities, don't exist. Or, if they do they are quickly exploited until they disappear.

Figure 1: US Dollars Per Euro

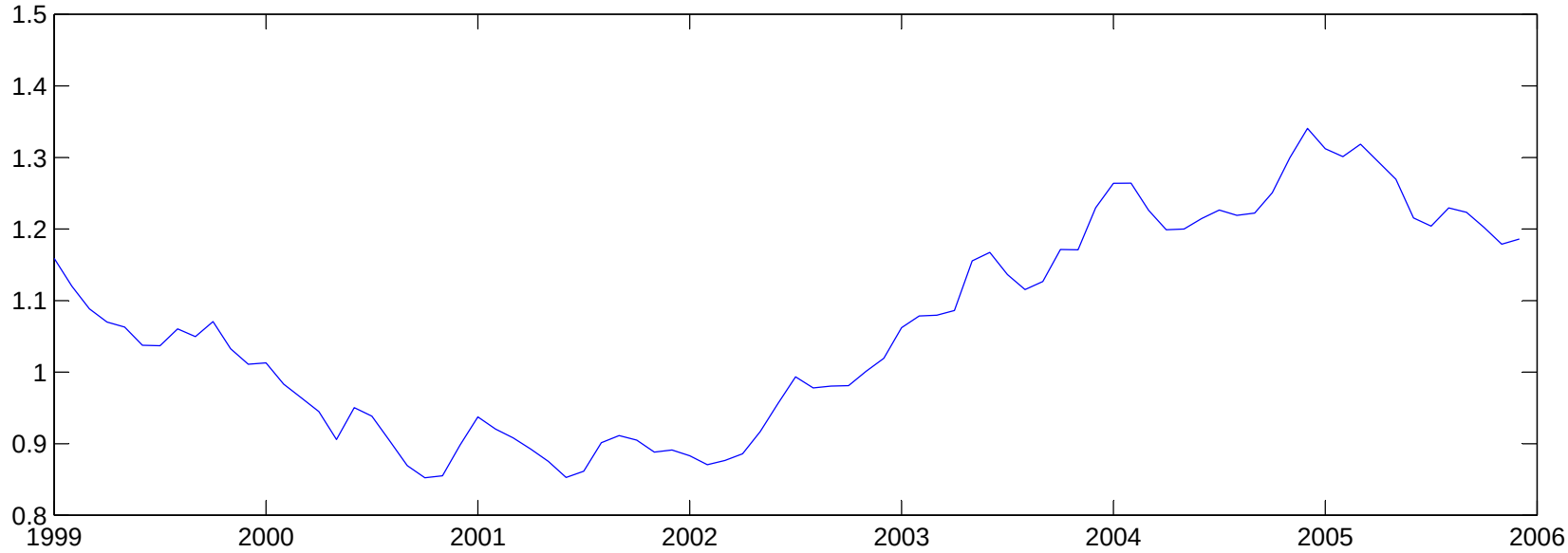

Figure 2: Annual Percent Change in Euro, Month t to Month t+12