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International Finance (Econ 421)
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Handout #4: Exchange Rates and Interest Rate Parity

1. Introduction

An exchange rate is the price of one currency in terms of another. Fluctuations in the exchange rate affect the value of *all* transactions carried out in foreign currency; as a result they are among the most important prices in open economies.

This handout first explains what exchange rates are, and then lays down the first building block of a model that will help us understand how exchange rates are determined. Following handouts will further develop this model.

We will take an asset-pricing approach for exchange rate determination. Under this approach, interest rates and expectations regarding the future level of the exchange rate are the key factors that determine today's exchange rate. The equilibrium condition that links interest rates, expectations, and the exchange rate is called **interest rate parity**. At this stage we will take the interest rates and expectations as given, and describe how changes in each of them affect the exchange rate. In following handouts we will extend the model to understand the determinants of interest rates and expectations.

2. Exchange Rates

2.1. The Basics

An exchange rate is the price of one currency in terms of another. Trade with other countries usually involves transactions in foreign currencies, and the exchange rate allows us to convert the value of these transactions to our domestic currency. For example, if you buy a can of Coke in France for €0.8 and the exchange rate is 1.25 dollars per euro ($/€), then the dollar price is €0.8 $\times$ 1.25$/€ = $1.0. Clearly, if we hold the euro price of Coke constant, then fluctuations in the exchange rate change the dollar value of the transaction.

We can express the dollar-euro exchange rate either as dollars per euro ($/€) or as euros per dollar (€/$). The first is said to be in American or direct terms while the second is in foreign or indirect terms. Note that in the example the exchange rate is quoted in American terms, 1.25$/€, this value implies that each dollar is exchanged for 0.8 euros, therefore, in European terms the exchange rate is 0.8€/$ (1 / 1.25$/€ = 0.8€/$).

A change in the exchange rate of a given currency is either called **appreciation** or **depreciation**, depending on the direction of the change. If the currency gained value (each unit worth *more* units of the foreign currency) we say that the currency has appreciated. If the currency lost value (each unit worth *fewer* units of the foreign currency) we say that the currency has depreciated. For example, when the dollar-euro exchange rate falls from 1.25$/€ to 1.20$/€, we say that the dollar appreciated against the euro since each dollar is worth more euros. Clearly, in this example each euro is worth fewer dollars and therefore the euro has depreciated against the dollar. Notice that when one currency is appreciating, another currency *must* be depreciating.

2.2. Exchange Rates and International Trade

Fluctuations in the exchange rate affect the value (in domestic currency) of transactions that are carried out in foreign currency. This is especially important for firms that face costs in one currency and revenues in another. For example, multinational corporations may locate their factories in foreign countries where labor is cheaper, while their main body of customers is located in the US. As a result they may face labor cost in, say, Thai bahts, while their income is in dollars. Fluctuations in the dollar-baht exchange rate directly affect their profit margins.

Exporters and importers may also face costs and revenues in different currencies. Exporters face cost in their domestic currency, while revenues come from abroad and are often denominated in foreign currency. Importers, on the other hand, face cost in foreign currency when they buy products from foreigners, and receive revenues locally in their domestic currency.

Consider, for example, a Colombian farmer who exports coffee to the US. Suppose that the farmer sells coffee to Americans for $0.6 per pound, and the exchange rate is 2400 Colombian pesos per dollar. Therefore, the farmer receives $0.6 × 2400peso/$ =

1440 pesos for every pound of coffee. Suppose also that the cost of production is in pesos (domestic labor, for example) and is equal to 1200 pesos per pound. Therefore, the farmer makes a profit of 240 pesos for each pound of coffee. Notice that the profits depend on the exchange rate. What happens if the peso depreciates against the dollar? Suppose that the peso loses value against the US dollar, and the new exchange rate is 2500 pesos per dollar (each dollar worth more pesos, hence the peso depreciated, i.e. lost value). If other prices don't change the farmer now receives $0.6 $\times$ 2500peso/$ = 1500 pesos per pound, and profits increase to 300 pesos for each pound of coffee. That is, other things equal, depreciation increases exporters' profits.

Notice that, by the same token, depreciation of the domestic currency makes imports less profitable since it increases the domestic price of foreign goods even if their foreign price is unchanged.

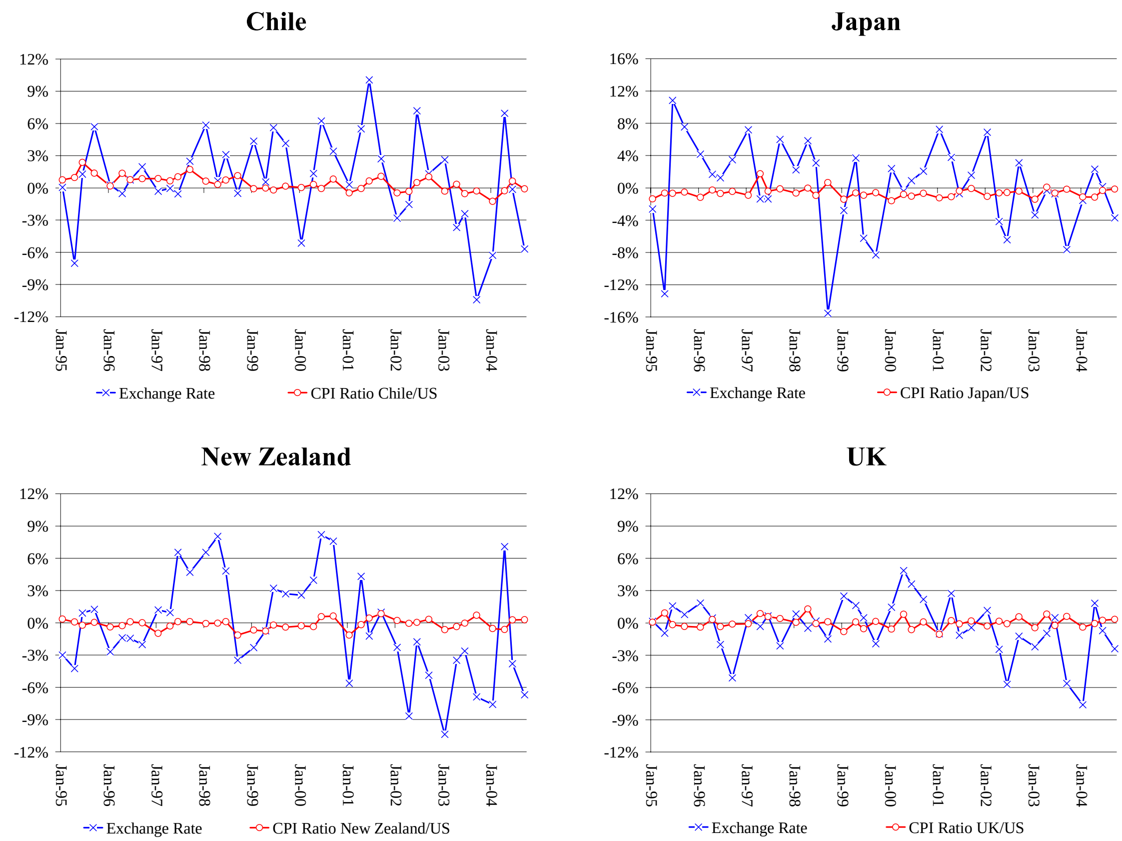
It is widely believed that depreciation stimulates the economy, especially in small open countries that depend heavily on exports. This example illustrates why this view is so popular. Note, however, that the argument depends heavily on the "all else being equal" assumption; if prices change together with the exchange rate, it is not clear anymore that depreciation has an expansionary effect on the economy.

Two comments are in order. First, in reality exchange rates are much more volatile than prices. This observation only reinforces the view that depreciation can stimulate the economy, since it suggests that the "all else being equal" assumption is not far from the truth. That is, when the exchange rate moves prices do not change. Figure 1 illustrates this point; it depicts the change in the exchange rate and the change in relative prices for four countries: Chile, Japan, New Zealand, and the UK. All exchange rates are expressed as national currency per US dollar, and changes in relative prices are measured as the changes in domestic consumer price index (CPI) relative to its American counterpart. In all cases fluctuations in the exchange rate are much greater than those of relative CPIs.[1]

[1] Notice that for the argument to hold, prices in each country need not be constant; they do, however, need to change at the same rate so that relative CPIs are constant.

Figure 1: Exchange Rates and Relative CPIs*

Percentage Change, Quarterly Data 1995-2004

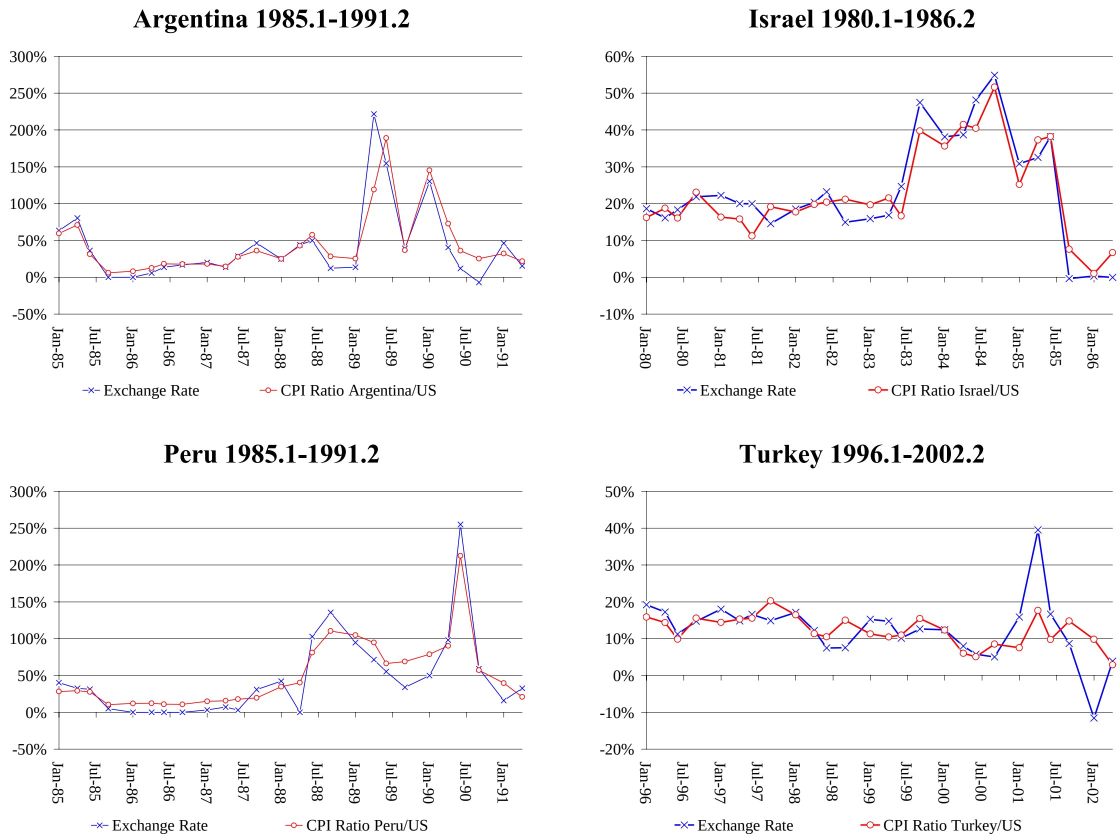


* Exchange rates are expressed as national currency per US dollar (that is, a positive change means appreciation of the dollar). Relative CPIs are calculated as national CPI over the US CPI (that is, a positive change means an inflation rate that is greater than the US inflation).
Source: International Financial Statistics.

Second, if all of this is true shouldn't countries attempt to *constantly* depreciate their currency? The answer is absolutely NO! First, it is simply impossible for all currencies to depreciate simultaneously, since when one currency depreciates another must appreciate. But suppose that Argentina, for example, is the only country that attempts to depreciate its currency; what happens then? All Argentinean exporters face higher prices abroad; therefore, they may be reluctant to sell their products at home at the current domestic price. This in turn puts pressure on domestic prices of their products to increase. In other words, depreciation may lead to inflation, and "all else" is no longer equal.[2]

[2] We will discuss the relationship between prices and the exchange rate more rigorously later in the course.

Figure 2: Exchange Rates and Relative CPIs During High Inflation Episodes*
Percentage Change, Quarterly Data



* Exchange rates are expressed as national currency per US dollar (that is, a positive change means appreciation of the dollar). Relative CPIs are calculated as national CPI over the US CPI (that is, a positive change means an inflation rate that is greater than the US inflation).
Source: International Financial Statistics.

Figure 2 presents the same variables as Figure 1, i.e. changes in the exchange rate and relative CPIs, however this time we concentrate on countries in periods of high inflation. In these episodes prices and the exchange rate tend to increase by approximately the same rate[3]. It should be stressed that although the graphs only depict consumer prices, nominal wages and other prices that affect the cost of domestic production follow similar patterns. Under these conditions, depreciation of the currency does not stimulate the economy because the domestic cost is increasing together with the exchange rate.

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[3] This is not to suggest that the high inflation episodes presented in Figure 2 were triggered by attempts of these countries to depreciate their currency, but rather to show that high inflation is associated with a similar rate of depreciation. There are many different scenarios that can produce high inflation; an attempt to constantly depreciate the currency is only one of them.

2.3. Spot and Forward Exchange Rates

The exchange rates depicted in figures 1 and 2 are the **spot** rates. The spot exchange rate is the *current* price of one currency in terms of another. When two parties agree to exchange currencies and execute the transaction immediately they use the spot exchange rate.

The spot exchange rates are highly volatile (see figures 1 and 2). As a result agents whose income depends on the exchange rate are exposed to risk. For example, consider again the Colombian farmer who exports coffee to the US. Growing coffee takes time, and the farmer pays the cost of production (in pesos) long before he sells the coffee for dollars. Imagine that he receives an order from Starbucks for 10,000 pounds for delivery three months from now at a price of $0.6 per pound. Suppose that the cost of production is 1200 pesos per pound. In order to make a profit, the exchange rate three month from now must be 2000 pesos per dollar (1200pesos / 0.6$ = 2000 peso/$) or higher. Any rate below 2000 pesos per dollar will result in losses.

In order to protect himself from the exchange rate risk, the farmer can sell his revenues, $6,000, *today* for pesos in the *future* at a known predetermined rate. Such transaction is called a **forward** transaction. In this example we say that the farmer sold dollars forward. The rate of exchange that is used in such transactions is called the **forward exchange rate**. For example, the farmer may go to his local bank and sell dollars for pesos in three months at a forward rate of 2400 pesos per dollar. This way a profit of 240 pesos per pound (2400peso/$ × 0.6$ – 1200 pesos = 240 pesos) is guaranteed regardless of the actual spot rate that realizes at the date of the exchange.

3. An Asset-Pricing Approach to Exchange Rate Determination

As mentioned in the introduction, we will take an asset-pricing approach to understand how exchange rates are determined. However, let’s first clarify what we mean by “asset-pricing approach”.

3.1. The Asset Pricing Approach

The price of any asset is a function of the stream of income it generates and its future price. For example, imagine you consider buying a house. The house can be rented for

$12,000 a year (assume you receive the rent at the end of the year), and you expect to sell it for $230,000 a year from now. Assuming you only care about the return from the house, how much should you be willing to pay for it today?

The answer depends on the return of alternative assets, since in equilibrium all assets must generate the same return.[4] One alternative is to put your money in the bank and get interest payments for the deposit. Therefore, you should be willing to pay for the house the amount of money that will give $12,000 + $230,000 = $242,000 a year from now if you save the money in the bank. Suppose the dollar interest rate is 10%, then in our example the answer is $242,000/1.1 = $220,000. Saving $220,000 today yields interest payments of $220,000 × 0.1 = $22,000, which is the same as the rent ($12,000) plus the capital gains, i.e. the change in price ($230,000 – $220,000 = $10,000), from buying the house.

Given the interest rate and the expected future price, anything other than $220,000 is inconsistent with equilibrium. If the price were higher, no one would buy the house. This would generate excess supply and put downward pressure on the price. A price below $220,000 would result in too many buyers, excess demand, and eventually a higher price.

Next we explain how all this is relevant for exchange rate determination.

3.2. Uncovered Interest Rate Parity

If we treat currencies as assets then, in equilibrium, the return on any two currencies must be the same.

Let $R_{\$}$ denote the dollar interest rate. $R_{\$}$ is the *dollar return* on deposits in dollars. Let $R_{€}$ denote the euro interest rate. $R_{€}$ is the *euro return* on deposits in euros. In order to compare the two we must express them in the same units. That is, we have to either figure out the dollar return on saving in euros (and compare the result to $R_{€}$), or calculate the euro return on dollar deposits (and compare the result to $R_{\$}$).

To calculate the dollar return on euro deposits we need to figure out how many dollars we expect to receive if we save $1 in euro deposits. However, in order to save in euro deposits we first have to convert the dollar into euros. Let $E_{\$/€}$ denote the American

[4] We are abstracting from other considerations that affect asset prices such as risk and liquidity. We assume that all we care about is the return on our money.

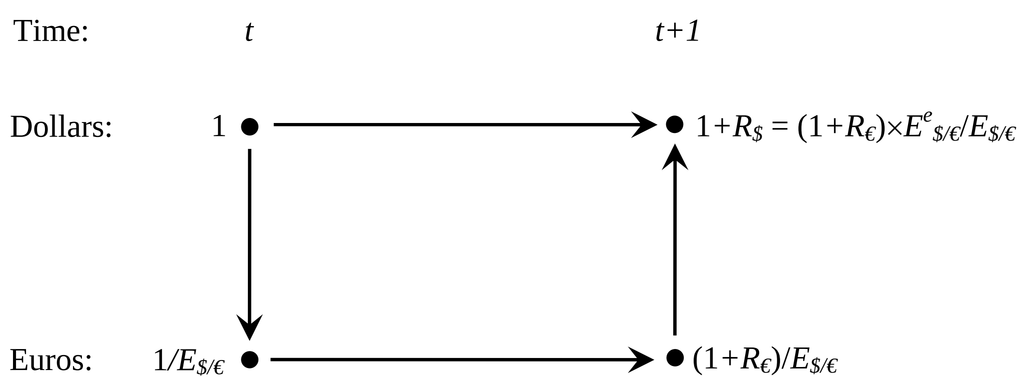
exchange rate (dollars per euro). Converting \$1 to euros gives us $1/E_{\$/€}$ euros. Saving in euro deposits gives us $1 + R_€$ euros for each euro we save. Therefore at the end of the period we get $(1 + R_€)\times(1/E_{\$/€})$ euros, or simply $(1 + R_€)/E_{\$/€}$ euros. Finally, we need to convert this quantity back into dollars. Let $E^e_{\$/€}$ denote the **expected exchange rate** at the end of the period. We can now conclude that by saving \$1 in euro deposits we expect to receive $(1 + R_€)\times E^e_{\$/€}/E_{\$/€}$ dollars after one period.

Saving \$1 in dollar deposits gives $1 + R_\$$ after one period. Therefore, in equilibrium we must have:

$$\mathbf{1 + R_\$ = (1 + R_€)\times E^e_{\$/€}/E_{\$/€}} \qquad \textbf{(1)}$$

This chain of transactions is illustrated in the figure below.

Figure 3: The Uncovered Interest Parity Condition



If the interest rates and the expected change in the exchange rate are relatively small (which is typically the case), this equation can be approximated by[5]:

$$\mathbf{R_\$ \approx R_€ + (E^e_{\$/€} - E_{\$/€})/E_{\$/€}} \qquad \textbf{(2)}$$

"Income" ***Capital Gains***

This equation is called **uncovered interest rate parity**. It equates the dollar return on dollar deposits with the dollar return on euro deposit. This formulation highlights the asset pricing approach since it decomposes the dollar return on euros into the income generated by euro deposits, $R_€$, and the capital gains from holding euros (i.e. the change in their price), $(E^e_{\$/€} - E_{\$/€})/E_{\$/€}$.

[5] To see this notice that equation (1) can be written as: $R_\$ = R_€ + (E^e_{\$/€} - E_{\$/€})/E_{\$/€} + R_€ \times(E^e_{\$/€} - E_{\$/€})/E_{\$/€}$. Assuming both $R_€$ and the expected depreciation, $(E^e_{\$/€} - E_{\$/€})/E_{\$/€}$, are small (say, less than 0.1), then their product is very small relative to the other elements in the equation and therefore can be ignored.

This equilibrium condition is called *uncovered* interest rate parity to emphasize that investors are not covered against risk. This is because the dollar return on euros depends on the *expected* exchange rate. If the *actual* exchange rate deviates from its expected value then the *actual* returns are not equated across currencies. Investors do not know in advance which currency yields the higher return and therefore they are exposed to risk. At the end of the handout we discuss the *covered* interest parity, where investors are covered against risk using the forward exchange rate.

Notice that by taking expectations and interest rates as given, the interest parity condition pins down the spot exchange rate. We can therefore use it to analyze how changes in expectations and interest rates affect the spot rate, which is the topic of the next sub-section.

3.3. Exchange Rate Determination

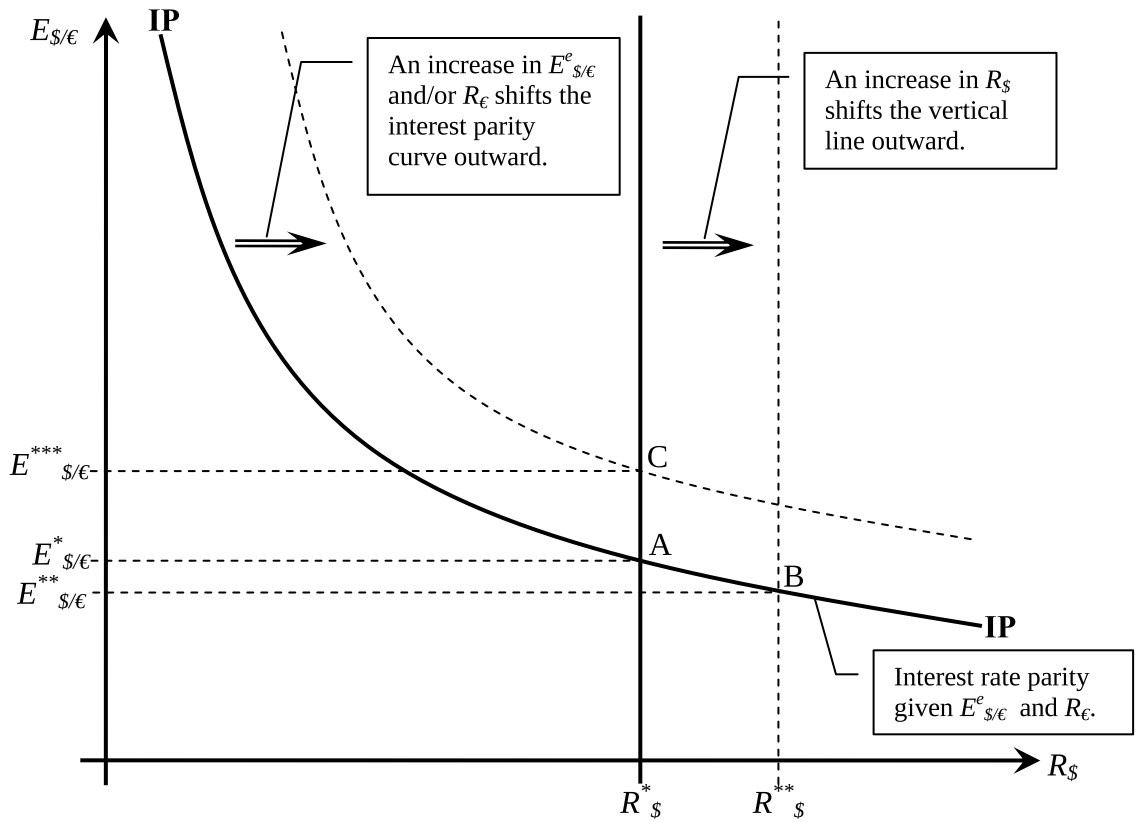
We use equation (1) to solve for the exchange rate:

$$\boldsymbol{E_{\$/€} = E^e_{\$/€} \times (1 + R_€)/(1 + R_\$)} \quad \textbf{(3)}$$

Clearly, the exchange rate falls with the dollar interest rate and increases with both the euro interest rate and expected future exchange rate. In what follows we provide some economic intuition to these findings.

Figure 4 depicts the dollar-euro exchange rate ($E_{\$/€}$) as a function of the dollar interest rate ($R_\$$). The IP-IP schedule is the interest parity condition for a fixed level of euro interest rate ($R_€$) and expectations ($E^e_{\$/€}$). As equation (3) indicates the exchange rate falls with the dollar interest rate, implying a downward sloping schedule. Fluctuations in $R_€$ and $E^e_{\$/€}$ move the IP-IP schedule; an increase in each of them shifts the curve outward. The vertical line indicates the level of $R_\$$; its intersection with the IP-IP schedule determines the equilibrium exchange rate.

Figure 4: Interest Rate Parity



An Increase in $R_\$$

Consider an unanticipated increase in the dollar interest rate from $R^*_\$$ to $R^{**}_\$$ (a shift in the vertical line in Figure 4).[6] This is an increase in the dollar return on *dollar deposits*. Therefore, in equilibrium, the expected dollar return on *euro deposits* must increase as well. Since $R_€$ is fixed, the euro must provide higher capital gains than initially anticipated, i.e. higher rate of appreciation against the dollar. Since $E^e_{\$/€}$ is fixed, the euro must *lose value on impact*; it therefore starts from a lower level and result in a higher expected rate of appreciation against the dollar. In Figure 4 this change is represented by a movement from point A to B, and the exchange rate falls from $E^*_{\$/€}$ to $E^{**}_{\$/€}$ (the dollar appreciates on impact). Another way to think about it is to notice that the increase in the dollar interest rate creates excess demand for dollars, and therefore on impact the dollar gains value (appreciates) against the euro, i.e. $E_{\$/€}$ falls.

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[6] If the change were anticipated then the system would have started to adjust prior to the actual increase in interest rate.

An Increase in $R_€$

Now consider an unanticipated increase in the euro interest rate ($R_€$). The increase in $R_€$ increases the dollar return on euro deposits. In order to maintain the interest parity condition, euros must provide lower capital gains than initially anticipated, i.e. lower rate of appreciation against the dollar. Since $E^e_{\$/€}$ is fixed, the euro must *gain value on impact*; it starts from a higher level and therefore results in a lower expected rate of appreciation against the dollar. In Figure 4 the increase in $R_€$ is represented by a shift of the IP-IP schedule outward. The system moves from point A to C, and the exchange rate increases from $E^*_{\$/€}$ to $E^{***}_{\$/€}$ (the dollar depreciates on impact). Notice that in this case euros become more attractive than dollars since initially their dollar return is greater than $R_\$$ and as a result the euro appreciates and the exchange rate increases to $E^{***}_{\$/€}$.

An Increase in $E^e_{\$/€}$

Finally, consider an increase in the expected future exchange rate ($E^e_{\$/€}$). That is, we expect the dollar to lose more value against the euro than initially anticipated. A fall in the expected value of the dollar increases the dollar return on *euro deposits*, making euros more attractive. In order to restore equilibrium, the expected capital gains from euros must fall back to their original level so as to equate the dollar returns on deposits in different currencies. On impact the dollar-euro exchange rate, $E_{\$/€}$, must increase (the dollar depreciates) and the expected rate of depreciation of the dollar falls back to its original level. In Figure 4 the increase in $E^e_{\$/€}$ is represented by a shift of the IP-IP schedule outward. The system moves from point A to C, and the exchange rate increases from $E^*_{\$/€}$ to $E^{***}_{\$/€}$ (the dollar depreciates on impact). As in the previous case (an increase in $R_€$), euros become more attractive than dollars since initially their dollar return is greater than $R_\$$ and as a result the euro appreciates and the exchange rate increases to $E^{***}_{\$/€}$.

4. Covered Interest Rate Parity

Recall that the interest parity condition we discussed so far hinges on the *expected* future exchange rate. This expectation may or may not be validated, which, in turn, exposes investors to uncertain returns and hence to risk.[7] We will now express the relationship between home and foreign interest rates using the forward exchange rate. This removes the risk element since the forward rate is known at the time of the transaction.

As we already discussed the forward exchange rate allows investors to insure themselves against fluctuations in the spot rate by locking in the future price of foreign currency. This, in turn, predetermines the dollar return on foreign currency deposits, and hence removes the risk.

In equilibrium the dollar return on dollar deposits and dollar return on foreign currency deposits must be the same. The condition that equates these returns is called **covered interest rate parity**. We now derive this condition.

As before, saving \$1 yields $1 + R_{\$}$ at the end of the period. To calculate the dollar return on euro deposits we need to figure out how many dollars we will receive if we save \$1 in euro deposits and lock in the future exchange rate by selling euros forward at a rate $F_{\$/€}$. In order to save in euro deposits we first have to convert the dollar into euros. Converting \$1 to euros gives us $1/E_{\$/€}$ euros. Saving in euro deposits gives us $1 + R_{€}$ euros for each euro we save. Therefore at the end of the period we get $(1 + R_{€})/E_{\$/€}$ euros. Finally, we need to convert this quantity back into dollars. Since we locked in the exchange rate at $F_{\$/€}$ we will receive $(1 + R_{€})\times F_{\$/€}/E_{\$/€}$ dollars after one period. Equating the returns gives:

$$1 + R_{\$} = (1 + R_{€})\times F_{\$/€}/E_{\$/€} \qquad \textbf{(4)}$$

This can be approximated by:

$$R_{\$} \approx R_{€} + (F_{\$/€} - E_{\$/€})/E_{\$/€} \qquad \textbf{(5)}$$

The quantity $(F_{\$/€} - E_{\$/€})/E_{\$/€}$ is called the *forward premium* of euros against dollars, or the *forward discount* of dollars against euros.

[7] Note that there is no uncertainty regarding the dollar return on dollar deposits, $R_{\$}$, and the euro return on euro deposits, $R_{€}$. The uncertainty stems from the future exchange rate which affects the dollar return on euros and the euro return on dollars.