Economics of Exchange Rates & Parity Relationships

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How do we define exchange rate?

- Exchange rate is the price of one currency in terms of another.
- We will use the following definition for "S":

  # of domestic currency units per unit of foreign currency

- In this definition, exchange rate will always express <u>one unit of **foreign currency**</u> in terms of <u>**domestic currency**</u>
- We use the following interchangeably:
  - Foreign Currency=Base Currency
  - Domestic Currency=Terms Currency

Examples

- EUR/USD 1.2010
- USD/JPY 120.10
- GBP/USD 1.3910
- USD/ARS 89.43

Basics: Change in the value of Currency

- You probably heard the terms **appreciation** and **revaluation** and **depreciation** and **devaluation**. In FX markets they mean the following:
  - **Revaluation** is an increase in the value of a government controlled currency → Driven by the monetary authority
  - **Appreciation** is an increase in the value of a freely floating currency → Driven by the market
  - **Devaluation** is a decline in the value of a government controlled currency → Driven by the monetary authority
  - **Depreciation** is a decline in the value of a freely floating currency → Driven by the market

Percentage Change in Foreign and Domestic Currency

- Change in the **base currency**:

$$\% \Delta = \frac{S_1 - S_0}{S_0}$$

- Change in the **terms currency**:

$$\% \Delta = \frac{S_0 - S_1}{S_1}$$

GBP/USD Post-Brexit

July 2016: Percentage Change in Foreign and Domestic Currency

- Change in the **base currency**:

$$\%\,\Delta GBP = \frac{1.2907 - 1.4878}{1.4878} = -13.24\%$$

- Change in the **terms currency**:

$$\%\,\Delta USD = \frac{1.4878 - 1.2907}{1.2907} = +15.27$$

February 2021:Percentage Change in Foreign and Domestic Currency

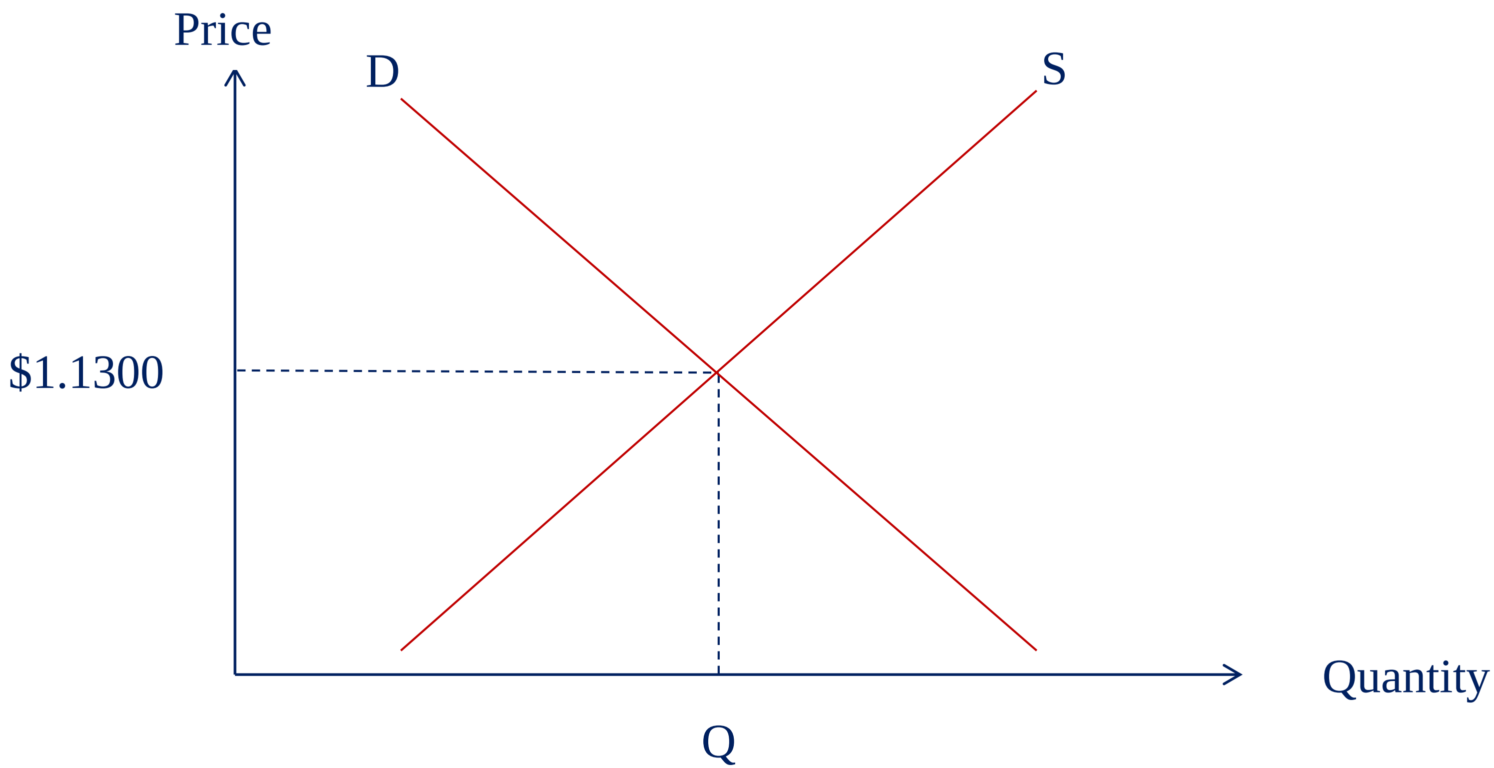
- Change in the **base currency**:

$$\%\Delta GBP = \frac{1.4078 - 1.2722}{1.2772} = +10.65\%$$

- Change in the **terms currency**:

$$\%\Delta USD = \frac{1.2722 - 1.4078}{1.4078} = -9.63\%$$

Demand and Supply for EUR and the Equilibrium Exchange Rate



If we consider EUR like any other commodity (e.g Milk), the price of EUR is determined by the demand and supply in the market.

Factors Affecting Demand and Supply of Local Currency

Demand for EUR

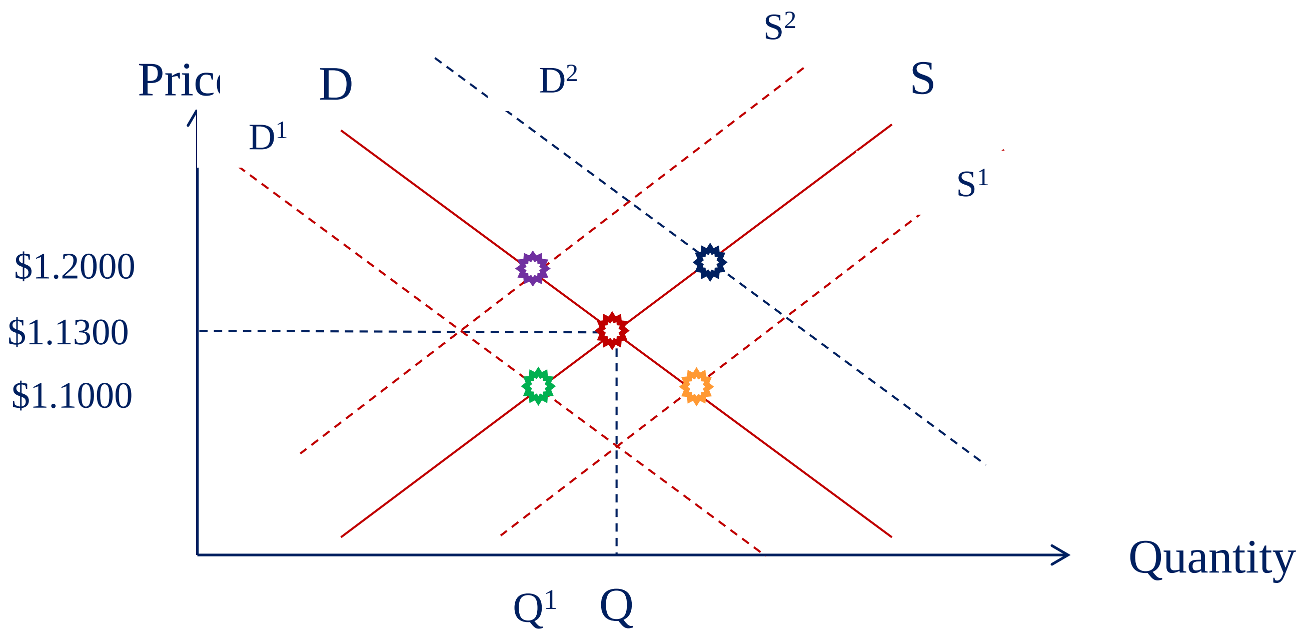
- **Increase in Exports**
  - Lower Inflation
  - Innovation
  - Productivity Increases
  - Higher Growth in trade partners

  Capital Inflows
  - Higher Interest rates in Eurozone
  - Higher corporate profitability
  - Lower risk premium

Supply of EUR

- **Increase in Imports**
  - Higher Eurozone Inflation
  - Innovation in trade partners
  - Productivity Increases in trade partners
  - Higher growth in Eurozone
- **Capital Ouflows**
  - Lower EZ Interest rates
  - Lower corporate profitability
  - Higher RP

Shifts in Demand and Supply Curves



Exercises: Evaluate the Impact on the value of EUR

1. US interest rates increase (ceteris paribus)

- B. Negative because, it will attract capital inflows into US; supply of EUR will increase and reduce the value of EUR

2. US growth rate exceeds Eurozone growth rate (ceteris paribus)

- A. Positive because US imports will increase and create demand for EUR, value of EUR will increase

3. US inflation is higher than Eurozone inflation (ceteris paribus)

- A. Positive because US goods will become more expensive for Eurozone consumers; supply of EUR declines

4. US corporations are expected to generate higher profits as compared to Eurozone corporations (ceteris paribus)

- B. Negative because, European investors will demand US stocks; supply of EUR will increase

5. Eurozone economic risks increase

- B. Negative because investors concerned about risk will sell their EUR denominated assets, supply of EUR will increase

6. Rumors emerged that Macron cheated on his wife?

- ???

7. Investors think Eurozone managed the COVID risk better than the US

- A. Positive because confidence in future recovery will increase demand for EUR

International Parity Relationships: A Map

- Purchasing Power Parity→ Exchange Rate and Price/Inflation relationship
  - Absolute Version → Big Mac Examples; Under/Overvaluation
  - Relative Version → Forecasting Future Exchange rate by using relative inflation rates
- PPP Related topics
  - Real Exchange Rates
  - Pass Through Effect
- Fisher Effect→ Relationship between nominal interest rate, real interest rate and inflation premium
- IFE → Exchange Rate and Price/Nominal Interest Rate relationship (underlying assumption is the real rates are equal across countries)
  - Uncovered Interest Parity and Carry Trade
- Interest Rate Parity → Spot rate-Forward Rate relationship
  - Covered Interest Arbitrage

Purchasing Power Parity→ Exchange Rate and Price/Inflation relationship

- **<u>Absolute Version</u>**
  - In its absolute form PPP simply says, "bilateral exchange rates between two currencies should be equal to ratio of price levels of comparable consumption baskets".

$$S_{d/f} = \frac{P^{d}}{P^{f}}$$

  - In practice, spot rates often deviate from their PPP implied levels.
  - When exchange rate deviates from its PPP implied level, it is referred to be either <u>over</u> or <u>under</u> valued.

Fair Value vs Market Price or Actual

- Suppose **EUR** is priced in USD terms.
- EUR/USD X.XXXX
- Think of PPP implied exchange rate as the fair value of the **EUR**
- If someone is paying more than the fair value in the market in USD terms, it is intuitive to think that the base currency (or foreign currency), EUR, is overvalued at the market price
- It is also intuitive to think that the terms currency (or Local Currency), USD, is undervalued

Fair Value vs Market Price or Actual

- If someone is paying less than the fair value in the market in USD terms, it is intuitive to think that the base currency, EUR, is undervalued at the market price
- If the base currency (foreign currency) is undervalued, local currency, USD, is overvalued.

Under/Over Valuation of the Local Currency

- If the actual spot rate is above PPP implied rate the exchange rate (of the LC) is undervalued.

$$S > PPPIER \rightarrow \text{LC is undervalued}$$

- If the actual spot rate is below PPP implied rate the exchange rate (of the LC) is overvalued.

$$S < PPPIER \rightarrow \text{LC is overvalued}$$

Example

- Suppose we stuff two containers identical goods that are consumed both in the US and Germany. The prices of the items in the container in respective countries:
  - Total Price-US: $1,200,000;
  - Total Price-Germany €1,000,000
- As per APPP, the equilibrium exchange rate should be:

$$S_{LC/FC} = \frac{P^d}{P^f} = \frac{\$1,200,000}{€1,000,000} = \$1.2000/€$$

- If the spot rate in the market is S=EUR/USD 1.3000 what can we say about the value of
  - Dollar
  - EUR

Under/Over Valuation of the Local Currency

- PPP Implied rate of EUR: $1.2000 or EUR/USD 1.2
- Actual Market Price of S=EUR/USD 1.3000

S>PPPIER

- USD is Undervalued
- EUR is Overvalued

Extent of USD Undervaluation @ Spot rate $1.3

- USD is local currency. We can calculate the extent of undervaluation:

$$Under/Over\ Valuation\ of\ LC = \frac{\text{PPP Implied Rate-Actual Rate}}{\text{Actual Rate}}$$

$$Under/Over\ Valuation\ of\ LC = \frac{1.2000 - 1.3000}{1.3000} = -7.69\%$$

- EUR is foreign currency. We can calculate the extent of overvaluation:

$$Under/Over\ Valuation\ of\ FC = \frac{\text{Actual Rate-PPP Implied Rate}}{\text{PPP Implied Rate}}$$

$$Under/Over\ Valuation\ of\ FC = \frac{1.3000\text{-}1.2000}{1.2000} = +8.33\%$$

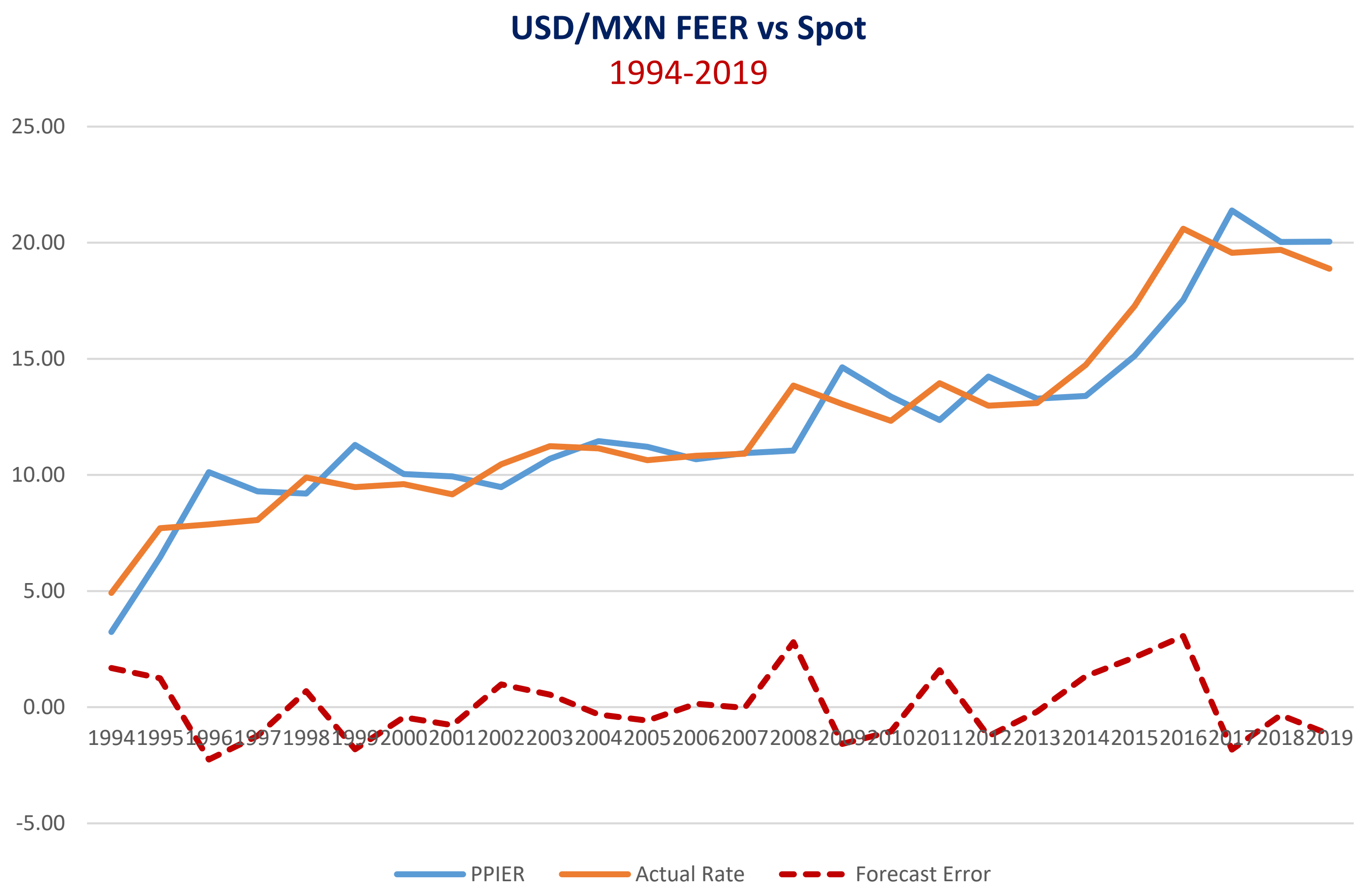
RPPP→ Forecasting Future Exchange rate by using relative inflation rates

- RPPP tells us that given the spot rate, **next period exchange rate** can be inferred from relative expected inflation rates at home and abroad.

$$S_1 = S_0 \times \frac{(1+\pi_d)}{(1+\pi_f)}$$

- This result can be expanded to a multi-period model. The idea here is that the exchange rates are a function of expected inflation rates.

USD/MXN PPP Forecast vs Spot



Example

- Assume that current spot rate is BRL1.95/$ (or USD/BRL1.95) and expected inflation rates in US and Brazil are 2.6% and 20% respectively.
- Note that the way exchange rate stated reveals:
  - BRL is home/domestic currency
  - USD is foreign currency
- RPPP gives us the forecast as:

$$\hat{S}_{t+1} = S_t \times \frac{(1 + \hat{\pi}_d)}{(1 + \hat{\pi}_f)_1}$$

$$\hat{S}_{t+1} = S_t \times \frac{(1 + \hat{\pi}_d)}{(1 + \hat{\pi}_f)_1} \rightarrow \hat{S}_{t+1} = 1.95 \times \frac{(1 + 0.20)}{(1 + 0.026)} = 2.28$$

Multi-period PPP Forecasting

$$S_{t+n} = S_t \times \left[\frac{\prod_{n=1}^{N} (1 + \pi_{d,n})}{\prod_{n=1}^{N} (1 + \pi_{f,n})} \right]$$

As the equation above suggests, we compound the inflation rates of domestic currency in the nominator and compound the inflation rates of foreign currency in the denominator.

Expected change in the exchange rate based on RPPP

Expected Change in the value of FC

$$\frac{S_1 - S_0}{S_0} = \frac{\pi_d - \pi_f}{(1 + \pi_f)} \cong \pi_d - \pi_f$$

Expected Change in the value of LC

$$\frac{S_0 - S_1}{S_1} = \frac{\pi_f - \pi_d}{(1 + \pi_d)} \cong \pi_f - \pi_d$$

These two formulas suggest that we can estimate the expected change in the **local** or **foreign** currency by using inflation rate differentials.

Example

- Suppose expected inflation in the US and Brazil are 1.6% and 12% respectively.
  - **What is the expected change in the value of USD?**
  - To answer the question we need to select domestic and foreign currencies; the decision is arbitrary. Let's assume USD is the domestic currency and BRL is the foreign currency.
  - If that is the case change in USD is the change in the LC which is given as

$$\frac{S_0 - S_1}{S_1} = \frac{\pi_f - \pi_d}{(1+\pi_d)} \rightarrow \text{Expected } \Delta\% \text{ in USD} = \frac{0.12 - 0.016}{(1+0.016)} = +10.23\%$$

  - **What is the expected change in the value of Brazilian Real (BRL)?**
  - Since we defined BRL as foreign currency, change in BRL is given as:

$$\frac{S_1 - S_0}{S_0} = \frac{\pi_d - \pi_f}{(1+\pi_f)} \rightarrow \text{Expected } \Delta\% \text{ in BRL} = \frac{0.016 - 0.12}{(1+0.12)} = -9.28\%$$

Fisher Effect

- **What is Fisher Effect**? It is a simple relationship between the nominal interest rates, inflation and real interest rates:

$$i=r+\pi+r\pi$$

- Where i=Nominal risk free interest rate;
- r=real interest rate
- π=inflation premium The expression above is derived from

$$(1+i)=(1+r)x(1+\pi)$$

- From a computational perspective if you know any two of the nominal rate, real rate and inflation rate, you should be able to calculate the third!!
- International Fisher Effect suggests that real interest rates are equal around the world.

International Fisher Effect

- IFE → Exchange Rate and Price/Nominal Interest Rate relationship (underlying assumption is the real rates are equal across countries). The relationship is given as follows:

$$S_{t+1} = S_t \times \frac{(1 + i_d)}{(1 + i_f)}$$

- This equation tells us that if we know the domestic (home) and foreign interest rates from time t to t+1, we can forecast the spot exchange rate at time t+1.

Example

- One year US and Euro-zone Treasury yields are 4.6% and 3.5% respectively. Given the spot rate of EUR/USD1.2315 today, what should be the IFE forecast of future spot rate exactly one year from today?

IFE Forecast of Future Spot Rate

Note that spot rate quote 1.2315 implies **USD is the domestic(terms) currency** and EUR is the **foreign (base) currency**. We place the interest rates accordingly in the formula

$$S_{t+1} = S_t \times \frac{(1+i_d)}{(1+i_f)} = 1.2315 \times \frac{(1+0.046)}{(1+0.035)} = 1.2446$$

If the spot rate at T=1 is 1.2446, the return earned on risk free assets, **when they are measured in USD or EUR will be equal to each** other:

USD 1,000 invested in EUR:

$$[(\$1,000 / 1.2315) \times (1+0.035)] / 1.2446 = \$1,046$$

- What if the expected spot rate one year from now is 1.20? What is the implication?
- Investors will sell EUR, buy USD and earn the following returns in EUR

$$[(EUR1{,}000 \times 1.2315) \times (1 + 0.046)] / 1.2000 = EUR1{,}073.45$$

- With this expectation, investors will sell EUR, buy USD and invest in USD. This would increase the demand for USD, as spot rate appreciates the returns on US Treasuries in EUR terms will converge to 3.5%

- What if the expected spot rate one year from now is 1.30? What is the implication?
- Investors will buy EUR and earn the following returns in USD

$$[(\$1,000 / 1.2315) \times (1 + 0.035)] \times 1.3000 = \$1,092.57$$

- With this expectation, investors will sell USD, buy EUR and invest in EUR. This would increase the demand for EUR, as spot rate of USD depreciates the returns on EUR Treasuries in USD terms will converge to 4.6%

Another way to look at the IFE

- IFE suggests the following equilibrium spot rate given an expected future spot rate:

$$S_t = \frac{[E(S_{t+1}) \times (1 + i_f)]}{(1 + i_d)}$$

- The nominator is the expected future value of 1 unit foreign currency in USD; like any other asset, its present value is calculated by discounting it at the appropriate discount rate, in this case the risk free domestic interest rate.

Example

- Assume that 1 year T-bill yields in US and Mexico are 1% and 12% p.a. respectively. If the current spot rate of USD is USD/MXP 7.70 (i.e Mexican Peso 7.70 per USD) what should be the exchange rate implied by International Fisher Effect in one year?

Answer

- Note that spot rate quote MXP7.7 per USD (from the quote USD/MXP7.7) implies **MXP is the domestic (terms) currency** and USD is the **foreign (base) currency**. We place the interest rates accordingly in the formula:

$$S_{t+1} = S_t \times \frac{(1+i_d)}{(1+i_f)} \rightarrow 7.70 \times \frac{(1+0.12)}{(1+0.01)} = MXP\,8.53\ per\,USD$$

Expected change in the exchange rate based on IFE

Expected Change in the value of FC

$$\frac{S_1 - S_0}{S_0} = \frac{i_d - i_f}{(1 + i_f)} \cong i_d - i_f$$

Expected Change in the value of LC

$$\frac{S_0 - S_1}{S_1} = \frac{i_f - i_d}{(1 + i_d)} \cong i_f - i_d$$

These two formulas suggest that we can estimate the expected change in the **local** or **foreign** currency by using interest rate differentials.

Example

- Assume that three month T-bills in the UK yield 2% p.a. and 0.9% in the U.S.
  - What should be the IFE implied exchange rate change in British Pound?
  - What should be the IFE implied exchange rate change in USD?

Example

- Assume that three month T-bills in the UK yield 2% p.a. and 0.9% in the U.S.
  - What should be the IFE implied exchange rate change in British Pound?
  - What should be the IFE implied exchange rate change in USD?
- As in the PPP example, here we also need to decide about the local and foreign exchange rates. Similarly, the choice is arbitrary. Let's select pound as domestic currency and USD as foreign currency:
  - What should be the IFE implied exchange rate change in British Pound?

$$\frac{S_0 - S_1}{S_1} = \frac{i_f - i_d}{(1 + i_d)} \rightarrow \text{Expected } \Delta\% \text{ in GBP} = \frac{0.009 - 0.02}{(1 + 0.02)} = -1.08\%$$

  - What should be the IFE implied exchange rate change in USD?

$$\frac{S_1 - S_0}{S_0} = \frac{i_d - i_f}{(1 + i_f)} \rightarrow \text{Expected } \Delta\% \text{ in USD} = \frac{0.02 - 0.0.09}{(1 + 0.009)} = +1.09\%$$

Using IFE to determine return on foreign investment

- Cross border investment is ubiquitous; US investors often invest in foreign markets in other currencies and borrow from foreign lenders in foreign currencies.
- When we invest or borrow in foreign currencies, it is important that we understand the impact of exchange rates on our returns or borrowing costs.
- An American investor, would like to know his/her expected return in USD terms as an American borrower would like to know its cost of borrowing in USD.
- IFE helps us to convert foreign investment returns into USD or foreign cost of borrowing into USD.

Using IFE to determine return on foreign investment

- We will estimate dollar return on an investment in another country and in another currency. To avoid confusion let's call the other country as investment country and the other currency as investment currency. Then dollar return is defined as:

$$i_{\$}^{IC} = (1 + i_{IC}) \times (1 + \Delta\% \text{ in IC}) - 1$$

- If the exchange rate is expressed as **USD per Investment Currency** then the formula will be:

$$i_{\$}^{IC} = (1 + i_{IC}) \times (1 + \Delta\% \text{ in IC}) - 1 = (1 + i_{IC}) \times \left(\frac{S_1}{S_0}\right) - 1$$

where S=dollars per investment currency and

S_1/S_0=(1+%change in investment currency)

- From above relationship we can **estimate our USD return** on our IC investment:

- Note that an investor who invests at time T=0, would only forecast of estimate the exchange rate at time T=1. Therefore the dollar return is dependent on the expected future spot rate S_1.

Using IFE to determine return on foreign investment

- In contrast if the exchange rate is **expressed investment country's currency per USD** then the change in the value of the formula change:

$$i_{\$}^{FC} = (1 + i_{IC}) \times (1 + \Delta\% \text{ in IC}) - 1 = (1 + i_{IC}) \times \left(\frac{S_0}{S_1} \right) - 1$$

where S=investment currency per dollar and

S_0/S_1=(1+%change in investment currency)

- From above relationship we can **estimate our USD return** on our IC investment:

Example-1:

- Assume that you invest in a German Corporate Bond and you expect to earn 4% return in Euro terms. Current spot rate is \$1.1990 per Euro and spot rate expected in one year is \$1.2500. What would be your dollar return on your Euro investment?
- In this question, we should first sort out the variables:
  - Investment Country: Germany
  - Investment Currency: Euro
  - Investment Currency expressed as USD per unit of Investment currency; this suggest that we treat investment currency as foreign currency and calculate change in its value accordingly:

$$i_{\$}^{IC} = (1 + i_{IC}) \times (1 + \Delta\% \text{ in IC}) - 1$$

$$(1 + \Delta\% \text{ in IC}) = \frac{S_1}{S_0}$$

$$i_{\$}^{IC} = (1 + i_{IC}) \times \left(\frac{S_1}{S_0}\right) - 1 = (1 + 0.04) \times \left(\frac{1.2500}{1.1990}\right) - 1 = 8.42\%$$

Example-2:

- Assume that you invest in a Japanese Corporate Bond and you expect to earn 1% return in JPY terms. Current spot rate is JPY125 per USD and spot rate expected in one year is JPY115. What would be your dollar return on your JPY investment?
- Sort out the variables:
  - Investment Country: Japan
  - Investment Currency: JPY
  - Investment Currency expressed as JPY per unit of USD; this suggest that we treat investment currency as domestic currency and calculate change in its value accordingly:

$$i_{\$}^{IC} = (1 + i_{IC}) \times (1 + \Delta\% \text{ in IC}) - 1$$

$$(1 + \Delta\% \text{ in IC}) = \frac{S_0}{S_1}$$

$$i_{\$}^{IC} = (1 + i_{IC}) \times \left(\frac{S_0}{S_1}\right) - 1 = (1 + 0.01) \times \left(\frac{125}{115}\right) - 1 = 9.78\%$$

Interest Rate Parity

- Interest Rate Parity suggests that spot rates, forward rates and interest rates are linked together by the following model:

$$F_{t,t+n} = S_t \times \frac{\left(1 + i_d \times \dfrac{n}{360}\right)}{\left(1 + i_f \times \dfrac{n}{360}\right)}$$

  - Note that all variables in this equation are observed at time t
  - n is days forward, for instance $F_{t,t+90}$ implies forward contract price at time t with 90 day maturity.

IRP & Covered Interest Arbitrage

- It is the strongest of the parity relationships; holds most of the time
- If IRP does not hold, arbitrage opportunities may emerge.
- It is possible to generate arbitrage gains by:
  - Borrowing
  - Buying Spot
  - Investing bought currency
  - Selling bought currency principal and interest forward
- If proceeds exceed the principle and interest in borrowed currency, arbitrage profits are generated

We mobilize money markets, spot markets and forward markets to generate arbitrage profits.

How to detect CIA opportunities?

- There are many ways to identify the covered interest arbitrage opportunities, but I will introduce one method to keep it simple:
- Since covered interest arbitrage involves home and foreign interest rates, spot and forward rates, we can use these to conduct a simple test. We have only two options:
  - Borrow in home currency and invest in foreign currency
  - Borrow in foreign currency and invest in home currency
- Our simple test will require us to compare return on investment and cost of borrowing

- If cost of borrowing at home is lower than return on investment from foreign investment, borrow at home and invest abroad.
- If cost of borrowing at home is higher than return on investment from foreign investment, borrow abroad and invest at home.

CIA Test

- Here is the test:
  - If $i_d=(1+i_f)(F/S_0)-1$ → There is no arbitrage opportunity (IRP holds)
  - If $i_d<(1+i_f)(F/S_0)-1$ → Borrow at home and invest abroad (IRP does not hold)
  - If $i_d>(1+i_f)(F/S_0)-1$ → Borrow abroad and invest at home (IRP does not hold)
- Note that the right hand side of the inequality is simply the home currency return on foreign investment.
- **IMPORTANT:** Interest rates are always expressed in annualized terms; to apply this test correctly we need to adjust the interest rates for the appropriate time frame

Example

- Data:
  - Spot Rate: IDR7500/USD
  - Forward Rate: IDR 8,000 /USD
  - i_{USD}: 5%
  - i_{IDR}:40%

Example: Apply the test to previous example

- Test: Indonesia is the **home country** and US is **foreign country** as per exchange rate expression:
  - Is $i_d<(1+i_f)(F/S_0)-1$? → Is $0.4<(1+0.05)\text{x}(8{,}000/7500)-1 =12\%$
  - 40% is not smaller than 12%
  - The answer is NO! This means that we reject borrowing at home and investing abroad argument and do the opposite. Or go to the next statement:
  - Is $i_d>(1+i_f)(F/S_0)-1$ → The answer is YES! Then, we borrow abroad and invest at home (IRP does not hold)
  - 40% is larger than 12%; so borrow abroad, invest home

Covered Interest Arbitrage Profit

- Borrow $1,000,000 at 5%
- Buy IDR $1,000,000 x 7,500=IDR7.5bn
- IDR7.5bn(1+0.4)=IDR10.5bn
- Sold forward @IDR 8,000 will generate:$1,312,500
- Return $ principal and interest:
- 1,312,500-1,050,000=262,500

Forward Premium/Discount of the Foreign (Base) Currency

$$\text{Forward Premium/Discount} = \frac{F_{t,t+n} - S_0}{S_0} \times \left(\frac{360}{n}\right) = \frac{i_d - i_f}{i_f}$$

Note that Forward rate has maturity T=t+n at time t. Interest rates are expressed in annualized terms. **Forward Premium or Discount** is annualized with the factor (360/n) where n is the number of days forward.

Forward Premium/Discount of the home (terms) Currency

$$\text{Forward Premium/Discount} = \frac{S_0 - F_{t,t+n}}{F_{t,t+n}} \times \left(\frac{360}{n}\right) = \frac{i_f - i_d}{i_d}$$

Note that Forward rate has maturity T=t+n at time t. Interest rates are expressed in annualized terms. **Forward Premium or Discount** is annualized with the factor (360/n) where n is the number of days forward.