Module - 16
Exchange Rate Arithmetic:
Cross Rates & Triangular Arbitrage

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Currency quotations may not be available for currencies which are not demanded in major way. For these kinds of infrequently traded currency pair, the spot and forward rate is calculated through another currency. Exchange rates calculated in such manner are known as cross rates.

Any mispricing of exchange rate between two or more currency pair gives rise to arbitrage opportunity and trader make substantial gain by quickly exploiting this arbitrage opportunity. Cross rates also provide an opportunity for arbitrage profit. The arbitrage profit arising difference in cross rates is known as triangular arbitrage.

After factoring in interest rate differential, if the actual forward exchange rate deviates from the theoretical forward exchange rate, then it gives rise to arbitrage profit—known as interest rate arbitrage.

Hence the objectives this module is to understand the following aspects:

- Cross rates for both spot and forward quotations
- Cross rate with bid-ask spread.
- Forward cross rates
- Implied cross rates
- Cross rates and Triangular Arbitrage
- Interest rate arbitrage and how traders exploit this arbitrage opportunity.
Cross rates for spot quotations have been discussed in the Session 13.2. However, at the cost of repetition, the cross rate calculation is given here, as it forms basis for calculation of forward cross rates.

A spot cross rate is a rate which can be calculated from two other spot rates. Suppose USDCAD (US dollar and Canadian Dollar) rate is given along with an USDAUD (US Dollar and Aussie Dollar) quotation.

\[
\text{USDCAD} = 1.1546 \quad (\text{CAD 1.1546 is equal to 1 USD})
\]
\[
\text{CADAUD} = 1.0421 \quad (\text{AUD of 1.3421 is equal to 1 CAD})
\]

The USDAUD rate = \( \frac{\text{CAD1.1546}}{\text{USD}} \times \frac{\text{1.0421AUD}}{\text{1 CAD}} \) = AUD1.2032/USD

However, in real life, the dealers give bid-ask spread for currency pair. With bid-ask spread, the cross calculation becomes little complex.

16.1:2: Cross Rate Calculation with bid-ask spared:

USDCAD bid-ask rate is given along with and USDAUD bid-rate is given in Table 16.1. The rates for CADAUD (or AUDCAD) can be calculated from the above two quotes.

<table>
<thead>
<tr>
<th>USDCAD</th>
<th>USDAUD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bid</td>
<td>Ask</td>
</tr>
<tr>
<td>1.1641</td>
<td>1.1646</td>
</tr>
</tbody>
</table>

From the above quotations, cross rate between AUD/CAD can be calculated as follows:

- Bank buys 1USD and pays (sells) 1.1641 CAD
- Bank sells 1 USD and receives (buys) 1.1646 CAD
- Bank buys 1 USD and pays (sells) 1.2948 AUD
- Bank sells 1 USD and receives (buys) 1.2956 AUD

To get the bid rate for CADAUD (CAD as base currency and AUD as quote currency), the bank must sell AUD and buy CAD. This is achieved in two steps. That is

- The bank must sell AUD and buy USD
- Simultaneously sell USD and buy CAD.
This indicates that 1.1646 CAD = 1.2948 AUD. In other words, 1 CAD = 1.1118 AUD.

To get the ask rate for CADAUD, the bank must sell CAD and buy AUD. This is achieved in two steps i.e. the bank must sell CAD buy USD and simultaneously sell USD and buy AUD.

This means that 1.1641 CAD = 1.2956 AUD. In other words, 1 CAD = 1.1129 AUD. Hence the cross rate, given in Table 16.2 is

Table 16.2: CADAUD cross rates

<table>
<thead>
<tr>
<th>Bid</th>
<th>Ask</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1118</td>
<td>1.1129</td>
</tr>
</tbody>
</table>

16.2: Forward Cross Rates:

Cross rates for different maturities can be found out in the similar manner like the spot cross rates. The following table, Table 16.3 lists the actual rates(forward contracts rates for) different maturities. From these rates, the cross rates have been calculated and listed in Table 16.4

Table 16.3 Outright Quotations for USD/INR and USD/ZAR(*)

<table>
<thead>
<tr>
<th></th>
<th>USDINR</th>
<th>USDZAR</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bid Rate</td>
<td>Ask Rate</td>
</tr>
<tr>
<td>Spot</td>
<td>47.0725</td>
<td>47.0745</td>
</tr>
<tr>
<td>1 week</td>
<td>47.0750</td>
<td>47.0775</td>
</tr>
<tr>
<td>2 weeks</td>
<td>47.0795</td>
<td>47.0835</td>
</tr>
<tr>
<td>1 month</td>
<td>47.0840</td>
<td>47.0890</td>
</tr>
<tr>
<td>2 months</td>
<td>47.0900</td>
<td>47.0965</td>
</tr>
</tbody>
</table>

Table 16.4 INR/ZAR(*) Cross Rates for different forward periods

<table>
<thead>
<tr>
<th></th>
<th>Bid</th>
<th>Ask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spot</td>
<td>0.16131</td>
<td>0.16135</td>
</tr>
<tr>
<td>1 week</td>
<td>0.16126</td>
<td>0.16131</td>
</tr>
<tr>
<td>2 weeks</td>
<td>0.16118</td>
<td>0.16124</td>
</tr>
<tr>
<td>1 month</td>
<td>0.16100</td>
<td>0.16112</td>
</tr>
<tr>
<td>2 months</td>
<td>0.16089</td>
<td>0.16105</td>
</tr>
</tbody>
</table>

(*): ZAR is the currency of South Africa. It is known as South African Rand but has a ISO code of ZAR.
Cross rate calculation becomes necessity when two currency pair exchange rate is not quoted by a dealer or bank. For example, an Indian company imports textile yarns from South Africa for which the payment has to be made in ZAR. As none of the Indian banks directly offer, INRZAR quotations, the exporter has to sell INR and buy USD and then sell USD and buy ZAR to make the payment. As most currencies of the world are quoted with either Euro/USD/Pound sterling, these currencies form one leg of trade in any cross currency transaction.

To summarize, for many infrequently traded currencies pairs, cross rates are the only sources of rate quotations as no dealer/bank directly offers quote.

### 16.3: Cross Rates and Triangular Arbitrage:

Cross rates are the exchange rates of 1 currency with other currencies, and those currencies with each other. Cross rates are equalized among all currencies through a process called triangular arbitrage. As different forex dealers quote different rates for a given currency pair at a given point of time, it provides forex traders with arbitrage opportunity. Hence this is known as “intermarket arbitrage”.

Cross rate calculations helps in identifying the intermarket arbitrage opportunity. The following table, **Table 16.5**, indicates the list of exchange rates for currency pair. From these pairs, cross rates can be calculated.

<table>
<thead>
<tr>
<th>Currency Rates</th>
<th>US $</th>
<th>¥en</th>
<th>Euro</th>
<th>Can $</th>
<th>UK £</th>
<th>Aust $</th>
<th>SFranc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 US $</td>
<td>1.0</td>
<td>92.1700</td>
<td>0.7161</td>
<td>1.1633</td>
<td>0.6218</td>
<td>1.2924</td>
<td>1.0843</td>
</tr>
<tr>
<td>1 ¥en</td>
<td>0.010843</td>
<td>1.0</td>
<td>0.007768</td>
<td>0.012614</td>
<td>0.006741</td>
<td>0.014014</td>
<td>0.011758</td>
</tr>
<tr>
<td>1 Euro</td>
<td>1.3958</td>
<td>128.6900</td>
<td>1.0</td>
<td><strong>1.6244</strong></td>
<td>0.8682</td>
<td>1.8052</td>
<td>1.5138</td>
</tr>
<tr>
<td>1 Can $</td>
<td>0.8592</td>
<td>79.2100</td>
<td>0.6153</td>
<td>1.0</td>
<td><strong>0.5344</strong></td>
<td>1.1106</td>
<td>0.9318</td>
</tr>
<tr>
<td>1 UK £</td>
<td>1.6072</td>
<td>148.1600</td>
<td>1.1512</td>
<td>1.8699</td>
<td>1.0</td>
<td><strong>2.0779</strong></td>
<td>1.7429</td>
</tr>
<tr>
<td>1 Aust $</td>
<td>0.7732</td>
<td>71.2900</td>
<td>0.5538</td>
<td>0.8997</td>
<td>0.4809</td>
<td>1.0</td>
<td><strong>0.8383</strong></td>
</tr>
<tr>
<td>1 SFranc</td>
<td>0.9218</td>
<td>85.0000</td>
<td>0.6602</td>
<td>1.0726</td>
<td>0.5735</td>
<td>1.1919</td>
<td>1.0</td>
</tr>
</tbody>
</table>


- 1 Can $ = 0.8592 US $.
- 1 Euro = 1.3958 US$.
- From these two rates, the cross rate for Can $/Euro can be calculated.
The implied cross rate calculated in this manner is compared with the actual rate quoted by another dealer or bank. If these two are significantly different, then arbitrage opportunity arises.

The actual Euro/Can$ rate given in Table 16.5 is Can$1.6244/Euro. The implied cross rate is very close to the actual rate. The minor difference arises as the transaction cost and bid-ask spread have not been factored into the calculation of implied cross rates.

Suppose there is a significant difference between the implied cross rate and the actual rate. This will lead to arbitrage profit.

Let us take a numerical example, to understand how triangular arbitrage happens. Three different banks are quoting spot rates for three currency pairs given below.

Bank of Japan quotes: $1 = 100 JPY/USD
Bank of America quotes: $1 = 1.60 USD/GBP
Bank of England quotes $1 = 140 JPY/GBP

If we consider the first two quotes, then JPY/GBP quote should be at 160 JPY/GBP. However bank of England quotes 140 JPY/GBP. It indicates that Bank of England is undervaluing GBP.

The triangular arbitrage happens:
- Borrow 100 USD
- Convert it to 10000 JPY at Bank of Japan.
- Convert 10,000 JPY to GBP at Bank of England. Receive 71.428 GBP.
- Convert 71.428 GBP to USD at Bank of America. Receive 114.285 USD.
- Profit of 14.285 USD before adjusting for USD borrowing cost.
In real life, the rates are quoted with bid-ask spread. The triangular arbitrage with bid and ask spread is given in Table 16.6

<table>
<thead>
<tr>
<th>Bank</th>
<th>Bid</th>
<th>Ask</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank A (GBP/USD)</td>
<td>1.60</td>
<td>1.61</td>
</tr>
<tr>
<td>Bank B (MYR/USD)</td>
<td>0.2</td>
<td>0.202</td>
</tr>
<tr>
<td>Bank C (GBP/MYR)</td>
<td>8.10</td>
<td>8.20</td>
</tr>
</tbody>
</table>

MYR : Malaysian Ringgit

With the rate given in Table 16.6, the triangular arbitrage happens in three steps:

- Sell USD 1.61 and Receive 1 GBP at Bank A ask rate
- Sell 1 GBP and Receive 8.10 MYR at Bank C bid rate
- Sell 8.10 MYR and Receive $ 1.62 at Bank B bid rate.

Arbitrage profit is $0.01 for every 1 USD investments. The investor takes full circle – sell USD to receive USD to get the benefit of triangular arbitrage.

The triangular arbitrage can also happen

- Sell 1 MYR, receive 0.2 USD
- Sell 0.2 USD and buy 0.124224 GBP (Sell 1.61USD and receive 1 GBP)
- Sell 0.124224 GBP and receive 1.0062 MYR.

Hence for every 1 MYR investment, the trader would be able to make a profit of MYR 0.006.

Can arbitrage happen, if the investors starts from GBP? This needs to be found out!

Exploiting Triangular arbitrage opportunity is a favourite hunting ground for forex traders. In fact, forex traders buy software packages which analyses real time bid-ask quotations offered by forex dealers, identify arbitrage opportunity and place order to benefit from the opportunity without any human intervention.
Arbitrage opportunities available to forex traders as discussed in Section 16.3 are known as the intermarket arbitrage. Forex traders regularly make arbitrage profit through interest rate differential in two countries. This is known as “interest rate arbitrage”.

**Interest rate arbitrage** works like this:

Spot rate £1 = €1.6140. Interest rate for coming 12 months is 5.5% for Pound Sterling and 3.75% for Euro. Suppose a bank quotes a 3 month forward rate as £1 = €1.5970. Now let us see whether there exists an arbitrage opportunity or not.

For example, a trader borrows £100,000 for 3 months. He has to pay £101,375 after 3 months. He converts £100,000 to € at the spot rate. He receives €161400. Invests €161400 at 3.75% interest rate for 3 months. He earns €162913. He converts euro proceeding to Pound sterling at the 3 month forward rate of £1 = €1.5970. He earns £102,012. He returns £101,375 and makes an arbitrage profit of £636.

This profit opportunity will entice many traders to borrow Pound Sterling, sell Pound sterling to buy Euro, invest in Euro and sell Euro forward to buy Pound Sterling. This will ensure that the arbitrage opportunity vanishes quickly. In fact, with spot bid £1 = €1.6140, interest rate for coming 12 months is 5.5% for Pound Sterling and 3.75% for Euro, the 3 month forward rate should have been £1 = €1.6070 and not £1 = €1.5970.

Interest rate arbitrage opportunity forms the core of **interest rate parity** and **covered interest rate arbitrage**. This aspect will be discussed in greater detail in later sessions.
1. Suppose spot USD/INR is 46.75 and 1 year US interest rate is 5% while it is 11% in India. The 1 year USD/INR forward rate is
   a. 42.22
   b. 42.29
   c. 49.42
   d. None of these.

2. If the EuroINR is equal to INR 70.25 and Bangadesi Taka EuroBTK exchange rate is BTK 99.18, the cross rate INR/BTK rate is
   a) 1.4118 INR for BTK
   b) 1.4118 BTK for INR
   c) 0.708 BTK for INR
   d) 0.708 INR for BTK.

3. USD is worth Yen 125 and is equal to 1.6949 Fijian Dollar. What is the cross rate between Yen/Fijian Dollar (with yen as base currency)?
   a. 73.75.
   b. 125.
   c. 1.69.
   d. 0.014.
   e. none of the above.

4. The theory of interest rate parity postulates that
   a. interest rates should always be equal in two countries.
   b. spot rate and the forward exchange rate difference must reflect difference in interest rates between two countries in the opposite direction
   c. spot rate and the future spot rate difference must reflect the interest rate difference between two countries in the opposite direction
   d. None of the above.
1. A Canadian Exporter exporting goods to USA will receive USD100,000 after 3 months. A bank quotes 3-month USDCAD forward bid–ask rate as (1.2302 – 1.2315). How much the Canadian exporter will receive if he enters the forward contract?

2. Suppose spot USD/INR is 46.75 and 1 year US interest rate is 5% while it is 11% in India. A bank is quoting 1 year forward rate as 43.35. Does this give rise arbitrage opportunity? If so how a trader can benefit from this opportunity?

3. A bank is quoting spot rate USD INR as 45.1560. Interest rate prevailing in USA is 3.5% and in India is 9%. Calculate what would be the 1 year USDINR forward swap points and what would be the 1 year USDINR outright forward quotations?

4. Bank A is quoting USDINR rate is 45.1725 and JPYUSD 0.0089. Bank B is quoting JPYINR rate of 0.4050. Find out the cross rate from Bank A’s point of view and check whether any arbitrage opportunity exist or not? If exists, show how the arbitrage profit can be made.

Answer to Multiple Choice Question:

1. (c)
2. (a)
3. (d)
4. (b)

References:

1. Importance of Length of Quotation in foreign Exchange. www.caclubindia.com/.../icici-fires-dealer-for-forex-fraud-26289.asp


3. The foreign Exchange Market (Chapter 5), Fundamentals of Multinational Finance, 3e (Moffett).