OULUN YLIOPISTO
UNIVERSITY of OULU

OULU BUSINESS SCHOOL

Thanushka Jayasundera

Persistence and Predictability of Forward Exchange Arbitrage in Managed Rate Currencies in Comparison to Free-floating Currencies

Master's Thesis
Finance Department
May 2014

UNIVERSITY OF OULU
Oulu Business School

ABSTRACT OF THE MASTER'S THESIS

Unit : Department of Finance

Author	Supervisor
Thanushka Jayasundera	Professor Hannu Kahra

Title
Persistence and Predictability of Forward Exchange Arbitrage in Managed Rate Currencies in Comparison to Free-floating Currencies

Subject	Type of the degree	Time of publication	Number of pages
Finance	Master of Science	Spring 2014	72

Abstract:

This paper attempts to analyse whether forward exchange arbitrage in currencies of managed rate regimes behave differently from currencies of free-floating regimes in the forward exchange market. For this purpose, currencies of Great Britain, the European Union, and Japan are used as proxy currencies for free floating currencies. Proxy currencies for managed rate currencies are the Sri Lankan Rupee, the Indian Rupee, the Russian Rouble and the Brazilian Real. The US dollar is used as the anchor currency for both sets of currencies.

The core of the paper revolves around the pricing difference between the fundamental forward price and the market forward price. Fundamental forward price is calculated based on the interest rate differentials of the two currencies; this is in concurrence with the interest rate parity condition. Market price is based on the forward pips and the spot rate.

This analysis concentrates on the persistence of mispricing availability, the availability of forward pricing differences and the predictability of the mispricing in both sets of currencies. Finally, we also test whether the current forward price can predict the future spot price based on the interest rate parity theory.

We present evidence that almost all the currencies have forward rate mispricing. However, we also present evidence to prove that mispricing in free-floating currencies is extremely small, while managed rate currencies offer significant mispricing that could be exploited for arbitrage purposes. We also present evidence to establish that persistence of mispricing is specific to the currency pair and cannot be clearly attributed to the exchange rate regime.

This paper also finds that it is not possible to statistically forecast the mispricing in both free floating and managed rate currencies. Further, failure of interest rate parity theory to accurately forecast the future spot rate is also documented.

Keywords

Managed rate currencies, Free floating currencies, Emerging markets, Interest rate parity theory, Arbitrage, Exchange rate risk, Forward price, Spot price, Moving average regression, Autoregressive processes.

Additional information

CONTENTS

TABLE OF CONTENTS FOR FIGURES

TABLE OF CONTENTS FOR TABLES

1 INTRODUCTION

Spot and Forward exchange markets are currently the biggest markets in the world. Given that there is no specific single location and that trading is mostly over the counter, the foreign exchange market has grown phenomenally in the last decade. Such growth is mainly fuelled by the growth in international trade and the explosion of information technology that is evident in the last decade. Today, trading takes place around the clock and speed of trading is counted in milliseconds. Main participants in the forex markets are Commercial banks, Investment banks, Brokers, Corporations, Hedge funds and Central banks, who facilitate international trade as well as act as speculators and arbitrageurs.

One of the largest markets within the foreign exchange market is the Forward market. The prices of forward contracts are determined by Interest rate parity between the two currencies involved and the strength of demand and supply for both currencies. The interest rate parity theory suggests that a currency's forward exchange rate is determined by the interest rate differential between the domestic currency and the foreign currency.

However, the actual price of a Forward contract may differ from the fundamental price of a forward contract. This leads way for speculators and arbitrageurs to earn a risk free profit using the mismatch in prices and carry trades. The reason for such price difference could be attributed to demand/supply pressure, transaction costs, and government intervention in the market.

The characteristics and persistence of such arbitrage spreads are different from market to market. However general perception is that Emerging markets are different from developed markets. This is due to most emerging markets using managed rate regimes while, developed markets are based on a free floating regime. This has led to Hedge funds using Global Macro strategies to exploit the mispricing in emerging markets.

While there have been extensive studies on interest rate parity and forward prices in currencies such US dollar, British Pound, Japanese Yen, European Euro and Singaporean dollar, studies on currencies in developing countries are not very encouraging.

This could be due to most of international trade being concentrated in the developed world and the magnitude of the volume simply outranks the analyst interest. It leaves us with an academic gap to exploit or analyse and see whether the parity condition is held in both sets of countries.

Ideally due to the sheer magnitude of analytical work carried out on currencies of developed countries, speculator interest and availability of liquidity, interest rate parity condition should hold in currencies of developed countries.
In the meanwhile it could be expected that currencies of developing countries will have deviations due to illiquidity as well as lack of interest, and in some cases anti market efficiency regulations.

In this paper I analyse currencies of United States, United Kingdom, Japan, European Union, Brazil, Russia, India and Sri Lanka on interest rate parity condition. Daily data are from 2011 to 2013, where data are available. For the countries where data begins from a different time scale, oldest data set has been used as the starting point.

2 RESEARCH PROBLEM

Global trade has increased in the past 30 years as it has never before. Peaceful environment that prevailed all over the world, except in a few countries, fuelled economic growth in the whole world as a general rule. Coupled with same, technological advancements in shipping, information technology and manufacturing created a boom in international trade.

The growth in international trade increased demand and supply for foreign currencies including currencies from developing markets. Further the increase in capital flow from developed nations to developing nations in the form of investments to facilitate outsourcing further strengthened the trade flow and demand for currencies in developing nations.

This made currencies the most demanded and supplied commodity in the world and accounted for a significant amount of trade in the financial markets all over the world.

This led to an integration of global financial markets, which can be termed as one of the most profound developments in the world economy in the last 30 years. This has led to national financial markets being more linked to each other than ever before. Capital and working capital flow from one country to another has become very efficient and smooth. Trade flows have become smooth and markets have gradually become more efficient.

This also means that arbitrage opportunities should also reduce in all markets significantly over time. As markets become more and more efficient and information of all markets become readily available to market participants arbitrage opportunities should fade away as all investors will react the same way on information that is available to them.

While this has been the normal scenario for developed markets, developing markets have been lagging behind on market efficiency. Most developing markets had fixed or managed exchange rate mechanisms for a long period of time. However the recent growth in international trade as well as integration on financial markets has made it difficult for governments to maintain fixed or managed rate regimes. Hence foreign exchange regimes have swiftly moved on to floating rate regimes all over the world, with arbitrageurs and speculators being aggressive on any disparity available in the market.

This means that interest rate parity condition should hold in currencies of both developed countries as well as currencies of developing countries.

The main purpose of this paper is to evaluate whether this parity condition holds in currencies of eight different countries. I select four currencies from developed countries and four currencies from developing countries. Using historical data, I attempt to analyse whether deviations from parity condition exists and if so how persistent such deviations are.

Once the deviations and persistence of such deviations are analysed, I attempt to predict the pricing error for the next 10 days. I will use 10 data points of out of sample data to compare against the actual to evaluate strength of the predictability of each currency.

Further as a supplementary study, I will also test whether interest rate parity condition can accurately forecast the future spot exchange rates. I will test the forward rate computed by interest rate parity condition against the respective spot rate of the tenure, in order to analyse whether the forward rate has materialised as a spot rate in a future date.

This paper is organized as follows. Section 3 reviews the applicable academia on foreign exchange markets. Section 4 reviews the current literature available in the topic, with interest in Liquidity, Market efficiency, Risk Premium, Political Issues and transaction costs applicable to the market. My data and the sources of data are presented in section 5. Section 6 discusses the research methods for all four analyses and the mechanisms used. The analytical results of the paper are presented in section 7. Section 8 provides a discussion of my results and section 9 suggests further possible research areas on the topic.

3 THEORITCAL REVIEW

There are two main theories that have been put forward to explain the determinants of forward prices of currencies. One, which is also discussed above is named the Interest rate parity theory and is based on the Interest rate differential between two currencies. The other is based on the purchasing power of two domestic economies. Both theories are discussed below in detail.

3.1 Interest Rate Parity Theory

Interest rate parity theory suggests that interest rate differential of two countries or the ability of an investor to deposit funds into a particular currency and earn interest instead of entering into a forward contract defines the forward price between two currencies.

In other words, the theory states that at equilibrium the forward price of a currency is equal to the interest rate differential between the domestic currency and the foreign currency. In formulae terms this follows,

$$\frac{Fwd - Spt}{Spt} = \frac{Ird - Irf}{1 + Irf}$$

Where Fwd and Spt are forward and spot exchange rates respectively, Ird and Irf represent domestic interest rate and foreign exchange rates. For this condition to hold, the tenures of both securities have to be the same. It is said that if the above condition holds, there will be no arbitrage opportunities available for speculators in the foreign exchange market. This could be further explained via the following diagram.

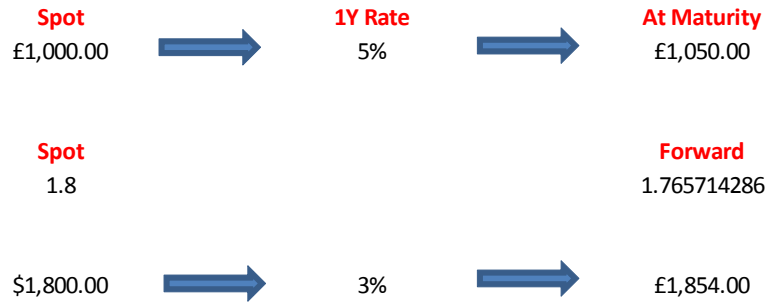


Figure 1: Illustration of Interest Rate Differential

Theory states that if the parity condition holds perfectly, the currency with a higher domestic interest rate should depreciate over the period. As a result, an investor should be indifferent to investing in any of the currencies, as his ultimate return would be the same.

Interest rate parity is studied with two conditions, Covered Interest Rate parity, and Uncovered Interest Rate parity.

Covered Interest Rate parity argues that relationship between two interest rates and the spot and forward prices of two currencies are in equilibrium, hence they prevent any interest arbitrage opportunities to market participants. Which means the forward exchange rate will react to any possible deviation from the equilibrium price eliminating arbitrage opportunities. Explained more simply, it argues that if one currency has a higher interest rate, the additional yield an investor may enjoy by converting at spot and the movement in forward rate will clear off investing in the currency.

Uncovered Interest Rate Parity argues that interest differences in two currencies are equal to the expected future foreign exchange rate differences between the two currencies. In other words, if one currency is expected to depreciate in the future, an investor will at least require the interest rate differential amount as the premium in order to have financial motivation to invest in it.

However, these parity conditions are challenged with factors associated with the efficiency of the foreign exchange market. An efficient market is where the price reflects all information available to the public. As such, no trader would have the opportunity to make an extra profit at the same level of risk acceptance as others. Factors such as information asymmetry, transaction costs, government intervention in the market or simply not allowing the currency to free float create market mispricing, rendering the interest rate parity theory invalid.

Above challenges are factors that make the topic more interesting. It could be safely argued that most free-floating currencies are informationally efficient while the contrary could be said for managed rate currencies. If the argument would be to hold, parity condition should hold for free-floating countries, while the condition should fail for managed rate currencies.

3.2 Purchasing Power Parity Theory

Purchasing power parity theory assumes that the exchange rate between the domestic currency and the foreign currency is determined based on the purchasing power of the two economies concerned.

In other words, a good should carry the same price in both economies once accounted for the exchange rate. Exchange rate is the dependant variable and will adjust accordingly to the prices of goods and services between two countries. This argument is referred to as the Law of one price. Law of one-price states that price of a good should be same in any currency once accounted for the exchange rate.

In the event the argument does not hold, one could buy the good from another country, other than the domestic country and make an arbitrage profit or saving. Such action will reduce the demand for domestic goods and increase the demand for foreign goods. This will to lead to an increase in price pressure on foreign goods and a decrease in price pressure on domestic goods, leading to an increase in price in foreign goods and decrease in price in domestic goods. Further, it will also put downward pressure on domestic currency exchange rate until the arbitrage opportunity disappears.

As such, this theory assumes that exchange rate between two economies are based on prices of goods and services in two different countries. Purchasing power parity theory uses inflation rates between two countries to arrive at the forward price of a currency. It is difficult to find comparable baskets of goods to compare purchasing power across countries; hence, the general price level of the economy is used. Further PPP is also more complicated since countries not only differ in price level but also with quantity and quality of goods as well. As such, a comparison is made for the cost of baskets of goods and services using a price index.

However similar to Interest rate parity theory, Purchasing power parity theory also has its own challenges. It is argued that even though prices of goods between two countries are significantly different, it will not be adjusted via exchange rate due to the existence of transaction costs, taxes, shipping costs or due to government regulations.

Transaction costs will simply eradicate the arbitrage opportunity on its own and it will not be economically worthwhile to import from a foreign country. Taxes and Shipping costs will also have a similar effect, while government regulations might simply prohibit an investor from importing the good. These pose significant challenges to the validity of Purchasing power parity theory.

4 LITEREATURE REVIEW

There have been extensive literature coverage on foreign exchange markets of developed countries, However literature on same, with regards to developing markets are limited.

However the theoretical backgrounds of developed markets are also applicable to developing markets. Hence the literature review relates the concepts to both developed markets as well as developing markets.

4.1 Efficiency of Forward Foreign Exchange Markets

An efficient market is where prices reflect all available information to participants of the market. In such a market it is not possible for an individual to make abnormal profits or beat the market on average, as all participants of the market will react to the same set of information in the same way.

The foreign exchange market is also expected to be an efficient market. Similar to any other market we expect the participants of the foreign exchange markets to be rational decision makers. Which means it is expected that participants of foreign exchange markets would use all available information to maximize their wealth.

Such behaviour will lead to a random walk in prices in foreign exchange markets. As new information on assets arrive randomly and independent of each other, participants of markets will also react to such information as and when they reach market independently. This forces prices of currencies to follow a random walk as well.

Further we also expect participants of foreign exchange markets to be risk neutral. This is due to the fact that we expect the gain from holding on to one currency to be offset from the opportunity cost of holding on to another.

4.2 Testing "Random Walk" of Forward Foreign Exchange Markets

In his paper "Speculative Prices as Random Walks", William Poole (1967) tests the efficiency of foreign exchange markets. He uses data from Argentina, Belgium, Canada, France, Italy, Japan, Norway, Sweden and United Kingdom from April 1919 onwards. He carries out three statistical tests of serial correlation; Variance time function and Alexander's filter analysis to evaluate whether random walk theory holds.

He finds that all three statistical tests fail to establish random walks in foreign exchange markets. All three tests find positive serial correlation, establishing non existence of random walks. He attributes this to transaction costs and positive inventory costs.

Further, Mark.P.Taylor in his paper "The Economics of Exchange Rates" (1995) explains that market efficiency in foreign exchange could be broken down to rational expectations and risk appetite. He argues that the aggregate investors in foreign exchange markets should be rational and risk neutral for market efficiency to hold. It is argued that if this condition holds, interest rate parity condition will hold.

He tests these arguments using a filter rule, where an investor buys a currency when it rises a certain percentage above the filter and sells the currency when it drops below the filter percentage. The argument is that, if the market is efficient and uncovered interest parity holds, a rational investor would not be able to make any profit from the transaction, since the interest costs of the transactions will wipe off the profits.

Taylor also articulates that efficiency of markets can also be tested via regression analysis. This is based on the fact that forward premium of any maturity is the difference between current forward premium and the current spot rate. If covered interest rate parity is to hold, the interest rate differential should be the same as the forward premium.

Since it is assumed that foreign exchange market participants are rational decision makers, their expectations are rational and the expected deviance from the exchange rate should only be by rational expectations forecast error.

Therefore, the uncovered interest rate parity condition could be tested via a regression as follows,

$$\Delta_{k\ St+1} = \alpha + \beta(f_t^{\ k} - S_t) + n_{\ t+k}$$

ft k = Logarithm of forward rate for maturity k
$n_{\ t+k}$ = Error term

It is argued that if participants are risk neutral and rational, intercept of the regression should be equal to one and the error term should be uncorrelated to information available at time t, or the error term should not have any influence on decisions made at time t.

It is found that it is difficult to establish that exchange rates follow a random walk. Researchers found that if exchange rates follow a random walk β should be close to zero, irrespective of the fact whether markets are efficient or not. However this is not the case. It is found that in practice, β is non zero almost all the time, rendering that foreign exchange markets are not always efficient and arbitrage opportunities are available most of the time.

This analysis carried out by Mark P. Taylor in 1995 is relatively recent and carries significant importance to this analysis. As Taylor's analysis mostly concentrates on currencies from developed world and it is found that there are deviations from parity condition in as recently as in 1995. While foreign exchange markets have advanced leaps and bounds in the last two decades it shows that deviations from parity conditions are possible for even currencies for more advanced economies.

4.3 Risk Premium of Forward Foreign Exchange Markets

Failure of efficient market hypothesis to explain forward premiums have led to other theories attempting to explain the forward foreign exchange markets. One such hypothesis is based on risk aversion and its subsequent risk premium.

In his paper Taylor also argues that efficient market hypothesis in foreign exchange markets fail due to a risk premium demanded by the participants of the market. It is argued that market participants are risk averse and they demand a higher return than the simple interest rate differential.

Hence the function of arbitrage is to ensure that interest cost of holding on to a foreign currency is equal to the expected depreciation plus a risk premium. Hence the parity condition could be restated as,

$$I_t - i_t = \Delta k\ St{+}1 + p_t$$

pt stands for the risk premium demanded by risk averse investors.

This means that equilibrium point will vary from currency to currency. Depending on the risk of the domestic economy and the risk appetite of the aggregate market participants, the parity condition equilibrium will be at different points for different currencies.

If the argument holds, ideally deviations in parity condition for currencies of developing countries should be larger than the deviations in parity condition for currencies of developed countries. This is a result of perceived risk of investing in developing countries being higher than the perceived risk of investing in developed markets.

4.4 Expectations of Forward Foreign Exchange Markets

Another hypothesis put forward in order to analyse foreign exchange market is the rational expectations hypothesis. This hypothesis explains that participants attach a small probability to large economic fluctuations that have effect on exchange rate movements. Such action will lead to a skewed distribution if expectations are rational. This idea is known as the "Peso Problem" and is initially put forward by Kenneth Rogoff (1979).

The "Peso Problem" could lead to deviations from parity condition in both sets of currencies. Hence, the impact of assigning unequal probabilities to economic events could lead to skewed distributions irrespective of the fact whether the currency is from a developed country or not.

However the impact on price of such action may deviate from currency to currency. A more liquid and a heavily traded currency with a narrow bid – offer spread may have a lower impact, while a relatively illiquid currency with a wide bid – offer spread may have a significant impact.

4.5 Political Risks of Forward Foreign Exchange Markets

It is generally argued that speculators prefer forward contracts to spot transactions. Even though the cost and price of the forward contract may be higher than the cost of a spot contract.

Explanation to this paradigm opens up a market imperfection. It is argued that this preference is fuelled by the fact that forward contracts do not require margin requirements like futures contracts and also because speculators could obtain greater leverage on forward contracts. This creates an arbitrage opportunity for speculators, creating an imbalance in demand and supply in forward markets for foreign exchange.

However such positions carry higher risks for the speculators, mainly in terms of political risk.

In his paper “Interest Rate Parity Theorem; A reinterpretation” Robert Z Aliber (1973) argues that political risk is a significant factor in exchange rate determination. The political stability of jurisdiction the currency is issued could lead to political risk, which can ultimately lead to exchange risk.

This could be due to an authority being interposed between investors and investments themselves or between imports and exports. He also argues that political risk does not necessarily need to be dramatic political events such as government change or civil war, but they could simply be, investors being concerned that a government might apply foreign exchange controls.

It is argued that forward contracts are entered into manage exchange rate risk, and the premium not explained by the interest rate differential in a forward contract accounts for political risk and any other risks that play a role in the underlying transaction of goods and services.

If the parity condition does not hold, it could be due to political risks, transaction costs or the tax differences in both jurisdictions. Hence market participants may not clear the difference. Therefore, it is argued that the posted exchange rate is not the effective exchange rate.

In the case where securities issued in different currencies carry the same political risk, the interest rate differentials should be able to forecast the forward rate accurately. In assets where the political risks are different, the difference in forward rates could be attributed to political risks, asp Robert Z Aliber.

4.6 Speculators and Arbitragers in FOREX market

In his paper “Interest Rate Parity Theorem; A reinterpretation” Robert Z Aliber also discusses the role of speculators and arbitragers in foreign exchange markets. It is stated that an investor who buys foreign currency at spot is exposed to both political risk and exchange rate risk, while an investor who buys foreign currency in the forward market is only exposed to exchange rate risk. An investor who buys foreign currency at spot and sells in forward will face political risk.

The said paper argues that interest rate cost is incurred by market participants in return for carrying both political risk and exchange rate risk. Any change in same will reflect the change in investor risk appetite.

It is argued that speculators attempt to make profits by capitalising on exchange rate movements via buying foreign exchange in the spot market or forward market. Further speculators also try to avoid political risk as argued by Aliber.

Role of arbitrageurs is to accept and manage political risk. For accepting and managing this, speculators will pay arbitragers. This is reflected in the forward premium speculators pay to obtain forward contracts. However the fact that speculators could obtain leverage at relative ease shows that political risk in forward markets are small.

However it could be argued that political risk may differ from country to country and that developing nations carry much greater political risk than that of developed countries. As such, an arbitrageur may require a much higher risk premium to enter into an arbitrage position in a country with high political risk. This means that the market may carry a mispricing for a longer period if the arbitragers feel that it is not worthwhile to accept the risk.

4.7 Minimum Interest Differential Required for Arbitrage

It is argued that according to interest rate parity theory, there is a minimum level of pricing disparity for the arbitrageurs to be interested in taking arbitrage positions. This is due to costs involved in taking arbitrage positions in foreign exchange markets.

One such cost of taking arbitrage positions is the cost of brokerage, which market participants have to bear as the broker's fee. Broker's fee is a mandatory payment to the broker which is calculated as a percentage of the total transaction value. It is argued that for a transaction to be profitable for an arbitrageur, the total yield of the transaction should exceed the broker's fee percentage.

Another such cost is the transfer pricing spread of the banks. Transfer pricing is where the total liquidity of a bank is managed centrally by the treasury department of a bank. When a retail department receives liquidity from a customer or a third party, that department will surrender funds to the treasury department, in return for which they will receive a payment to their P & L named “Value of funds”.

Similarly when there is a payment to be made or a loan to be disbursed, the retail department will borrow funds from the treasury and will disburse it out to the third party. For this borrowing, the retail department will make a payment to the treasury department named” Cost of funds”.

As per the paper written by P.A Einzig on “A Dynamic Theory of Foreign Exchange” (1961), the credits of value of funds and debits of cost of funds are charged and credited to the retail function with a margin.

He explains that such charges and credits are adjusted from the interbank lending rates. Value of funds is credited minus the treasury margin to the foreign exchange department, while cost of funds is debited plus the treasury margin to the retail function. As per P A Einzig, there is a significant spread between value of funds and cost of funds rates charged to the foreign exchange departments.

The significance of this spread is a factor that will interest arbitrageurs in foreign exchange markets. As the spread becomes larger it will discourage foreign exchange market participants to take arbitrage positions, while as the spread becomes thinner it will be a motivation for arbitrageurs to take positions.

In his paper “The Minimum Covered Interest Differential Needed for International Arbitrage Activity” Branson H William (1969) argues that the arbitrage spread available for arbitrageurs to make a risk free profit should be at least greater than the funding cost spread and brokerage cost put together. If not, arbitrageurs may not take arbitrage positions and the disparity will remain.

Consequently, it is argued that as the margin between cost of arbitrage and actual arbitrage spread increases positively, the fund flow to arbitrage activity will also increase and vice versa as the margin decreases.

Tsiang (1959) in his paper "The Theory of Forward Exchange and the Effects of Government Intervention in the Forward Exchange Market" argues that arbitragers will become reluctant to transfer spot liquid funds to a foreign destination after a certain point. Using this information Branson builds his model and estimates that the minimum covered arbitrage required in U.S – U.K market and U.S - Canada market is 0.18%.

Based on same, the validity of classical theory arbitrage, enforced as 0.18% is within the amount suggested by Keynes (0.5%) and 0.06% which is suggested by Einzig.

This margin may differ from one jurisdiction to another, especially since cost of brokerage and transfer pricing spreads are country specific. It would be safe to assume that countries with high interest rates will have high transfer pricing spreads in comparison to countries with low interest rates. As such, we can expect countries with high interest rates to have a higher spread than 0.18%.

4.8 Real Interest Rate Parity

In their working paper for the IMF, Manmohan Singh and Abhisek Banerjee (2006) test whether real interest rates of emerging markets converge with world interest rates in the long run and short run.

It is expected that as the world financial markets will integrate, capital flows become international instead of national. Thus arbitrage opportunities will reduce significantly. As the markets become more and more interdependent, it is expected that long run real interest rates of countries will converge. This phenomenon is known as the real interest rate parity hypothesis.

They use data from Argentina, Brazil, Bulgaria, Indonesia, Korea, Malaysia, Mexico, Pakistan, Poland, Singapore, South Africa, Sri Lanka, Thailand and Turkey for this

test. It is expected that as improvements in fundaments and monetary policy management policies take place in these countries, real interest rates of these countries will converge with the world interest rates.

However they find that there are significant deviations from real interest rate parity in the short run and they assign such deviations to inflationary pressure of the domestic investors of the country. In addition, they also find that there is some convergence in the long run, even though it is not sufficient to hold the real interest rate parity condition.

This provides us with the interesting conclusion that arbitrage opportunities are still available in emerging markets.

4.9 Liquidity of Foreign Exchange Markets

A liquid market is where there are lot of buyers and sellers generating a significant amount of volume. The same is applicable to the foreign exchange market as well. A liquid foreign exchange market will offer minimum arbitrage opportunities and have very small Bid-Offer spreads.

For any asset market, the provision of liquidity is of paramount importance. This is also applicable to forward exchange market of any currency. The level of liquidity available for the forward price of a currency may decide the amount of pricing error or the efficiency of the market. Liquid markets tend to have less volatility and low transaction costs as well.

Hence it is important to identify who are the liquidity providers and takers in the foreign exchange market are. The conventional belief is that market-making financial institutions, mainly commercial banks are the main liquidity providers to the foreign exchange market. However it should also be noted and accepted that non financial institutions and central banks also play a significant role.

In contrast to this belief, in their paper “Liquidity provision in the overnight market” by Geir Bjonnes and Dagfinn Rime (2005) find that non-financial customers are the main source of liquidity in the long term foreign exchange market.

They find that restrictions on dealers have led to limited overnight positions of financial institutions, while non-financial organizations fill that gap. Hence they conclude that market making banks provide intraday liquidity, while long term liquidity is provided by non-financial participants of the market.

This could be an interesting phenomenon, as general conception is that currencies that have managed-rate regimes are relatively less liquid than the free floating currencies. This also could be due to managed rate currencies being currencies of developing countries and the development of non financial participants in the market are still ongoing, in comparison to developed countries, which have free floating regimes. Hence the inflow of transaction volume from non-financial institutions to the forex market may be smaller than that of developed countries. This could also be a reason for the relative illiquidity in those currencies.

5 SAMPLE DATA FOR RESEARCH

This paper attempts to analyse the following.

- Existence of forward exchange mispricing
- Persistence of forward exchange mispricing
- Predictability of forward exchange mispricing
- Interest rate parity condition accurately forecasts forward exchange rates.

In order to test this condition data from eight countries are selected and 3 month and 6 month tenures are used as the proxy.

Sample data set is two years of interest rate and exchange rate data of all eight countries, ending on 30th August 2013. Daily data is obtained from Bloomberg financials. However availability and type of data may differ from country to country, hence specifics are as explained below.

5.1 U.S Dollar (United States of America)

United States operates a free floating mechanism and the Federal Reserve is responsible for setting short term interest rates. Tools used by the Federal Reserve to intervene in the money market are buy/sell treasury securities, discount rate management and the reserve ratio adjustment. Interbank market is liquid and USD Libor rates are calculated based on average USD lending rates of banks.

Data for U.S Dollar is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

Us dollar will be used as the anchor currency to evaluate the forward rate valuation of each currency.

5.2 Rouble (Russia)

The bank of Russia manages the monetary policy of Russia. The bank of Russia manages the domestic interest rates via open market operations, acting as the lender of last resort and maintaining reserve requirements. Exchange rate regime is a managed float regime. However float is allowed only within a band of RUB 32.30 – 39.30 for a basket of USD and EURO. The basket consists of 0.45 Euros and 0.55 US dollars for each ruble.

Data for Rouble is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.3 Euro (European Union)

European Central Bank (ECB) and the national central banks manage the monetary policy for the European Union. Mission of the ECB is to ensure price stability and maintain the inflation rate around 2%. The ECB influences short term interest rates of the EURO via open market operations and maintains a floating exchange rate regime. Interbank market is liquid and EUR Libor rates are calculated based on average EUR lending rates of banks.

Data for EURO is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.4 Real (Brazil)

Brazil also follows an inflation targeting mechanism and the central bank manages interests via open market operations. However even though the exchange rate regime is a free floating mechanism, the central bank has intervened in the market via interest rates and foreign exchange reserves to control the exchange rate.

Data for REAL is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.5 Yen (Japan)

Japan operates a free floating mechanism and the bank of Japan is responsible for setting short term interest rates. Bank of Japan carries out open market operations, acts as lender of last resort and participates in repo and reverse repo transactions in order to manage interest rates. Interbank market is liquid and Yen Libor rates are calculated based on average Yen lending rates of banks.

Data for YEN is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.6 Indian Rupee (India)

Reserve Bank of India controls the monetary policy of India. In order to control the short term interest of Rupee, RBI carries out open market operations, sets repo and reverse repo rates, and sets statutory reserve ratio and cash reserve ratio. Indian rupee is subject to a managed float; where the RBI intervenes in the foreign exchange markets from time to time control the exchange rate. Further, the interbank market is not a liquid market; hence for the purpose of this analysis risk free security rates are used as interest rates.

Data for Indian rupee is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.7 British Pound (United Kingdom)

The United Kingdom operates a free floating mechanism and the monetary policy committee of Bank of England is responsible for setting short term interest rates. Bank of England follows an inflation targeting mechanism and the target inflation rate is 2%. Interbank market is liquid and GBP Libor rates are calculated based on average GBP lending rates of banks.

Data for British Pound is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

5.8 Sri Lankan Rupee (Sri Lanka)

Interest rates for Sri Lankan rupee are set by the Central Bank of Sri Lanka. The central bank sets the statutory reserve rate requirement, sets the repo and reverse repo rates, acts as the lender of last resort and carries out open market operations as well. However, as the interbank market is not liquid, government Treasury bill rates are used for the purpose of this analysis. Sri Lankan rupee has a free floating exchange rate mechanism. However the central bank intervenes in the foreign exchange market to control the exchange rate via currency swaps and Foreign exchange reserves.

Data for Sri Lankan rupee is obtained from Bloomberg financials and data starts from 29th July 2011 and continues on a daily basis till 30th August 2013.

6 METHODOLOGY

This paper carries out analyses to establish whether forward market mispricing is persistent in managed rate currencies as well as free floating currencies. USD is used as the anchor currency for all currencies and checked against all other seven currencies in the analysis. The process of statistical analysis could be broken down into four major categories, namely,

- Mispricing calculation
- Evaluating the persistence of mispricing
- Testing the predictability of mispricing
- Testing whether Interest rate parity condition can predict the future spot rate.

6.1 Mispricing Calculation

I obtain interest rate data of all eight currencies from Bloomberg. Exchange rate data including spot and forward pips are obtained via Reuters. Using this information I proceed to calculate the forward mispricing or the arbitrage opportunity for each currency against the dollar.

I add 3 month and 6 month percentage in points (pips) to the spot rates of all currencies to arrive at the 3 month and 6 month forward rates of the market. In order to arrive at the 3 month and 6 month fundamental price of forward contracts, I use the interest rate data obtained from Bloomberg. Interest rate data is used in the interest rate parity condition formula as below,

$$F = S\,\frac{1 + id}{1 + if}$$

Once the fundamental forward price for 3 month and 6 month forward rates are calculated, I compare the fundamental forward price with the market forward price for respective tenors to evaluate the existence of mispricing or arbitrage opportunities. I consider the fundamental price as the base and if the market price is lower than the fundamental price, the mispricing will be shown as positive, while if

the market price is higher than the fundamental price, the mispricing will be shown as negative.

6.2 Evaluating the persistence of mispricing

Persistence testing is done via breaking down the time series data into monthly samples. I break the data into 30 day interval samples. Once the 30 day samples are identified, I calculate mean and standard deviation of the mispricing for each sample.

The mean figure for each sample data is compared with the mean mispricing value of other sets of samples. Further, once the mean values are calculated I calculate the variance and standard deviation of the mean values to establish the volatility of the mean figures.

In the event the mean figure has minimum volatility and does not change over time or if the mean figure has an upward trend, I establish that the mispricing is persistent. Further, if there is volatility in the mean figure or it simulates a downward trend, I conclude that the mispricing is not persistent and arbitrage opportunities are not available or are diminishing.

6.3 Testing the predictability of the mispricing

I use econometric models to analyse the time series data to test the predictability of mispricing. These models may include but are not limited to Autoregressive processes (AR) and Moving average regressions (MA).

I use the data of the time series as, in sample data, except for the last 10 data points. The last 10 data points will be used as out of sample data to test the accuracy of the model predictions. Strength and the accuracy of the prediction are tested using the R square method. R square measures the accuracy of a prediction taking into account the variation of the prediction from the actual and the variance of the observation from its mean.

6.4 Testing whether interest rate parity condition can predict the future spot rate.

Interest rate parity condition invariably predicts theoretically what the future spot rate should be. However the actual spot rate may vary depending on other economic and political factors that influence the spot rate.

In the last section of our analysis I attempt to evaluate whether the interest rate parity condition can accurately predict the future spot rate. For this purpose I run the following regression,

For 3 months;

$$\ln S_{t+90} = a + b\ln f_t + e_t$$

For 6 months;

$$\ln S_{t+180} = a + b\ln f_t + e_t$$

In the event a = 0 and the coefficient is equal to 1, it is concluded that interest rate parity could accurately forecast the future spot rate.

7 ANALYTICAL REVIEW

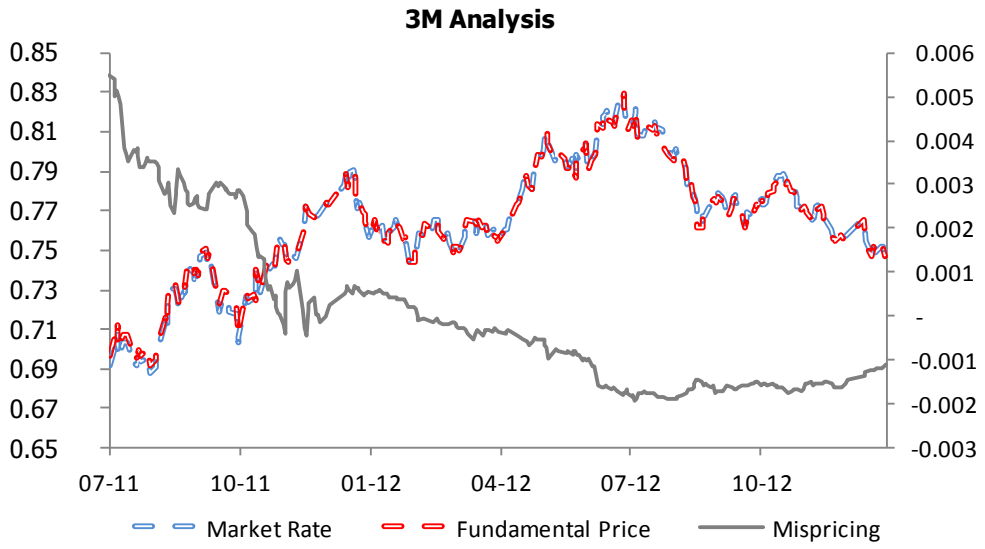
This section will concentrate on the analysis of the data for each currency and will also serve as the prelude to the conclusion. Analysis of each currency under each subsection will be discussed with an introduction to the results. I concentrate on each research topic and will present my findings for each currency under the respective research problem.

7.1 Market mispricing of forward rates

It is found that all currencies, both free floating currencies as well as managed rate currencies have daily mispricing of forward rates. However the magnitude of the arbitrage opportunity is significantly different from free floating currencies to managed rate currencies. The arbitrage opportunity in free floating currencies is extremely low; hence any profit taking from such mispricing would lead to losses once the transaction costs are accounted for. However the managed rate currencies offer lucrative arbitrage opportunities. Analysis of each currency's mispricing is as below;

- **EURO**

  Forward rates for European euro for US dollar do not deviate significantly from its fundamental price. This could be observed in both 3 month rates as well as 6 month rates. However rates for both tenors do deviate from the fundamental rate at all data points observed.



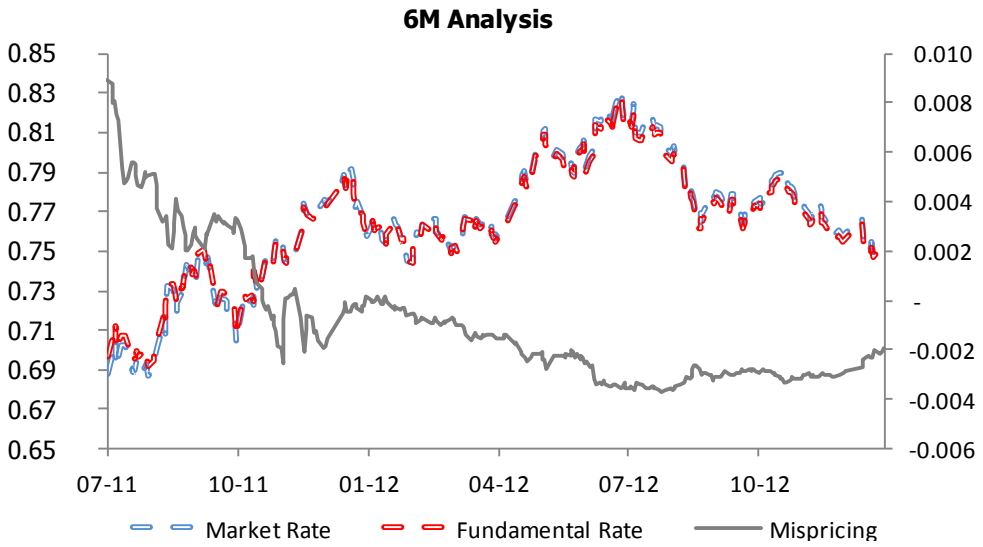


Figure 02 & 03: Movement of 3 month and 6 month mispricing for EUR

The absolute mispricing value is shown in the secondary axis, while the market forward rate and the fundamental forward rates are shown in the blue and red dashed lines respectively.

Both 3 month and 6 month forward rates exhibit minimum mispricing, as could be observed by the mispricing line. The line never reached +/- 0.01 marks, making it impossible for any arbitrage activity within interest rate and foreign exchange market. It could also be observed that both 6M and 3M forward rates move in the same trend, cancelling out any other arbitrage opportunities between the rates.

Further it could also be observed that as the global economy recover from the subprime mortgage crisis and becomes steadier the mispricing of forward rates gradually becomes thinner and thinner. Mispricing in both tenors, which is slightly lower than 0.01 start to close up on zero by September 2013. I attribute this to the gradual stabilization of economies involving both currencies.

- **British Pound**

British pound, another free floating currency similar to EURO also exhibit minimum mispricing discrepancies in forward rates. Similar to EUR, GBP also exhibits small mispricing within the rates which cannot be exploited for arbitrage purposes. Interestingly, even the minimum mispricing exhibited in GBP/USD is also smaller than the slight mispricing seen in EUR/USD rates.

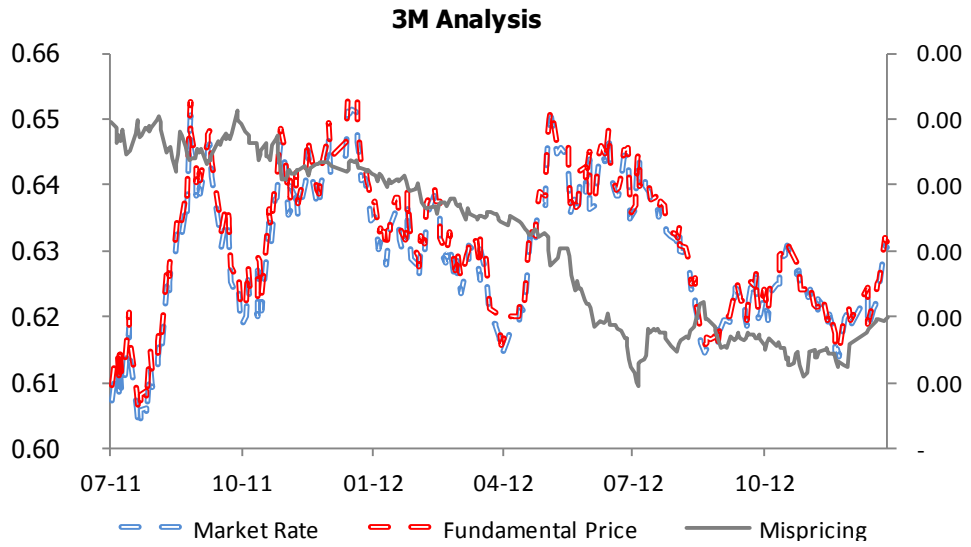


Figure 04: Movement of 3 month mispricing for GBP

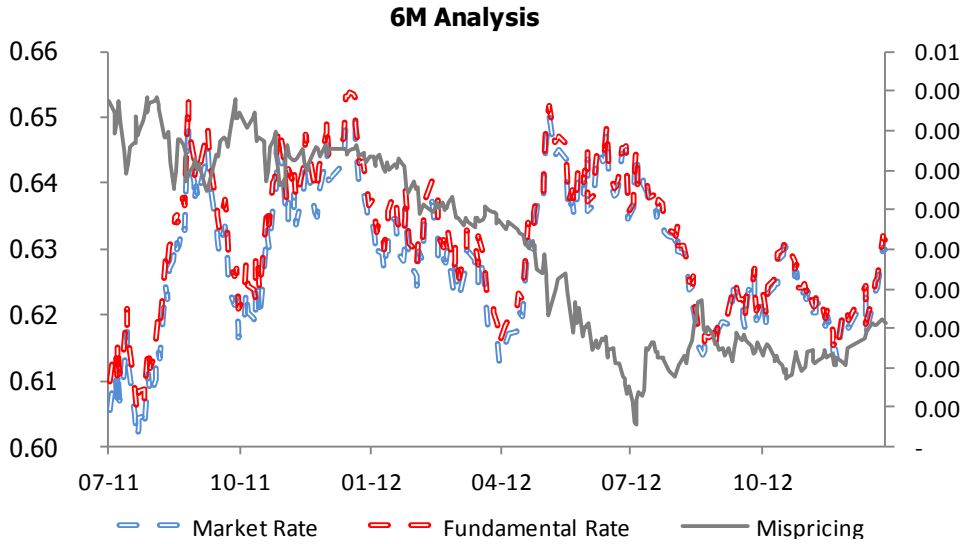


Figure 05: Movement of 6 month mispricing for GBP

British pound also exhibits similar characteristics to the EUR. While the mispricing is evident, mispricing values are extremely small, making it impossible to be exploited for any arbitrage opportunities. Further it also exhibits the trend of closing onto zero as the economies become more stable.

- **Japanese Yen**

Japanese Yen, the only free floating Asian currency featured in this analysis also reflects strong fundamentals in pricing forward contracts. However as the forward prices fluctuate more than the EUR and GBP forwards, small mispricing between the market prices and fundamental prices remain during the period in purview.

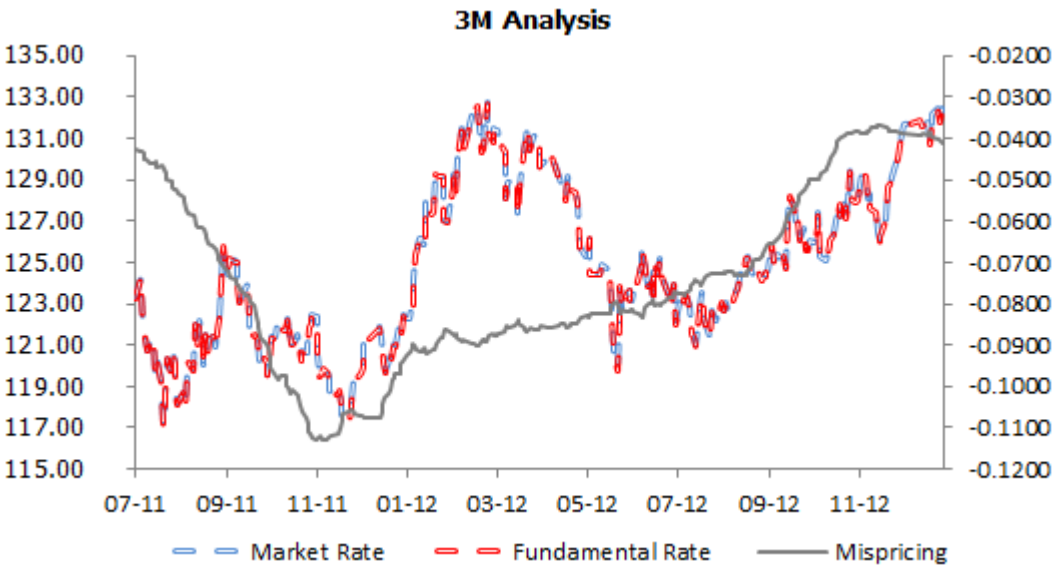


Figure 06: Movement of 3 month mispricing for YEN

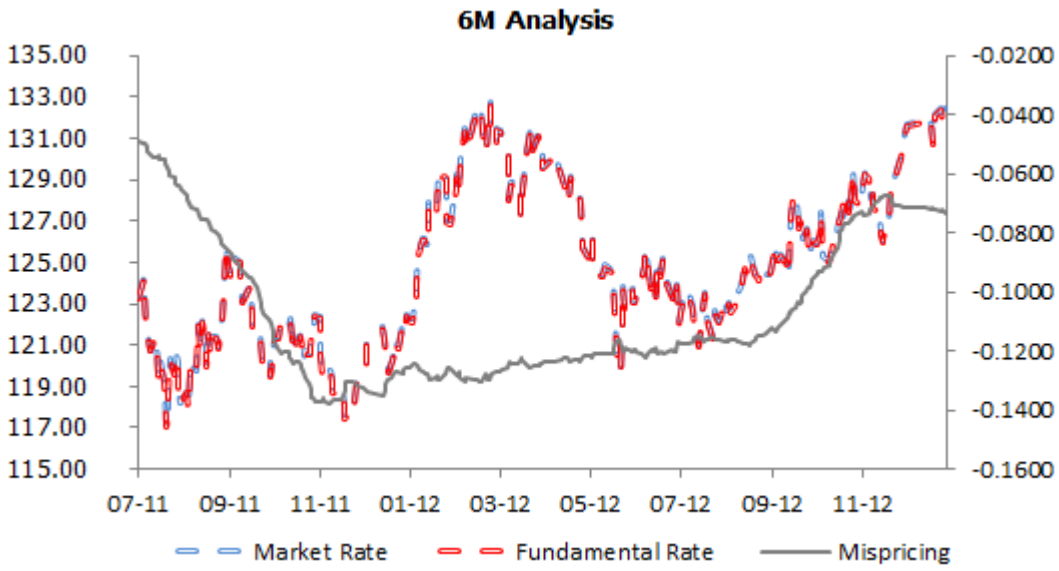


Figure 07: Movement of 6 month mispricing for YEN

Yen also exhibits characteristics that are found in other free floating currencies. Both 3 month and 6 month rates follow the same trend and any arbitrage opportunities are virtually non existent. Similar to both EUR and GBP, mispricing becomes thinner as the global economy recovers.

- **Sri Lankan Rupee**

Sri Lankan rupee is a managed rate currency. Currency is managed by the monetary authority of the country and the exchange rate is intervened upon. Central bank of Sri Lanka intervenes in the foreign exchange market via currency swaps and outright sales and purchases of U.S Dollars to maintain the exchange rate at its desired level.

Over the past two years Sri Lankan rupee has had significant arbitrage opportunities in both 3 month and 6 month rates. Both tenors exhibit mispricing of approximately 4-4.5 rupees in certain days. It is seen that as the forward rates increase or as rupee depreciates against the dollar, the mispricing or the arbitrage opportunity also widens.

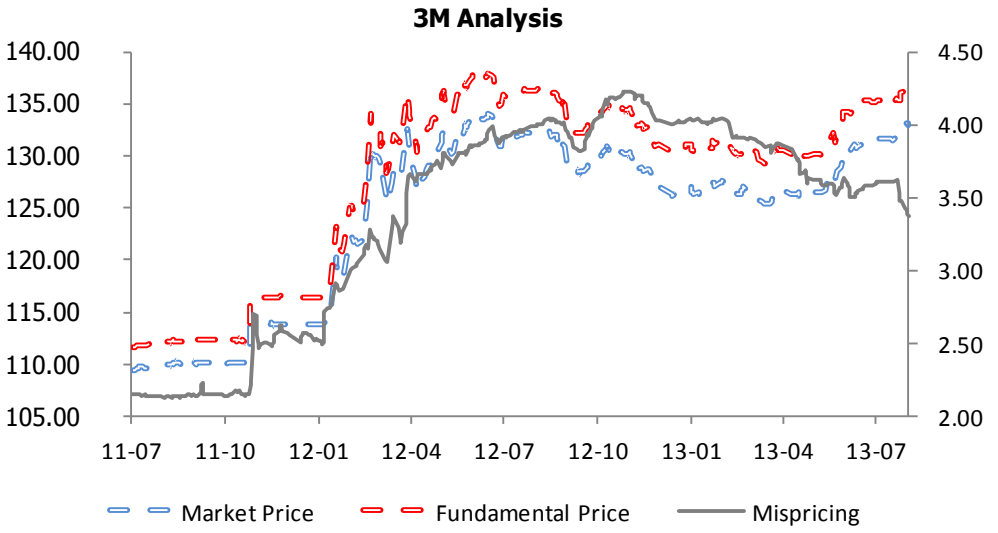


Figure 08: Movement of 3 month mispricing for LKR

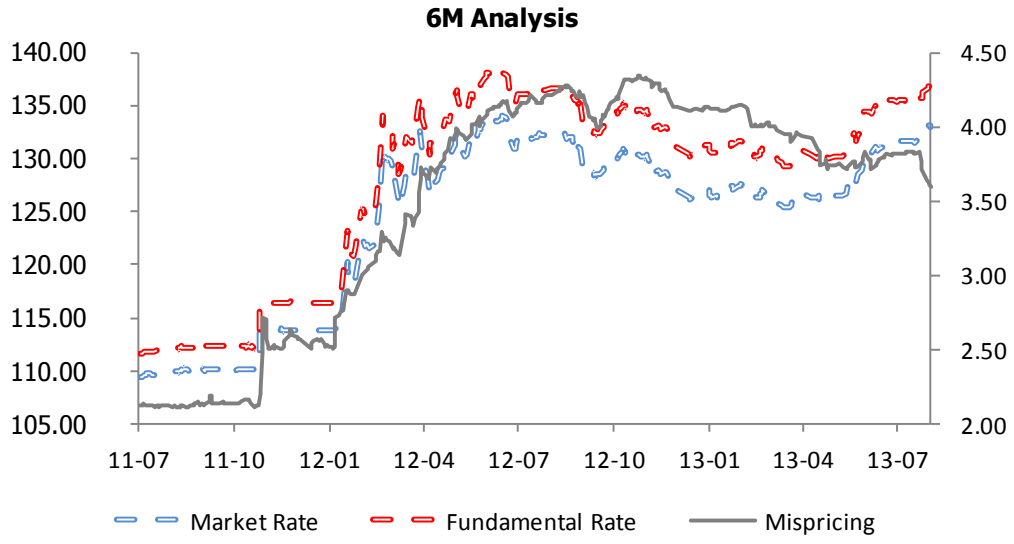


Figure 09: Movement of 6 month mispricing for LKR

As it could be observed from both charts, the fundamental forward price is higher than the market price. This is a result of market intervention by the regulator to keep the exchange rate suppressed, rather than what the interest rates may suggest. However this could also suggest the inflow of capital to the country and an increase of domestic interest rates in the same period. Increase in domestic rates push the fundamental forward price up, while inflow of capital and increase in exports push the market

PIPS down leading to a gap between the fundamental rate and market forward rate.

- **Russian Rouble**

Russia has a managed exchange rate mechanism. However, as discussed earlier, float is managed within a range by the monetary authority of Russia. The Rouble is allowed to float within a band of RUB 32.30 – 39.30 for a basket of USD and EURO. The basket consists of 0.45 Euros and 0.55 US dollars for each ruble.

The forward rate for the Rouble also hovers around the same range. The maximum 3 month rate for Rouble for the period in concern is approximately 34 for both market and fundamental rates, while the minimum for both is approximately 28. Minimum and maximum rates for both market and fundamental rates 6 months also are approximately same for the Russian Rouble.

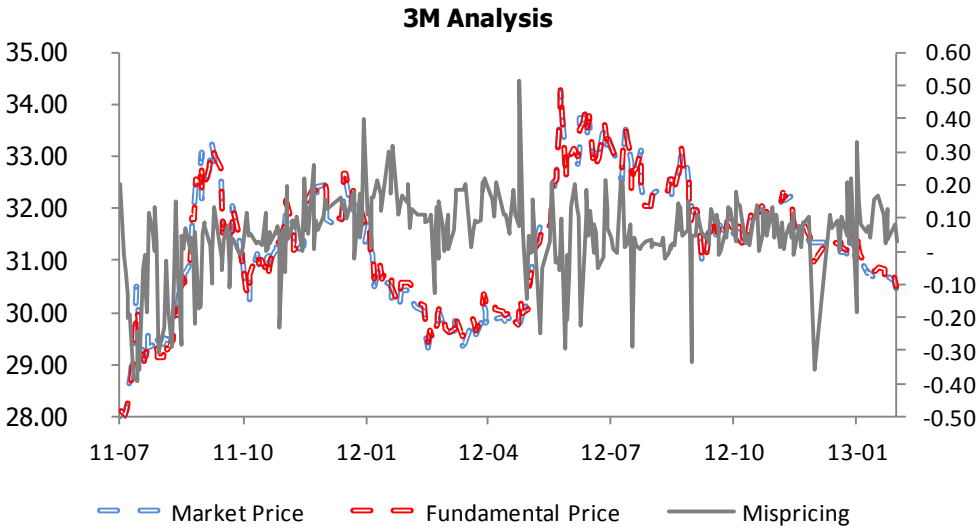


Figure 10: Movement of 3 month mispricing for RUB

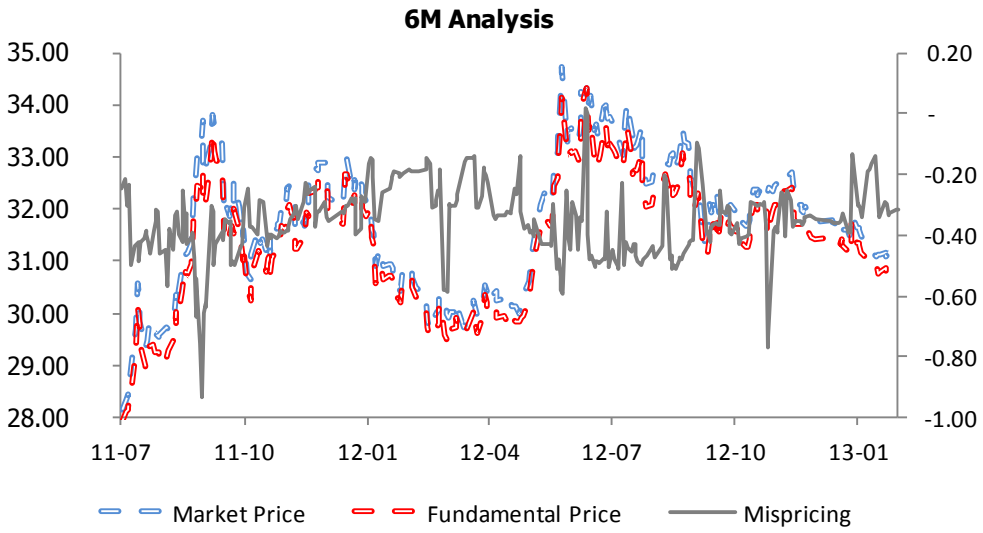


Figure 11: Movement of 6 month mispricing for RUB

Russian Rouble is a managed rate currency; it exhibits mispricing and arbitrage opportunities in both 3 month and 6 month markets. Further, the existences of arbitrage opportunities are significantly volatile as well.

Mispricing for 3 month rate varies from 0.51 (where fundamental price is high) to -0.39 (where market pips are high), while Mispricing for 6 month rate varies from 0.02 (where fundamental price is high) to -0.93.

Even though both the 3 month and 6 month forward rates follow the same trend, mispricing of contracts follow different trends from each other. While the 3 month rate is almost equally distributed between market rates being high Vs fundamental rate being high, 6 month rate is almost dominated by the market rate being higher than the fundamental price.

The higher pips in 6 month tenor could be attributed to the political uncertainty in the Russian economy, where investors and traders are uneasy about the currency's stability in the longer horizon. This leads to higher demand in forwards in the 6 month tenor. This could also be seen to a lower extent in the 3 month tenor.

- **Brazilian Real**

Similar to the Russian Rouble, Brazilian Real is also a managed rate currency. Meanwhile, unlike the Russian Rouble there is no stipulated band that the currency could operate within. Instead, the monetary authority of the country intervenes in the foreign exchange market as it sees fit to manage domestic inflation and interest rates.

Given the nature of the intervention by the authorities, currency exhibits mispricing and arbitrage opportunities in both 3 month and 6 month markets. Further, the existences of arbitrage opportunities are also significantly volatile.

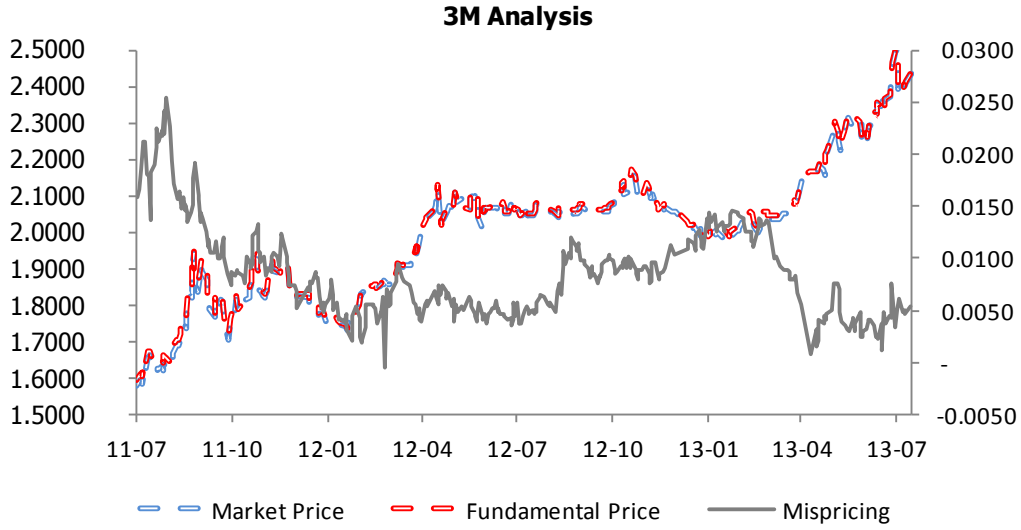


Figure 12: Movement of 3 month mispricing for BRL

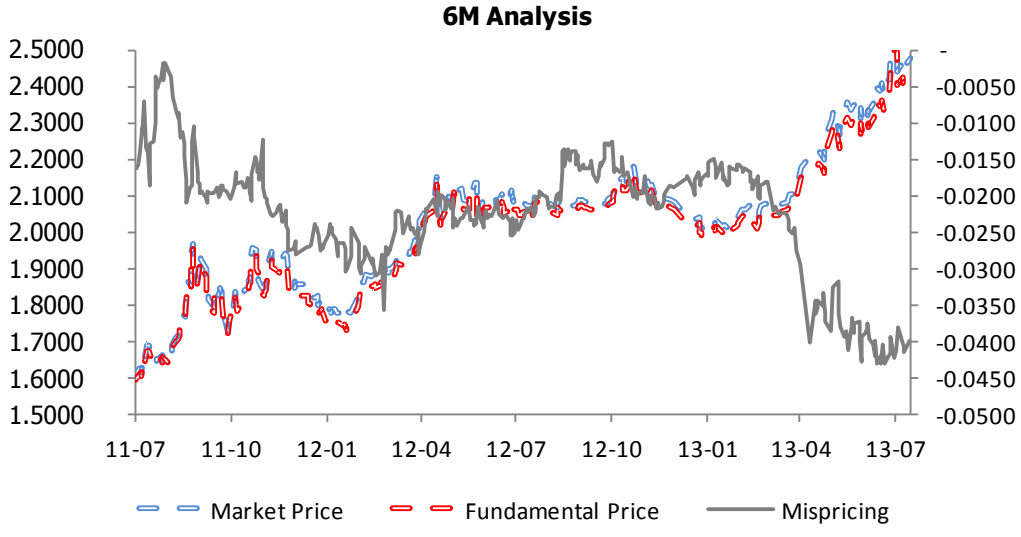


Figure 13: Movement of 6 month mispricing for BRL

- **Indian Rupee**

Exchange rate of the Indian rupee is plagued with an illiquid interbank market for interest rates as well exchange rates. Further, the Reserve Bank of India intervenes in the foreign exchange market to maintain the exchange rates at its desired level.

On the one hand, it is understood that the exchange rate is managed in order to protect the export industries of the economy. On the other hand, such management has resulted in forward mispricing in both 3 month as well as 6 month tenors.

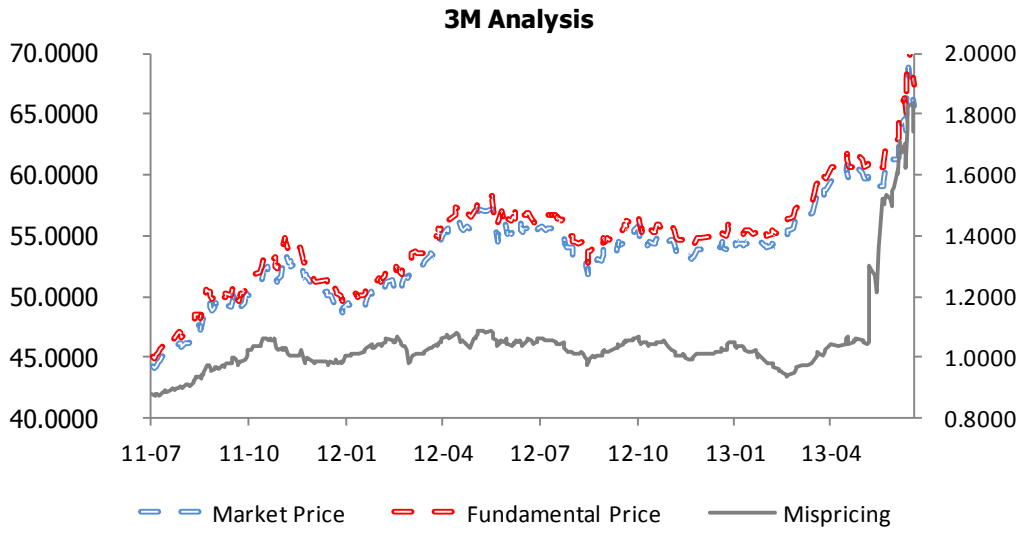


Figure 14: Movement of 3 month mispricing for INR

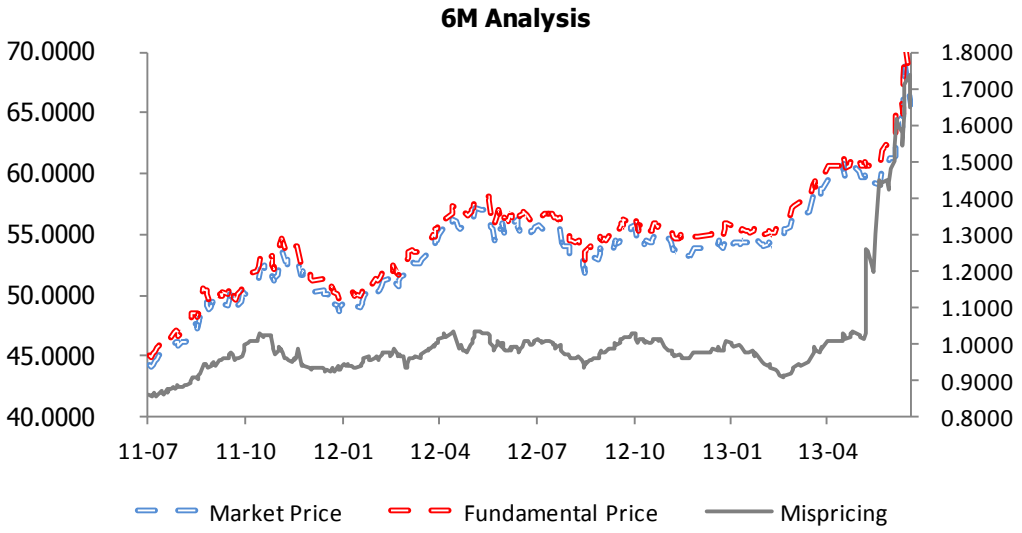


Figure 15: Movement of 6 month mispricing for INR

It could also be observed that the Indian Rupee depreciates against the US dollar over the period analysed. Such deprecation also results in an increase in arbitrage spread in both tenors.

7.2 Persistence of Mispricing Analysis

In the previous section I analyse the existence of arbitrage opportunities in both free floating currencies as well managed rate currencies. It is found that arbitrage opportunities exist in both sets of currencies.

In this section I analyse whether the existence or the non existence of such arbitrage opportunities are persistent and stable. For this purpose I group the mispricing data of each month and look at the mean mispricing figures of each group. Test is to evaluate whether the mean mispricing figure of each group is not significantly different from the rest.

- **EURO**

  It is quite clear that the EURO does not present any arbitrage opportunities to arbitrageurs in terms of forward mispricing. The non existence of arbitrage opportunities is also persistent through out the period in concern. The monthly mean arbitrage figure moves within a range of 0.005 to -0.003, making it impossible for any arbitrage activity.

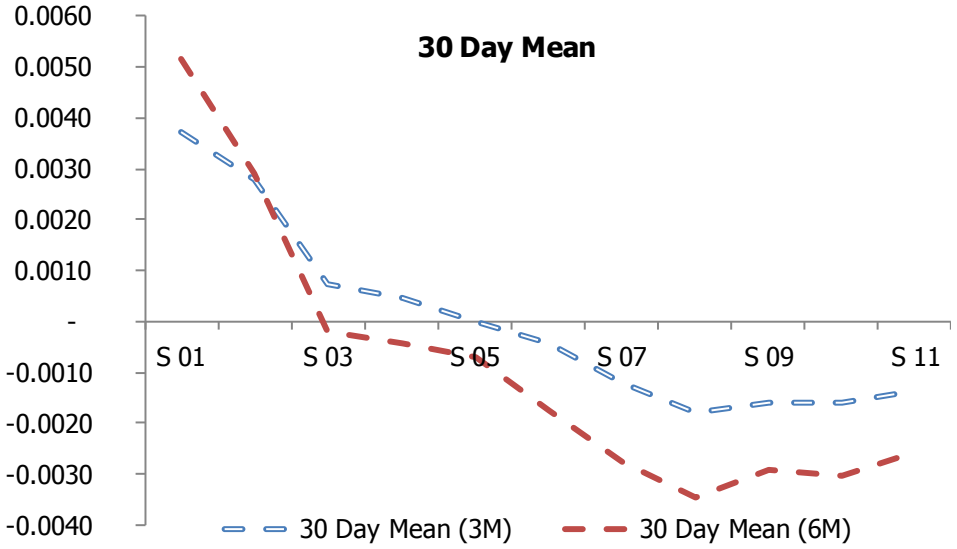


Figure 16: Range of mispricing Movement for EUR

An analysis of the basic statistics of the data series also shows that nonexistence or the stability of forward rates are prevalent and exhibited low volatility.

Table 1: Persistence Statistics for EUR

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	-0.002	0.004	-0.0003	0.002	0.84	-0.755
6 Month	-0.003	0.005	-0.0009	0.003	1.032	-0.265

Means of both rates show extremely low mispricing, while standard deviation is also very low, indicating that the volatility of the distribution is also low.

However skewness of both distributions is close to one, indicating that the distribution is more positively skewed and is not evenly distributed. This means that whenever arbitrage opportunities do arise they arrise due to the fundamental forward rate being lower than the market rate. This also means that the arbitrageur should take short EUR/USD forward positions in order to benefit from the mispricing.

Kurtoses for both the distributions are also in the negative range, indicating that the distribution is more centered around its mean. A further indication of the strength of the non availability of any arbitrage opportunities in forward pricing for EUR/USD pair.

- **British Pound**

British pound also did not yield any ground to arbitrageurs in the forward exchange market. Market efficiency is also seen persistent during the period in concern. Any mispricing during the period moved within a range of 0.007 to 0.04 for forward rates of both tenors.

Mean of both rates are close zero and standard deviation is 0.001 exhibiting very low volatility. It showcases the efficiency of the market and the persistence of the same as well.

Table 2: Persistence Statistics for GBP

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	0.0007	0.002	0.001	0.0006	-0.0321	-1.943
6 Month	0.001	0.004	0.002	0.001	-0.022	-1.987

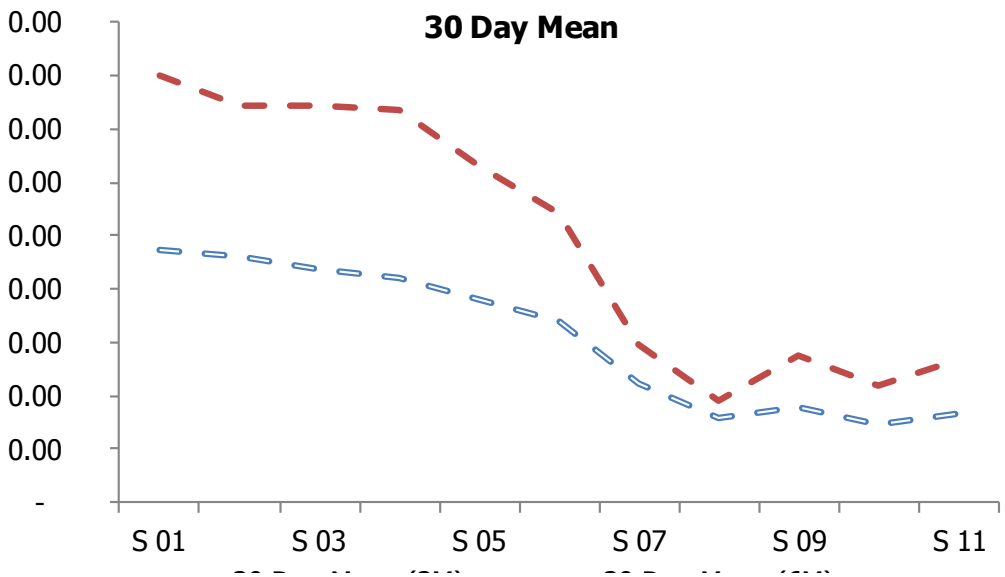


Figure 17: Range of mispricing Movement for GBP

Skewness for both tenors is also close zero, indicating that the distribution is more evenly spread. This means that in the event there are arbitrage opportunities, it could occur on either side of the currency.

Similar to EUR, GBP also exhibits negative kurtosis, indicating the distribution is centered around the mean, which is close zero, highlighted via the negative kurtosis as well.

- **Japanese Yen**

Unlike EUR and GBP, market efficiency is not persistent for JPY. The mean Market price for a 3 month forward exceeds the fundamental price by 0.11 yen in certain samples, while for 6 month contracts it even reached 0.13. However there are also samples where mean mispricing reached 0.04, signifying that the market may reach efficiency as well.

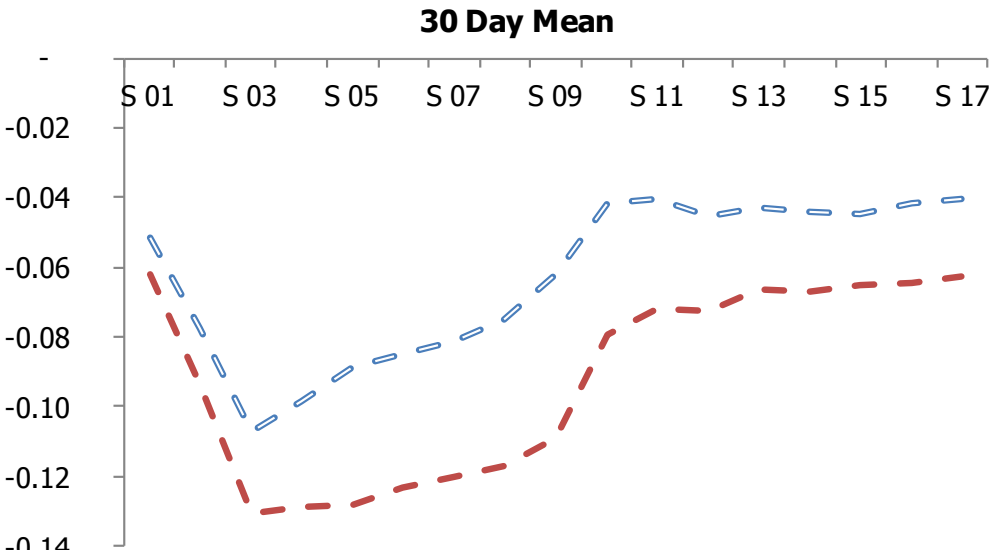


Figure 18: Range of mispricing Movement for YEN

As could be observed from the chart, market efficiency is not persistent right though out the period observed for JPY/USD in both 6M and 3M tenors. Mispricing for both tenors varies within a range of -0.13 and -0.04.

Table 3: Persistence Statistics for YEN

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	-0.107	-0.04	-0.06	0.023	-0.496	-1.383
6 Month	-0.13	-0.06	-0.0918	0.028	-0.246	-1.8358

Standard deviations for both the rates are also relatively higher than that of EUR and GBP, signifying volatility in the distribution. It could be interpreted that the market efficiency for Japanese Yen is not persistent and arbitrage opportunities may present itself for arbitrageurs in the market.

Negative skewness in the distribution suggests that when the arbitrage opportunities do occur, them occurring with values higher than the mean is a relatively high possibility.

The negative kurtosis indicates that the distribution is centered around the mean. While the kurtosis may suggest that possibilities of extreme outliers are rare, skewness and slightly high standard deviation suggest that the JPY/USD forward market is less efficient than GBP/USD or EUR/USD markets.

- **Sri Lankan Rupee**

Sri Lankan rupee offers significant arbitrage opportunities during the period in concern. The minimum mispricing amount during the period is approximately 2 rupees while the maximum is approximately 4 rupees.

This indicates that the market never reaches an efficient state during the period in concern.

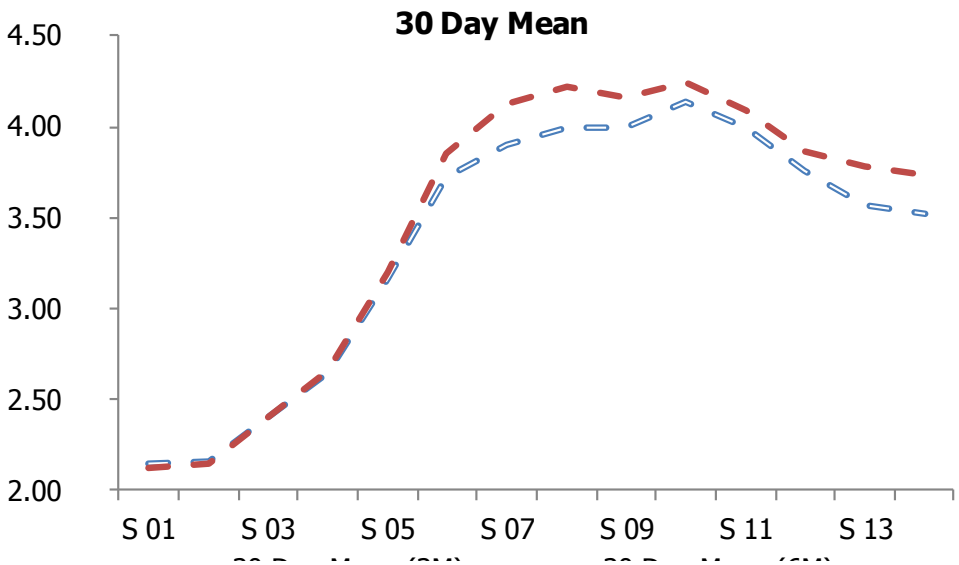


Figure 19: Range of mispricing Movement for LKR

As it could be observed, mispricing is always positive, which means that the fundamental forward rate is higher than the market forward rate at all times. This provides arbitrage opportunities in both interest rate market as well as foreign exchange market for arbitrageurs.

An arbitrageur could sell USD on spot and enter into a forward contract to buy USD in the forward market at a cheaper price and invest the LKRs today on government bills, creating a risk free profit. This could also be used as a tool to create LKR liquidity at a low price as well.

However, such actions put significant pressure on monetary authorities of managed rate currencies to maintain their exchange rates at their desired level.

Table 4: Persistence Statistics for LKR

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	2.14	4.13	3.36	0.72	-0.62	-1.34
6 Month	2.12	4.23	3.47	0.8	-0.64	-1.37

The mispricing indicates higher volatility. A standard deviation above 70% indicates that the distribution could not be close to the mean even though the mean is high. Further the distribution is negatively skewed with negative kurtosis. While negative kurtosis suggests that extreme outliers would be rare, negative skewness suggests that when mispricing occurs, it being higher than the mean is a relative probability.

All this indicate that the LKR/USD has been inefficient in the period concerned. Further such inefficiency has been persistent, creating opportunities for arbitrageurs.

- **Russian Rouble**

Russian Rouble also exhibits mispricing in both 3 month and 6 month rates. However, the arbitrage spread in 6 month rates are much higher than the 3 month spread.

While the 3 month rates have a minimum of -0.101 and a maximum of 0.153, the 6 month rates have a minimum of -0.464 and a maximum of -0.262.

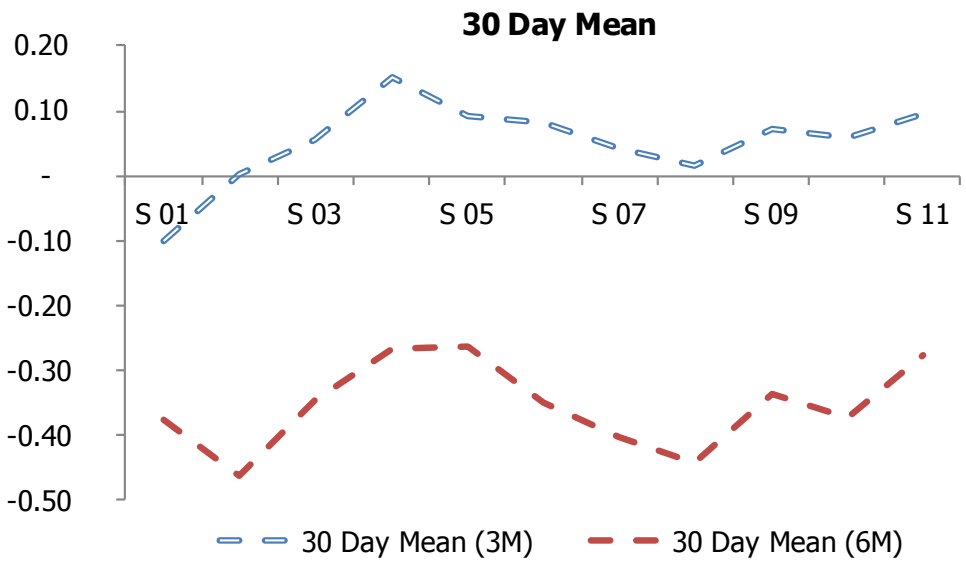


Figure 20: Range of mispricing Movement for RUB

Table 5: Persistence Statistics for RUB

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	-0.101	0.153	0.051	0.064	-0.833	0.412
6 Month	-0.464	-0.262	-0.354	0.066	-0.066	5.492

The 6 month rates for Rouble exhibit a higher mean and almost the same standard deviation of the 3 month rate. This is an indication that higher mispricing is persistent with low volatility. Low skewness also suggests that the distribution is closer to a normal distribution. However kurtosis for 6 month rate is much higher, which means that the distribution has fatter tails. Fatter tails in the distribution is an indication that big positive or negative returns could occur in the distribution.

- **Brazilian Real**

Real is also a managed rate currency that has mispricing in both 3 month as well as 6 month rates.

However, similar to the Russian Rouble, 6 month rates exhibit more mispricing than the 3 month rates. Three month rates have a range of 0.02, while the 6 month rates have a range of 0.03.

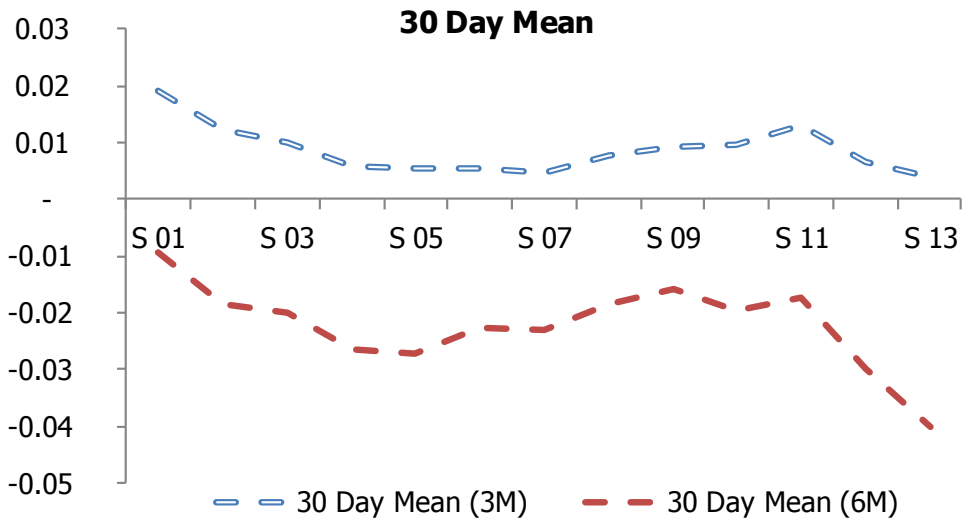


Table 6: Persistence Statistics for BRL

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	0.004	0.019	0.008	0.004	0.977	0.127
6 Month	-0.04	-0.009	-0.022	0.007	-0.652	0.166

Both rates exhibit low standard deviations, indicating that the inefficiency in the market is persistent as well. It should also be noted that the Brazilian Real mispricing is much less than the mispricing in other managed rate currencies that we have discussed so far.

Mean mispricing of both rates are significantly low, with 3 month rate being at 0.008, while the 6 month rate is at -0.022.

- **Indian Rupee**

Given the illiquid nature of the interbank market it is expected that the mispricing is persistent in the forward market for Indian rupee. The mean mispricing for all groups is approximately 1 rupee, with relatively low standard deviation. It indicates the persistence of the inefficiency of the market.

Table 7: Persistence Statistics for INR

Tenor	Minimum	Maximum	Mean	Std.dev	Skewness	Kurtosis
3 Month	0.9	1.593	1.059	0.165	2.487	5.369
6 Month	0.879	1.508	1.013	0.152	2.534	5.492

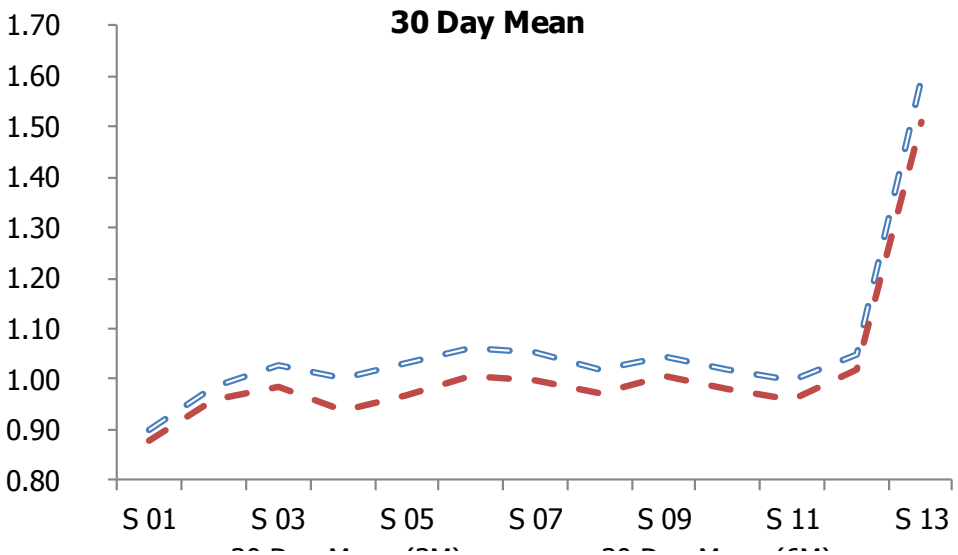


Figure 22: Range of mispricing Movement for INR

Positive skewness suggests that the observations may occur with values lower than the mean, while high kurtosis suggests that extreme outliers are also possible.

Similar to the Sri Lankan Rupee, Indian Rupee also always has positive mispricing. This means that the fundamental forward rates are higher than the market forward rate at all times. This provides arbitrage opportunities in both interest rate market as well as foreign exchange market for arbitrageurs.

Similar to Sri Lankan Rupee, a speculator could sell USD on spot and enter into a forward contract to buy USD in the forward market at a cheaper price and invest the resulting INRs today on government bills creating a risk free profit. He creates himself the opportunity. Banks also use this opportunity to create domestic currency liquidity at a cheaper rate. Since domestic short term interest rates in India are based on T-Bill rates and not on Interbank rates, it makes it an even more attractive source of risk free profit.

7.3 Predictability of Mispricing Analysis

7.3.1 Statistical Framework

Stationary Processes

A time series is assumed to be stationary if all statistical properties of its behavior are unchanged by shifts of time. This means that even though time series could have seasonal trends and may generate very different returns, the mean and variance of the time series are often unchanged. However, full stationarity is a hard assumption, therefore, for the purpose of this paper, I will be looking at weak form stationary, where mean, variance, and covariance are unchanged by time shifts.

Weak White Noise

Weak white noise is an example of a stationary process. In a white noise process, each and every data point is an independent random variable leading to a mean of zero and a variance of 1. This is also called the Gaussian white noise process. Due to the lack of correlation it is impossible predict future white noise values from past information.

Autoregressive Models

If the future values of a time series are predicted based on its own past values, such time series is called an Autoregressive model. The term autoregression indicates that it is a regression of the variable against itself. The next value is calculated based on the weighted average of past values plus the white noise (error).

Moving Average Models

A moving average model uses past forecast errors in a regression to forecast future values instead of past values. It is assumed that the next data point is the moving average of past forecast errors or the weighted average of its white noise process.

In this section I attempt to forecast the next ten data points of forward exchange mispricing against the dollar for the seven currencies. I use Autoregressive models, Moving Average models and Autoregressive Moving Average models to arrive at the forecast values.

Model checking will be based on Autocorrelation of residuals, test of P Values at 95% confidence intervals and Akaike information Criterion (AIC). I attempt to build a model that has zero autocorrelation in residuals, model that has its values above critical P value and a model that has the lowest Akaike information criterion.

Once the model is built, the predicted values will be compared against the actual values for the ten data points. R square measures the strength and the accuracy of the prediction. If the prediction has an R square above 80%, it will be concluded that the model is accurate and the forward exchange mispricing could be predicted for the respective currency.

- **EURO**

  EUR 3 month time series has an Augmented Dickey-Fuller test result of -3.3327 with a P value of 0.015. While the Dickey-Fuller tests for the 6 month series is -3.8 with a P value of 0.01. Both values are slightly above the critical values to reject the null hypothesis of a unit root.

  However, the autocorrelation functions of EUR3M and EUR6M time series does not decay to zero. Hence I have to look at the first order difference of both data series in order to evaluate whether it should it be an Autoregressive model or a moving average model.

  On the 3 month time series, Autocorrelation function has significant lags up to lag 9, while partial autocorrelation shows significant lags up to lag 16. However the 6 month time series shows significant lags up to lag 9 in Autocorrelation, while only 8 lags are significant in partial autocorrelation. Hence I test both Autoregressive models as well as moving average models for both time series.

For the EUR 3 month series I first develop an MA model. The model developed is 9 lags due to the Autocorrelation effect discussed earlier. Once the insignificant lags are removed, model has an AIC criterion of -4507.13 and a Box-Ljung test P value of 0.1192. Further Autocorrelation of residuals are also above the 5% critical value, indicating that the model seems fine. Once the insignificant lags and extremely small intercept are removed, the model would read as follows,

$$\text{MA(9)} , Yt = -0.1186_{t-7} + 0.1014_{t-8} + 0.2560_{t-9} + et$$

Attempts to build an Autoregressive model for the 3 month series are futile, since the model has to extend up to 16 lags, which is a significant number for a time series model. Therefore, in order to predict the EURO 3 month mispricing for the next 10 data points, the MA model above will be used.

Both moving average and Autoregressive models for the 6 month have similar results. Both models eliminate any correlations of residuals and have low AIC values. However, the Autoregressive model require only 8 lags in comparison to the 9 lags of the MA model, while the Autoregressive model also has a slightly lower AIC value than the MA model. Therefore, in order to predict the next 10 data points for the 6 month series I use the AR model as shown below.

$$\text{AR(8)} , Yt = 0.1990_{t-1} + -2.2488_{t-3} + -0.1888_{t-6} + -0.1454_{t-8} + et$$

Even though model checking shows that the models are sufficient enough to predict the future values, R squared figures turn out to be poor for both 3 month time series and 6 month time series. R square value for the 3 month prediction is -1230% while the R square for 6 month is -1020%, showing that the model prediction is far away from the actual result.

- **British Pound**

The Augmented Dickey-Fuller tests of both 3 month and 6 months series result in -0.5951 and -1.0938 with P values lower than 0.01 indicating that both times series are Unit roots.

Further, the autocorrelation function of both GBP 6 month and 3 month time series do not decay to zero. Hence, I have taken the first order difference of both time series' in order decide on the correct time series model.

The 3 month time series of GBP has significant lags up to lag 16 in autocorrelation, while partial autocorrelation shows significant lags only up to lag 4. Hence, I have selected an Autoregressive (AR) model to forecast the GBP 3 month time series.

Autoregressive model developed for the GBP 3 month series has 4 lags, however the 3rd lag and the intercept are insignificant and are removed. Once they are removed, the model has an AIC criterion of -5000.95 and there are autocorrelations of residuals. Further P values of Ljung Box statistic is also above the 5% critical value. Hence the model is deemed adequate and is as follows,

AR(4), $Yt = -0.1634_{t-1} -0.1127_{t-2} - 0.1346_{t-4} + et$

Both ACF and PACF for the 6 month series have auto correlated lags till deep history. ACF has significant lags up to 16 lags, while PACF has lags up to 15 lags. Hence both AR and MA models are considered.

MA model has significant lags up to 16 lags, Box Ljung tests for the MA model shows a P value of 0.0012 with an AIC criterion of -4536.2. Further there are no autocorrelations in residuals as well.

AR model has significant lags up to 15 lags, Box Ljung tests for the AR model shows a P value of 0.012 with an AIC criterion of -4528.2. However there are autocorrelations in residual values. As such, it indicates that the MA model is better suited to predict the GBP 6 month

series. Once the insignificant intercept and lags are removed, model is as follows,

MA(16) , $Yt = -0.0959_{t-1} -0.1408_{t-2} -0.1689_{t-3} +0.1648_{t-5} - 0.0885_{t-9} - 0.1422_{t-12} + 0.1859_{t-16} + et$

However, similar to EUR, GBP forecast also results in poor R Square values. The forecasted values fall quite far from the actual values in both the 3 month series and 6 month series.

R square for the 3 month prediction is -25%, while it is -1443% for the 6 month series. This indicates that the model prediction are poor and forward exchange mispricing of GBP/USD cannot be reliably predicted.

- **Japanese Yen**

The Augmented Dickey-Fuller tests of both 3 month and 6 months series result in -0.4848 and -1.0867 with P values lower than 0.01 indicating that both times series are Unit roots.

Further, the autocorrelation function of both JPY 6 month and 3 month time series do not decay to zero. Hence I have taken the first order difference of both time series' in order decide on the correct time series model. However, even at the first order difference, ACF does not decay to zero in both JPY 3 month and 6 month time series, while PACF decays to zero within the first 10 lags. Hence by default, Autoregressive models are be used for both JPY 3 month and 6 month series.

For the JPY 3 month series Partial Autocorrelation function shows significant lags up to, lag 10. Hence an AR 10 model is developed. Once the insignificant lags and the small intercept are removed, the model has an AIC criterion of -5736.37 and there are no autocorrelation in residuals. Further P values for Ljung-Box test is also above its critical value. Hence the model is deemed sufficient and shown below,

$$AR(10)\ ,\ Yt = 0.2440_{t-1} + 0.1797_{t-2} + 0.1479_{t-5} + 0.1449_{t-10} + et$$

Similar to the JPY 3 month series, 6 month series also shows Partial Autocorrelation lags up to, lag 10. Hence an AR 10 model is developed. Once the insignificant lags and the small intercept are removed, model has an AIC criterion of -5384.68 and there are no autocorrelation in residuals. Further P values for Ljung-Box test is also above its critical value. Hence the model is deemed sufficient and shown below,

$$AR(10)\ ,\ Yt = 0.1582_{t-1} + 0.1651_{t-2} + 0.1763_{t-5} + 0.1810_{t-10} + et$$

Even though model checking showed that the models are sufficient to predict the future values, R squared figures turn out to be poor for both 3 month time series and 6 month time series. R square value for the 3 month prediction is 8% while the R square for 6 month is -98%, showing that the model prediction is inaccurate.

- **Sri Lankan Rupee**

Similar to the previous currencies, Sri Lankan rupee also proved to be unit root. The Augmented Dickey-Fuller tests of both LKR 3 month and 6 months series result in -1.6611 and -1.6867 with P values lower than 0.01.

The autocorrelation function of both LKR 6 month and 3 month time series do not decay to zero as well. Hence the first order difference of both time series are taken in order decide on the correct time series model.

Partial Autocorrelation function shows significant lags up to, lag 17 for LKR 3 month series, suggesting an AR (17) model. Autocorrelation function shows significant lags up to lag 2, suggesting a MA (2) model. Therefore, given the nature of the two models an MA (2) model is selected for the LKR 3 month time series.

The model developed, has an AIC criterion of -1469.45 and there are no autocorrelation in residuals. Further P values for Ljung-Box test are also above its critical value. Hence the model is deemed sufficient and shown below,

$$MA(2),\ Yt = 0.0037 + 0.2673_{t-1} + 0.0085_{t-2} + et$$

LKR 6 month time series also exhibited characteristics similar to the LKR 3 month series. While the ACF suggested a MA (1) model, PACF suggests an AR (13) model. Hence, given the number of lags involved the MA (1) is selected.

The model developed, has an AIC criterion of -1525.3 and there are no autocorrelation in residuals. Further P values for Ljung-Box test are also above its critical value. Hence the model is deemed sufficient and shown below,

$$MA(1),\ Yt = 0.0043 + 0.2565_{t-1} + et$$

Despite having a wide arbitrage spread right through out the period observed, it is seen that the models are not sufficient to predict the future values. R squared figures turn out to be poor for both 3 month time series and 6 month time series. R square value for the 3 month prediction is -270% while the R square for 6 month is -265%, indicating that it is not possible to accurately predict future mispricing of LKR/USD pair.

- **Russian Rouble**

The 3 month series has a Dickey-Fuller test result of -8.0012 and the 6 month has Dickey-Fuller test results of -6.9966 confirming that the time series' are not Unit roots.

.

The Autocorrelation function of the 3 month series has significant lags up to lag 1, suggesting a MA (1) model, while the Partial Autocorrelation function had significant lags up to lag 9, suggesting an AR (9) model. However, further analysis reveals that in addition to having a lower number of lags, the MA model also has a lower AIC value. Hence the MA model is selected for the 3 month series.

The MA (1) model for the 3 month series has an AIC value of -485.19 and clear any autocorrelation in residuals. Further the P value of Ljung-Box statistics are also above the critical value. Once the insignificant intercept is removed, the model read as follows,

$$\text{MA(1)}, \quad Yt = 0.0006 - 0.8901_{t-1} + et$$

The 6 month time series also demonstrates similar characteristics for the Rouble. While the ACF suggests a MA (3) model, PACF suggests an AR (5) model. However, the MA model has a lower AIC value; hence the MA model is selected.

$$\text{MA(3)}, \quad Yt = 0.0002 - 0.3103_{t-1} - 0.3481_{t-2} - 0.1664_{t-3} + et$$

Similar to the previous currencies analysed, the Rouble also results in poor R square values. R square for the 3 month time series is -4%, while the R square for the 6 month series is 24%.

- **Brazilian Real**

The 3 month series of Brazilian Real has a Dickey-Fuller test result of -2.4641 and the 6 month has a Dickey-Fuller test result of -1.1689 confirming that the time series are Unit roots. Further, ACF's of both time series' do not decay to zero as well. Hence the first order difference is considered for both time series' for Brazilian Real as well.

Both ACF and PACF show significant lags up to lag 4. Hence, both MA and AR models are considered for this time series. Both models seem to exhibit validity, with no autocorrelations on residuals and P values higher than the critical value of Ljung-Box statistic. However, the AIC value of the AR (4) is slightly lower than the MA model. Hence the AR (4) model is chosen, which is shown below,

$$\text{AR (4)},\ Yt = -0.1887_{t-1} - 0.1446_{t-3} - 0.1143_{t-4} + et$$

Similar to the 3 month series, 6 month series also demonstrates significant lags up to lag 4 in both PACF and ACF. However in contrast to the 3 month series, MA (4) model has lower AIC than the AR (4) model in the 6 month series. Hence, an MA (4) model is used to model the 6 month time series for Brazilian Real,

$$\text{MA (4)},\ Yt = -0.1923_{t-1} - 0.1458_{t-3} + et$$

BRL R square values also follow the trend so far. For the 3 month series R square is at -162%, while the 6 month series recorded an R square of -212%.

- **Indian Rupee**

For the INR 3 month series, ACF suggests a MA (5), while the PACF suggests an AR (10) model. Even though the AR model has a higher number of lags, it is seen that the AR model has a lower AIC and has no autocorrelations of residuals, while the MA model has a higher AIC and Autocorrelations of residuals. Hence the AR (10) model is chosen.

$$\text{AR(10)},\ Yt = 0.0015 - 0.0999_{t-2} - 0.1411_{t-3} + 0.3661_{t-4} + 0.3986_{t-5} + 0.2497_{t-7} - 0.3873_{t-9} - 0.2223_{t-10} + et$$

For the INR 6 month series a MA (5) model is developed, since PACF suggests lags up to lag 14. MA (5) model does not have autocorrelations on residuals and P value of Ljung-box statistic is above the critical value. Model had an AIC value of -1988.9

MA(5) , $Yt = 0.0015 + 0.0903_{t-1} -0.1048_{t-2} - 0.1132_{t-3} +0.1935_{t-4} + 0.4785_{t-5} + et$

R square values for both 3 month and 6 month series of INR also turn about to be extremely poor.

7.4 Analysis on whether Interest Rate parity can predict the future spot rate.

As stated earlier this section attempts to evaluate whether the Interest Rate parity condition has the capacity to accurately predict the future spot rate.

In the event the Interest Rate Parity condition could predict the future spot rate, it can be assumed that the role of forward contracts would become obsolete in the near future. This is because, ultimately, a forward contract is a risk management tool that attempts to mitigate the uncertainty of the exchange rate in a future date. If the Interest Rate Parity condition could predict the future spot, that uncertainty is removed, rendering the forward contract obsolete.

However, as much as I do not expect the Interest Rate Parity condition to forecast the future spot rate with 100% accuracy, I do expect a reasonably accurate forecast of the future spot. This is tested via a regression, where I evaluate whether the intercept is equal to zero and the coefficient is equal to 1.I have used the Newey-West model to arrive at the correct standard errors and the T-values. Results of same are as shown in below tables.

Table 8: Intercept and Coefficient of Free Floating Currencies for 3 month tenor (Newey-West)

Tenor	EUR		GBP		YEN	
	α	**β**	**α**	**β**	**α**	**β**
3 Month	0.74168	0.0468	0.7362	-0.1658	5.89003	1.00729
Std.Err	0.12438	0.16816	0.13738	0.21616	28.45313	0.22863
T – value	5.9630	0.2786	5.3859	-0.7668	0.2070	4.4058

Table 9:Intercept and Coefficient of Free Floating Currencies for 6 month tenor (Newey-West)

Tenor	EUR		GBP		YEN	
	α	**β**	**α**	**β**	**α**	**β**
6 Month	1.11648	-0.44767	0.81129	-0.28696	-49.1913	1.5014
Std.Err	0.13443	0.18879	0.086177	0.137748	84.1359	0.6855
T – value	8.3050	-2.3712	9.4143	-2.0832	-0.5847	2.1903

As seen in above tables, the interest rate parity condition fails to predict the future spot rate accurately based on interest rate differentials of the two currencies involved. All currencies at both tenors have an intercept higher or lower than 0, indicating the slope of the curve. Further coefficient of the forward rate is also not equal 1 or 100%. This indicates that the sensitivity of spot rate to the forward is of varying degrees and not a constant for free floating currencies.

Similar to the free floating currencies, I calculate Newey-West standard errors and T statistics for the managed rate currencies as well. Results of which are shown in below tables,

Table 10:Intercept and Coefficient of Managed Rate Currencies for 3 month tenor (Newey-West)

Tenor	LKR		RUB		BRL		INR	
	α	β	α	β	α	β	α	β
3 Month	107.5354	0.1626	34.6959	-0.1163	0.7	0.6789	24.6450	0.5670
Std.Err	33.93359	0.27882	5.91209	0.20533	0.626	0.362	22.282	0.473
T – value	3.169	0.583	5.8686	-0.5662	1.12	1.87	1.10	1.1973

Table 11: Intercept and Coefficient of Managed Rate Currencies for 6 month tenor (Newey-West)

Tenor	LKR		RUB		BRL		INR	
	α	β	α	β	α	β	α	β
6 Month	142.8976	-0.1075	36.3064	-0.1527	1.1377	0.5016	28.5935	0.5235
Std.Err	43.56798	0.36585	7.49575	0.23040	1.80	1.026	55.62	1.14
T – value	3.2799	-0.2938	4.8436	-0.6629	0.6304	0.4885	0.5141	0.4575

Similar to free floating currencies, managed rate currencies also fail to accurately estimate the future spot rate based on current forward rates. Intercepts are not equal to zero and the coefficients are not equal to 1.

Further, it is also not possible to draw a distinction between two sets of currencies based on the results. Both sets of currencies showcase similar results. Even though it could be observed that the managed rate currencies have a relatively higher intercept, it could be assigned to the weaker position of these currencies in comparison to the dollar, as it is also evident in the Yen.

8 CONCLUSION

It is observed that both Free-floating currencies and Managed rate currencies have mispricing in forward rates and that arbitrage opportunities are available. This finding is also consistent with the findings of Mark P Taylor in his paper "Speculative Prices as Random Walks" in 1995. However, the magnitude of the arbitrage opportunities is significantly different from free floating currencies to managed rate currencies. While the free floating currencies have very small pricing deviations, managed rate currencies have significant deviations. As a result, it is impossible for an arbitrageur to profit from the mispricing in free floating currencies, once transaction costs are discounted for. However, arbitrageurs could make significant profits from mispricing in managed rate currencies. Hence, it could be concluded that, while the pricing error in free floating currencies is not economically significant, managed rate currencies pricing error is economically significant.

It is not possible to differentiate between free-floating currencies and managed rate currencies in terms of the persistency of the efficiency of each market. While EUR and GBP are extremely stable and efficient at all times observed, YEN is volatile and offers arbitrage from time to time. Further, it is also observed that, as the world economy stabilizes, the pricing error of free floating currencies becomes narrower and narrower. However, the currencies of Managed Rate regimes offer significant arbitrage opportunities at all times. They fail to reach market efficiency at any time during the period observed. Hence, it could be concluded that, while managed rate currencies are persistent in market inefficiency, free-floating currencies achieve market efficiency subject to economic stability of the domestic and global economies.

Predictability of mispricing of both sets of currencies prove challenging. While both free floating and manage rate currencies have mispricing and could be modeled, the predictions remain poor. Not a single currency pair's mispricing forecast could achieve an R square figure above 50%. This could be as a result of volatile variables involved in determining the mispricing itself. As such, it is concluded that, accurately forecasting the forward exchange pricing error in both 3 month and 6 month tenors is not possible for all currencies.

It is observed that interest rate parity condition could predict future spot rate of neither free floating currencies nor managed rate currencies. Both sets of currencies have an intercept far from zero and a coefficient far from 1. Hence, it is concluded that, Interest Rate Parity condition could not accurately forecast the future spot rate for any set of currencies.

9 FURTHER RESEARCH SUGGESTIONS

9.1 Does market liquidity affect pricing error of forwards?

It is expected that highly liquid markets to not offer any arbitrage opportunities. It would be interesting to test this on the foreign exchange forward markets as well. As currencies such as Japanese Yen offer pricing errors time to time and currencies such as Russian Rouble have volatile pricing errors, it should be analysed whether this is correlated to the market liquidity at the given time. Correlation of widening Bid-Offer spreads and higher pricing error should be analysed to see whether higher liquidity actually nullifies any price errors in the forward exchange market.

9.2 Is market intervention cost effective?

Most governments or monetary authorities intervene in the foreign exchange markets in order to manage inflation, protect infant industries and grow their export industries. However, such market intervention takes place at a significant cost to the monetary authority, as the monetary authority has to intervene via SDRs or country's foreign exchange reserves. It would be beneficial to analyse the cost effectiveness of intervention strategies against the desired outcome of such strategies.

10 REFERENCES

Books

Ruppert, David (2004) *Statistics and Finance, an Introduction(1st Edition)* USA Springer Texts in Statistics.

Gujarati ,Damodar N (2009) *Basic Econometrics* (4th Edition) Jamshedpur, Tata McGraw Hill Education Private Limited

Papers

POOLE, WILLIAM "Speculative Prices as Random Walks: An Analysis of Ten Time Series of Flexible Exchange Rates" Southern Economic Journal, Vol. 33, No. 4 (Apr., 1967), pp. 468-478

TAYLOR, MARK P and TAYLOR, ALAN M "The Purchasing Power Parity Debate" Prepared for Journal of Economic Perspectives, (Draft paper)

TAYLOR, MARK P "The Economics of Exchange Rates" Journal of Economic Literature, Vol. 33, No. 1 (Mar., 1995), pp. 13-47

ALIBER, ROBERT Z "The Interest Rate Parity Theorem: A Reinterpretation" Journal of Political Economy, Vol. 81, No. 6 (Nov – Dec., 1973), pp. 1451 - 1459

DOOLEY, MICHAEL P and SHAFER, JEFFREY R "Analysis of Short Run Exchange Rate Behaviour" Mar.1973 to 1981, in exchange rate and trade instability. Eds: David Bigman and Teizo Taya, Cambridge, M.A Ballinger, 1983, pp. 43 – 69

LEVICH, RICHARD M and THOMAS, LEE R. "The significance of Technical – Trading Rule, Profit in the Foreign Exchange Market: A Bootstrap Approach" J. Int Money Finance, Oct 1993, 12(5), pp 451-74

ROGOFF, KENNETH “Expectations and Exchange Rate Volatility” Unpublished Ph.D. thesis, Massachusetts Institute of Technology, 1979.

LEWIS, KAREN K. “Changing Beliefs and Systematic Rational Forecast Errors With Evidence from Foreign Exchange” American Economic Review, September 1989, 79(4), pp. 621-36.

BRANSON, WILLIAM H. “The Minimum Covered Interest Differential Needed for International Arbitrage Activity” Journal of Political Economy, Vol. 77, No. 6 (Nov – Dec ., 1969), pp. 1028 - 1035

ENZIG, P A and HOLMES, A R “A Dynamic Theory of Foreign Exchange” Macmillan 1961.

TSIANG, S.C. “The Theory of Forward Exchange and the Effects of Government Intervention in the Forward Exchange Market” IMF staff papers 7 (April 1959), 75 – 106

KEYNES, J.M “Monetary Reform. New York” Harcourt, Brace, 1924.

FRENKEL, JACOB A. “Covered Interest Arbitrage; Unexploited Profits?” Journal of Political Economy, Vol. 83, No 2 (April 1975), pp. 325 - 338

SINGH, M and BANERJEE A “Testing Real Interest Parity in Emerging Markets” IMF working paper, Middle east and Asia department, November 2006, WP/06/249

AKRAM,FAROOQ and LUCIO SARNO, DAGFINN RIME “Arbitrage in the Foreign Exchange Market” Journal of International Economics

RICHARD T BAILLIE AD SANDERS S CHANG “Carry Trades, Momentum Trading and Forward Premium Anomaly” Journal of Financial Markets

GEIR BJONNES,DAGFINN RIME AND HAAKON O A SOLHEIM “Liquidity Provision in the overnight foreign exchange market” Journal of International Money and Finance. (2005)