Fundamental determinants of the real exchange rate of the Indian rupee: Long run equilibrium and short term behavior

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Abstract

This paper seeks to develop a short run model of exchange rates to explain the behaviour of the rupee in foreign exchange markets in the nineties when India moved from a fixed to a floating exchange rate.

In the model estimated the real exchange rate deviates from that determined by real interest parity due to risk and intervention. These, apart from the interest differential and the expected exchange rate determine the current period's exchange rate.

The expected exchange rate is a convex combination of the rates derived from extrapolative behavior and the equilibrium exchange rate which is determined by a version of the purchasing power parity condition.

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1. Introduction

An economy is linked to the world economy through two broad channels: trade and finance. India's economic policy reforms of 1991 sought to globalise the hitherto relatively closed Indian economy by opening up both these channels. The changes in both trade and the financial sector have been slow giving the economy time to adjust. Despite restrictions, the trade channel between India and the rest of the world was far more open than financial markets. Not only was the financial sector closed to international agents, the price of capital (interest rate) or of the domestic currency (exchange rate) was not market determined. The nineties saw a twin development in financial markets - one, prices were allowed to be determined by the market, and two, the domestic financial market was integrating with international financial markets.

The economy continued to have features of the closed economy and fixed exchange rate regime that had prevailed for a long period, even after rates were supposed to be market determined. Capital controls continue. While current account convertibility for both inflows and outflows by residents and non-residents was established as early as August 1994, controls continue on the ability of resident individuals and corporates to send capital abroad.

The objective of this paper is to develop a short run model of exchange rates to explain the behaviour of the rupee in foreign exchange markets in recent years. In the nineties India moved from a fixed to a floating exchange rate. The challenge here lies in modelling the exchange rate for a time during which there were significant changes in the foreign exchange regime as the transition from a fully fixed to a largely market determined rate took place. Between 1991 and 1993 there existed a system when only a proportion of export earnings could be converted into the domestic currency at the market determined exchange rate. After January 1993 the exchange rate became fully 'market determined'. However, it was kept constant for a long period by the central bank intervention in the foreign exchange market.

There is a vast amount of literature on exchange rate modelling (Isard, 1995). Neither the text book models of the closed economy on the one hand, nor the Mundell - Fleming model of perfect capital mobility and flexible exchange rates on the other, capture the essence of an economy in transition from a closed to an open one. There is limited empirical work on exchange rate modelling for transition economies, as exchange rate determination has been modelled more commonly for developed countries. In the case of India, exchange rate was fixed by the central bank until the recent policy changes and there is little historical experience in modelling exchange rate for the Indian Rupee with a freely moving exchange rate.

Even in the case of developed and open financial markets empirical evidence does not often support structural models. Meese and Rogoff (1983) conducted a study for the dollar-pound sterling, dollar-mark, dollar -yen, and trade weighted dollar exchange rates using data running from March 1973. The exchange rate models tested corresponded to the monetary models- flexible and sticky price and portfolio balance models. They compared out of sample performance of these equations to the forecasting performance of the random walk model, the forward exchange rate, a univariate autoregression of the spot rate, and a vector autoregression. In the out of sample prediction they used actual values of the various independent variables. However, their conclusion was that none of the exchange rate models tested outperformed the simple random walk model.

As mentioned before in the case of India, exchange rate was fixed by the central bank until the recent policy changes and there is little historical experience in modelling exchange rate for the Indian Rupee with a floating exchange rate. To explain the determination of the exchange rate of the rupee we seek to identify the underlying economic forces that are submerged under an interventionist market structure. We believe it is worthwhile to identify the long run equilibrium properties this exchange rate should have if it were completely determined by output markets. The model presented in the paper suggests that a version of the purchasing power parity hypothesis would anchor the long run behaviour of exchange rates. In the short run the exchange rate is a function of the expected exchange rate and interest differentials. The expected exchange rate is based on the notion that the agents form convex combinations of forward-looking expectations and extrapolative behaviour. There are deviations from the interest parity conditions due to differences in the level of risk associated with assets of a country and intervention by central banks and other factors such as third country currency crisis that may affect risk perception for a country.

In the following section we briefly look at the exchange rate regime in India, recent trends in the rupee-dollar and the nominal and real effective exchange rates. Section 3 outlines the theoretical model. In section 4 we present the estimation and results. Next we evaluate the performance of the model and analyze its response characteristics. Finally we examine the implications of our results for domestic policy making.

2. India: Exchange rate regime and recent trends

The movement towards market determined exchange rates in India began with the official devaluation of the rupee in July 1991. In March 1992 a dual exchange rate system was introduced in the form of the Liberalized Exchange Rate Management System (LERMS). Under this system all foreign exchange receipts on current account transactions were required to be submitted to the Authorized dealers of foreign exchange in full, who in turn would surrender to RBI 40% of their purchases of foreign currencies at the official exchange rate announced by RBI. The balance 60% could be retained for sale in the free market. As the exchange rate aligned itself with market forces, the Re/$ rate depreciated steadily from 25.83 in March 1992 to 32.65 in February 1993. The LERMS as a system in transition performed well in terms of creating the conditions for transferring an augmented volume of foreign exchange transactions onto the market. Consequently, in March 1993, India moved from the earlier dual exchange rate regime to a single, market determined exchange rate system.

The deepening of the foreign exchange market has been aided by the implementation of some of the recommendations of the Sodhani Committee on Foreign Exchange Markets (1995) and the Tarapore Committee on Capital Account Convertibility (1997). The

Sodhani Committee (1995) made recommendations to develop, deepen and widen the forex market. A number of its recommendations regarding introduction of various products and removal of restrictions in foreign exchange markets to improve efficiency and increase integration of domestic foreign exchange markets with foreign markets have been implemented. Liberalisation measures undertaken on the capital account relate to foreign direct investment, portfolio investment, investment in joint ventures/wholly owned subsidiaries abroad, project exports, opening of Indian corporate offices abroad, and raising of Exchange Earners Foreign Currency entitlement.

While trade flows and foreign investment have had a role to play in the determination of the exchange rate, another important development that has led to the capital movements has been the reform that has taken place in other segments of financial markets in India. This has led to increasing integration of broad segments of the market such as the money market, government securities, capital market and the foreign exchange market. Market participants and move from one market to the other leading to inter-linking of these markets. The link between the forex and domestic market has increased due to the freedom given to banks to maintain foreign currency assets and liabilities that can be swapped into rupees and vice versa. On the liabilities side there are foreign currency borrowings from overseas offices, borrowings for lending to exporters, foreign currency non-resident deposits (FCNR-B) deposits and Exchange Earners Foreign Currency deposits of corporates. Banks are permitted to use these funds either for raising rupee resources through swaps or for lending in foreign currency. Banks have been allowed to lend in foreign currency to companies in India for any productive purpose without linking to exports or import financing. Corporates can substitute rupee credit for foreign credit as they now have the choice to borrow either in foreign currency or rupees depending on the cost, taking both interest cost and exchange risk into account (Reddy, 1999). Evidence suggests that the nineties have seen growing inter-linkages between money, foreign exchange and government securities markets.

Fig 1a. Nominal Exchange Rate (Rs/$)

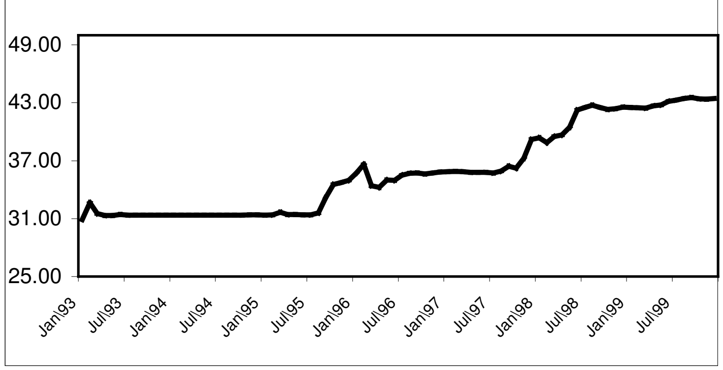
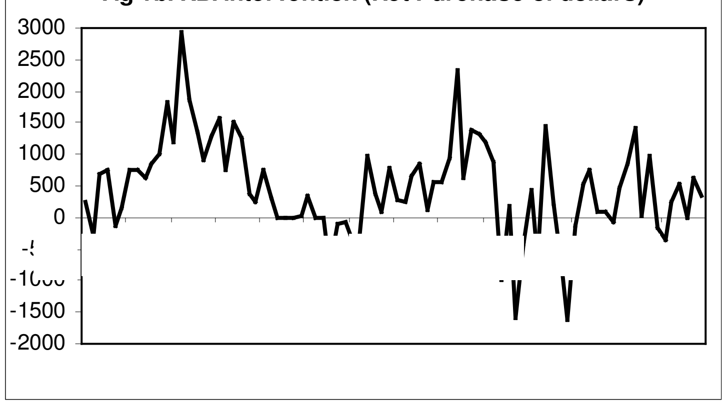
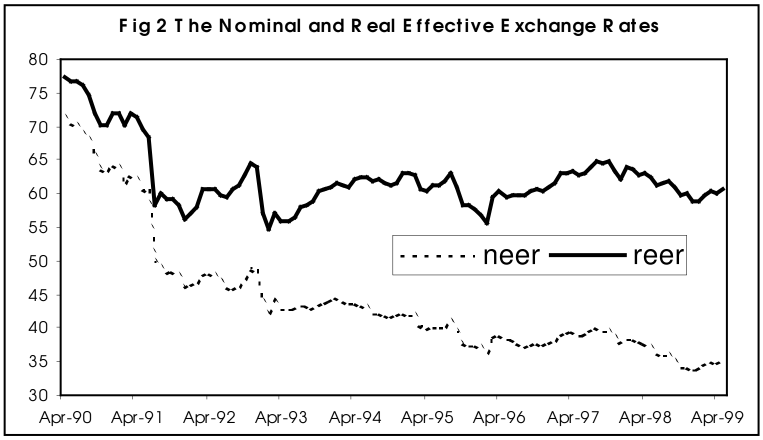


Fig 1b. RBI intervention (Net Purchase of dollars)

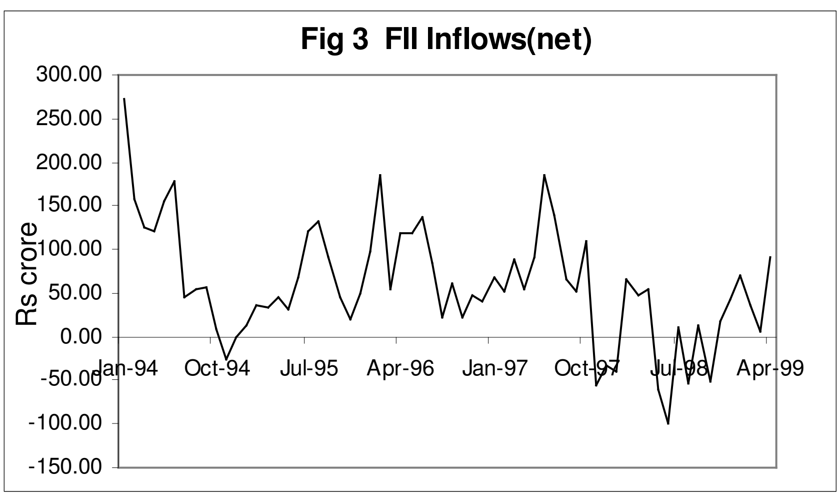


During 1994-95 there was upward pressure on the rupee because of foreign portfolio capital inflow that was now allowed to enter India. However, the rupee was not allowed to appreciate but was kept constant by the RBI (fig 1a and 1b). This was due to the conflict between the objectives of export promotion and the free movement of the rupee. The market was not freely allowed to determine the exchange rate of the rupee. If it had, the rupee would have appreciated. The RBI intervened to maintain the nominal value of the rupee at a constant level of Rs/$ 31.4 for a period of sixteen months from March 1993 to July 1995. In real terms the rupee appreciated as inflation levels in India were higher than in the partner countries (fig 2).

As figure 3 indicates, in 1995 the initial surge was over and buying pressure from FIIs reduced. As the rupee continued to be overvalued the current account deficit started mounting (Fig 4). There was downward pressure on the rupee. A depreciation in the



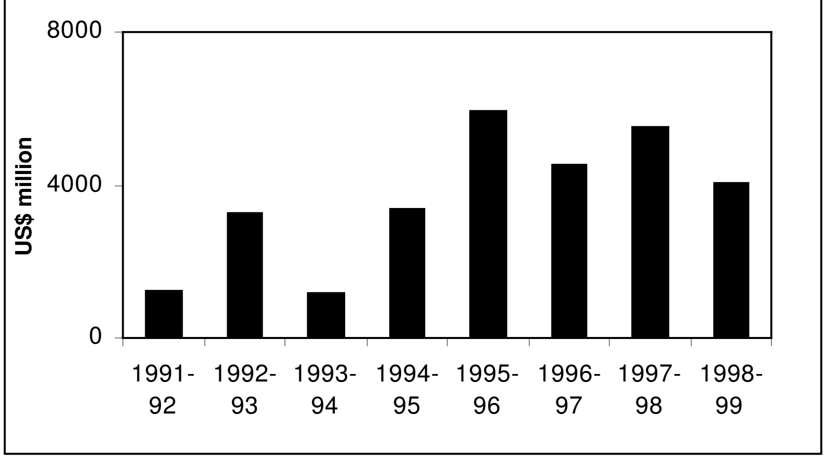
Re/$ was welcome as the appreciation in the real exchange rate had made exports uncompetitive. The nominal rate fell to Rs/$ 35.65, recording a fall of 13.6% over the rate of Rs/$ 31.37 that had been maintained for about two years . In the following year, the appreciation of the US dollar against other major currencies put upward pressure on the rupee. The policy of stabilizing the exchange rate of the rupee against the dollar ensured that the rupee traded in the range of Rs.34-Rs.35 to a dollar. In 1997-88 and 1998-99 the RBI allowed the rupee to be more or less determined in the market. In this period there



has been little pressure on the nominal rate to appreciate and whenever political, economic or other reasons have introduced volatility in the foreign exchange market the RBI has intervened. The stated objective of the RBI's exchange rate policy is to reduce volatility and speculation in the foreign exchange market and to keep the rate in line with economic fundaments.

As figure 1 b clearly shows, the number of episodes of the net purchase of dollars by RBI in the foreign exchange market far out number those when it was negative. Thus RBI followed a policy to prevent appreciation, even for prolonged periods of time. Episodes when it stepped in to sell dollars were short and few and usually associated with a crisis

Fig 4: Current account deficit



that might have caused excess volatility. To keep the exchange rate 'in line with economic fundamentals' the rupee should have been continuously depreciating in nominal terms to prevent a real appreciation. Thus, if for any short-term reasons such as capital flows, there was excess demand for the rupee leading to a pressure on the rupee to appreciate, the RBI purchased dollars to push up their demand for dollars and prevent the appreciation.

2.1 . Exchange rate modelling in India

In an econometric model of the exchange rate of the Indian rupee Marwah (1987) finds that in the period 1974 (Q1) to 1982 (Q4) the rupee was determined by its demand and supply in the foreign exchange market. The domestic rate of interest is endogenised in the model and net inflow of foreign capital is assumed to be a function of the differential between domestic and foreign interest rates. Relative excess demand on supply of the Indian rupee in the foreign exchange market is measured by changes in the stock of net foreign assets. Apart from supply and demand, the exchange rate of the rupee is also specified to be a function of debt service as a ratio of the stock of net foreign assets where a larger debt service puts downward pressure on the rupee. The domestic interest rate is determined by the balance between the supply and demand for money, while the money supply is determined by the money base, an important element of which is Net Foreign Exchange Assets (NFEA). The interest rate also tracks the bank rate and the stock price index. It fluctuates with the value of the rupee in the foreign exchange market. As the rupee appreciates, NFEA rise, money supply increases and the interest rate falls.

Bhattacharya, Barman and Nag (1994) incorporate the determination of the exchange rates of the Indian Rupee in a macroeconometric model of the Indian economy. The exchange rate is assumed to be a function of last period's current account balance, last period's stock of foreign exchange reserves and the wholesale price index. Introduction of the last period's exchange rate is expected to incorporate the discrepancy between the desired and the actual exchange rate. Results suggest that though the exchange rate was fully regulated by the RBI till 1991, these forces strongly influenced the RBI exchange rate policy. An average of 60 per cent of the changes in the exchange rate can be attributed to trade and balance of payments factors. They also find that the behaviour of exchange rate has changed significantly during the 1980s, as revealed by the dummy for 1980s. In the model the exchange rate affects exports and the current account balance which in turn impact net foreign exchange assets that determine money supply and domestic prices in the economy. Further, the exchange rate affects the unit value of imports or the price of imports. This in turn affects the volume of real imports which is a determinant of real GDP. A rise in the unit value of imports also impacts domestic prices raising wholesale prices.

The exchange rate is thus linked to prices through its effect on the price on imports, and to output through its impact on the volume of imports. Being supply determined, real GDP is not affected by its effect on the volume of exports or the domestic price level in this model.

The macro model operated at NCAER (Bhide et al., 1996) simulates the supply and demand for foreign exchange for current account transactions. While the transactions other than trade, such as transfers by non resident Indians from abroad are exogenous much of the trade account is simulated by export and import equations. Thus, the model captures many of the interlinkages between the domestic economy and the foreign exchange transactions. The model has been used to obtain the rate of depreciation of the rupee to reduce the current account deficit by a specified target.

3.The Model

It is assumed that in the short run capital movements take place due to differences in expected returns across countries. The uncovered interest parity (UIP) condition states that the foreign exchange market is in equilibrium when expected rates of return on assets denominated in different currencies are the same. The expected returns on deposits of any two currencies must be equal when expressed in the same currency. The parity condition is expected to hold when potential holders of foreign-currency deposits view them all as equally desirable assets.

If i is the return on domestic assets and i* the return on foreign assets, E^e is the expected future exchange rate, the UIP condition states that

$$i = i^* + (E^e - E) / E \qquad (1)$$

The equation above states that when domestic and foreign currency assets are perfect substitutes, the foreign exchange market is in equilibrium only if interest parity condition holds.

Empirical evidence suggests that support for the uncovered interest parity condition is limited. Deviations from the parity condition arise due to a number of factors. The most important among these may be risk. The above analysis assumes that the foreign exchange market is in equilibrium only when expected returns on domestic and foreign currency bonds are the same. This assumption is known as perfect asset substitutability. Two assets are perfect substitutes when it does not matter to investors how their portfolios are divided between them, provided both yield the same expected rate of return. However, if two assets differ in terms of the risk associated with them, they are not perfectly substitutable. Differences in degrees of risk associated with different assets leads to imperfect asset substitutability. If assets denominated in different currencies have different degrees of risk, investors may be willing to earn lower expected returns on assets that are less risky. A very risky asset may be held only if the return on it is expected to be very high.

When domestic and foreign assets are not perfect substitutes, equilibrium in the foreign exchange market requires that the domestic interest rate equal the expected domestic currency return on foreign assets plus a vector of variables that lead to deviations from UIP such as risk premium, Ω, that reflects the difference between the riskiness of domestic and foreign bonds due to inflation risk or country risk and other factors such as central bank intervention (Π). A stochastic version of the UIP that captures risk, central bank intervention and a random error may be written as

$$i = i^* + (E^e - E) / E + \Omega + \Pi + \varepsilon \qquad (2)$$

Corresponding to the relation between nominal interest rates and nominal exchange rates we now define the relationship between expected real interest rates and real exchange rates. Assuming for the moment that domestic and foreign currency assets are perfectly substitutable, the nominal interest parity condition equates nominal interest rate differences between currencies to expected changes in nominal exchange rate. The real interest parity condition similarly equates expected real interest rate differences to expected changes in real exchange rates. The expected real interest rate, r^e, may be written approximately as the nominal interest rate, i, less the expected inflation rate, π^e.

r^e = i- π^e (3)

Adding the expected inflation differential π^{e^*} -π^e to both sides of equation (2), we get an equation explaining the expected real interest differential between home country and foreign country assets:

$$(i-\pi^e)-(i^*-\pi^{e^*}) = \frac{E^e - E}{E} + \pi^{e^*} - \pi^e + \Omega + \Pi + \varepsilon \qquad (4)$$

Using log approximation[i] we have

$$(E^e - E)/E = \log E^e - \log E$$

$$\pi^e = \log P^e - \log P\ ; \quad \pi^{e^*} = \log P^{e^*} - \log P^*$$

Rewriting equation (4)

$$r - r^* = \log E^e - \log P^e + \log P^{e^*} - [\log E - \log P + \log P^*] + \Omega + \Pi + \varepsilon$$

$$\Leftrightarrow\ r - r^* = q^e - q + \Omega + \Pi + \varepsilon \qquad (5)$$

where $q = \log(E\, P^* / P)$; $q^e = \log(E^e\, P^{*e} / P^e)$

Short run equilibrium in the foreign exchange market may be as described by equation (5). The log of real exchange rate, q_t , in period t is a function of the expected rate (where $q_{t+1/t}$ is the expectation in period t of the rate that would be observed in period t+1), the real interest rate differential between the home and foreign country, the risk premium and a random noise ε_t.

$$q_t = (q_{t+1|t}{}^e) - (r_t - r_t{}^*) + \Omega_t + \Pi_t + \varepsilon_t \qquad (6)$$

where $q^e_{t+1|t}$ is the log of the expected real exchange rate for period t+1 in period t.

Such expectations may be assumed to be formed in a number of ways, depending on what we assume to be the expectation rule. For instance, (I) they may be entirely extrapolative based on the past value of the exchange rate as in a partial adjustment model (chartists); (II) they may be a function of the equilibrium exchange rate (fundamentalists), or a combination of (I) and (II). It is assumed that agents in the forex market are either chartists or fundamentalists and market expectations are a combination of their respective expectations.

Thus, we assume that the expected exchange rate depends on both the underlying equilibrium rate, as the market expects to move towards it in the long run, and the current exchange rate since agents are aware that adjustments to the exchange rate are not instantaneous.

Thus, we assume that expectations of the future value of the real exchange rate are a convex combination of extrapolation and the equilibrium level of the real exchange rate. Or,

$$q^e{}_{t+1|t} = (1-\beta)\overline{q}_t + \beta q_{t-1}$$

In the model, therefore, the current real exchange rate is determined by real interest differentials, the risk premium, intervention in the foreign exchange market by the monetary authorities and the expected exchange rate. The expected exchange rate is a function of the lagged exchange rate (the lagged rate replaces the current in the equation to avoid the current rate appearing on the right hand side as well) and an equilibrium exchange rate.

$$q_t = ((1-\beta)\overline{q}_t + \beta q_{t-1}) - (r_t - r_t^*) + \Omega_t + \Pi_t + \varepsilon_t \qquad (7)$$

We now examine how the equilibrium exchange rate is determined.

3.1. Equilibrium Exchange Rate

The purchasing power parity (PPP) hypothesis remains the most important theoretical construct in seeking to explain the long run behaviour of exchange rates. Though evidence has been conflicting and PPP has often been rejected as a predictive theory in the empirical literature, it still remains the most powerful tool to understand the behaviour of the movement of exchange rates of different currencies.

Beginning in the 1980s, empirical literature on purchasing power parity has focussed on the time series properties of the real exchange rate. Evidence of non-stationarity of the exchange rate has been viewed as evidence that PPP does not hold in the long run. Recently, there is some evidence to support long run PPP. This includes Kim (1990), Whitt (1992), and Abauf and Jorion (1990). Frankel (1986), Edison (1987) and Lothian and Taylor (1996) use data for nearly 100 or more years and find evidence in favour of PPP but the long time horizon methodology has been criticized on account of mixing data for both floating and fixed exchange rate regimes. Other studies that find evidence supporting PPP use panel data. For instance, Frankel and Rose (1995) and Wei and Parsley (1995) both use evidence for a number of countries and find evidence to support PPP. Among those who reject stationarity of real exchange rates and long-run PPP include Meese and Rogoff (1988) and Mark (1990). Recent work on the PPP adopts panel data and unit root or cointegration approaches. This includes Jorian and Sweeny (1996), Oh (1996), Wu (1996), Canzoneri et. al. (1997), and Lothian (1997) whose results support PPP.

Deviations from the prediction of PPP hypothesis have been explained in terms of the limitations to the applicability of the law of one price, the central idea of the PPP theory, across all commodities. Systematic deviations from the PPP are due to the fact that not all goods are tradable and hence their prices do not equalize. Changes in output markets such as productivity growth or demand shifts lead to changes in price ratios of traded and nontraded goods that determine the exchange rate.

Balassa (1964), Samuelson (1964) and earlier Harrod (1933) explained the deviation from purchasing power parity in terms of the distinction between traded and non-traded goods. Since all goods are not traded, a non-traded good (services) was introduced into the traditional international trade model. It may be argued that in the absence of trade restrictions, the exchange rate will equate the prices of traded goods, with allowance made for transport costs. Since nontraded goods (services) enter the calculation of purchasing power parities, the PPP between the currencies of the two countries will differ from the equilibrium exchange rate. The country with higher productivity levels (and higher wages assuming wage equals marginal cost) will have costlier services (assuming that internal mobility of labour equalizes wages across the traded and non-traded sectors). The greater are productivity differentials in the production of the traded goods between the two countries, the larger will be differences in wages and in the prices of services, and correspondingly, the larger will be the gap between PPP and the equilibrium exchange rate.

Productivity growth rates differ in the traded and non-traded sectors in the two countries. This leads to changes in the relative prices of traded and non-traded goods in each country. Each country's price level increases both in terms of tradables and non-tradables. International productivity differences can have implications for relative international price levels, that is, for real exchange rates. The Harrod-Samuelson-Balassa effect is a tendency for countries with higher productivity in tradables compared with non-tradables to have higher price levels. More precisely, it can be shown that if a country's productivity growth advantage in tradables exceeds its productivity growth advantage in non-tradables the Harrod-Samuelson-Balassa effect suggests that it will experience a rise in its relative price level or in other words a real appreciation of the exchange rate.

Further, changes in demand lead to changes in the real exchange rate. For instance, a shift in demand in one country away from tradables and towards nontradables raises the relative price of tradables and change in the price ratio leads to change in the exchange rate.

Recently a body of literature has arisen that examines the determination of exchange rates in the spirit of the Balassa- Samuelson theorem. These include Hsieh (1982), Neary (1988), Bergstrand (1991), DeLoach (1997) and Strauss (1999). Real exchange rates are determined by equilibrium conditions in traded and non-traded goods markets. The existence of non-traded goods leads to a breakdown of PPP for all goods and so PPP holds only in the case of traded goods. In other words, this class of literature may be seen as testing PPP for traded goods only. Changes in the real exchange rate are determined by changes in the relative prices of traded and non-traded goods.

3.11. Purchasing Power Parity (PPP)

We now illustrate how the presence of nontradables leads to the failure of PPP in a two country, two good case. We assume that there are two goods: tradables and nontradables. We define P^T to be the price of tradables included in the consumption basket and P^{NT} to be the price of nontradables included in the basket. The overall price level may be then defined as a weighted average of the price of tradables and nontradables. The weights are the proportion of family income spent on the good.

Though the law of one price is not expected to hold in the case of the nontradable good, we assume that it holds for the tradable good. According to the law of one price (assuming no tariffs), the price of tradable expressed in terms of the domestic currency would be the same in the foreign and home country.

$$P^T = E * P^{T*} \qquad (8)$$

The general price level in the home country may be written as an average of the Indian price of tradables and nontradables. Let α be the share of nontradables in a typical consumption basket in the home country. $1-\alpha$ is the share of tradables. The overall price level may be defined as

$$P = (P^{NT})^{\alpha}(P^T)^{1-\alpha} \qquad (9)$$

Similarly for the foreign county if α^* is the share of nontradables in the typical consumption basket, $1-\alpha^*$ is the share of nontradables, the overall foreign price level is

$$P^* = (P^{NT*})^{\alpha^*}(P^{T*})^{1-\alpha^*} \qquad (10)$$

The ratio of the price level of the home and foreign country that underlies the PPP condition is then

$$P/P^* = (P^{NT})^{\alpha}(P^{T})^{1-\alpha} / (P^{NT^*})^{\alpha^*}(P^{T^*})^{1-\alpha^*} \qquad (11)$$

Since the price of tradables in domestic currency are equal in the foreign and home country, we can divide the numerator of the above expression by the price of domestic tradables in the home currency, and the denominator by its equivalent – the price of foreign tradables expressed in the home currency.

We can express the PPP condition in terms of the price of tradables in the home currency. In the long run the exchange rate may be defined as

$$E = (P/P^*) * (P^{NT^*}/ P^{T^*})^{\alpha^*}/ (P^{NT})/(P^{T}))^{\alpha} \qquad (12)$$

The above equation generalizes the PPP theory of the exchange rate by taking into account the relative price of nontradables and tradables in each of the two countries being compared. This generalized model asserts that the long run exchange rate is determined as a multiplicative product of two factors. The first of these factors, the ratio of national price levels, (P/P*) is the one emphasized in the simple version of the PPP. The second factor, the last fraction depends on output market conditions specific to each country. It tells us that given the overall national price levels, the rise in the price of foreign nontradables relative to foreign tradables causes the domestic currency to depreciate. Similarly, a rise in the price of domestic nontradables relative to domestic tradables (P^{NT}/P^{T}) other things being equal, causes the domestic currency to appreciate.

This relation between nominal exchange rates and prices brings us to the concept of the real exchange rate. To define the real exchange rate we refer to a two country example where India is the home country and US the foreign country. The real rupee/dollar exchange rate is the number of typical Indian consumption baskets needed to purchase a typical US consumption basket.

The real Re/$ exchange rate , λ,may be defined as

$\lambda = E * P^*/P$ (13)

In terms of the two country example,

$\lambda = E_{Re/\$} * P_{US}/P_{IND} =$ ((Re/$)*($/US output)/ (Re/Indian output)

= Indian output/US output.

The real exchange rate measures the cost of living in India relative to the US. A rise in the real Re/$ exchange rate (which we call a real depreciation of the Re against the dollar) indicates a relative increase in the US cost of living. A fall in the real Re/$ exchange rate (a real appreciation of the rupee against the dollar) indicates a relative increase in India's cost of living.

According to the absolute PPP theory, the real exchange rate must always equal unity. In other words, $E_{Re/\$} = P_{IND} / P_{US}$ so $\lambda = E_{Re/\$} * P_{US}/P_{IND} = 1$. According to relative PPP, the real exchange rate may not equal 1, but its value, whatever it is, never changes.

Deviations from the PPP (real appreciation or depreciation) that occur in reality may be explained by changes in the relative price of nontraded goods and services and changes in the ratio of tradable goods prices in different countries.

All else remaining equal, a rise in the relative price of US nontradables (P^{NT}_{US}/P^{T}_{US}) raises the cost of living in US relative to India, thereby causing a real depreciation of the rupee against the dollar. In general, this real exchange rate change may be brought about through changes in any of the three prices $E_{Re/\$}$, P_{US} and P_{IND} that enter into the definition of the real exchange rate. If P_{US} and P_{IND} are held constant, a rise in P^{NT}_{US}/P^{T}_{US} must cause $E_{Re/\$}$ to rise. Similarly a rise in P^{NT}_{IND}/P^{T}_{IND} by raising the cost of living in India relative to the US, causes a real appreciation of the rupee against the dollar (and causes the $E_{Re/\$}$ to fall if P_{US} and P_{IND} do not change) .

Given that the real exchange rate depends on the relative prices of nontradables and international differences in the price of tradables, we find that demand and supply changes in output markets move those prices and the real exchange rate. A shift in private or government demand away from tradables and towards nontradables raises the relative price of tradables. The relative price change causes factors of production to move out of the tradables sector and into the nontradables sector, increasing the supply of nontradables and helping to bring the market for nontradables into equilibrium. Less obviously, an increase in spending on both tradables and nontradables is also likely to raise the relative price of nontradables. While the increased demand for tradables can be satisfied by importing more tradables from abroad, the increased demand for nontradables can be satisfied only by producing more tradables at home. The relative price of nontradables P^{NT}/ P^{T} will therefore generally rise.

Suppose, for example, that the demand shifts in favour of nontradables occur in India. The resulting increase in the relative price of Indian nontradables tends to reduce the real exchange rate in both cases (a real appreciation of the rupee). Because the prices of tradables are determined in part in world markets, these prices are likely to be less responsive to purely domestic demand disturbances than prices of nontradables. We therefore assume that an Indian demand shift away from tradables and towards nontradables causes a real appreciation of the rupee.

An increase in productivity in nontradables causes factors of production to migrate from the tradables sector to the nontradables sector. As the supply of nontradables expands relative to the demand for them, their price in terms of tradables falls to maintain market equilibrium. An increase in productivity in tradable industries causes capital and labour to move in the opposite direction, out of nontradables and into tradables. The supply of nontradables, therefore, shrinks and as a result, their relative price rises.

To determine the effects of these supply disturbances on the real exchange rate, we assume that the disturbances occur in India. A productivity increase in Indian nontradables, by lowering P^{NT}/ P^{T}, tends to depreciate the real Re/$ exchange rate. If the price of tradables is set largely in world markets in the long run, a productivity increase in Indian tradables is likely to result in a real appreciation of the rupee.

We therefore identify the long run equilibrium real exchange rate to be determined by the following definition

λ= E * P*/P

where P = $(P^{NT})^{\alpha}(P^{T})^{1-\alpha}$ and P* = $(P^{NT*})^{\alpha^*}(P^{T*})^{1-\alpha^*}$

And assuming P^T=E * P^{T*}

Expressing in logs and substituting in the equation for the real exchange rate it can be shown that

$$\log \lambda = \alpha^* (\log P^{NT}{}^* - \log P^{T*}) - \alpha (\log P^{NT} - \log P^{T}) \tag{14}$$

The equilibrium exchange rate may therefore be expressed as a function of the price ratios of non-traded to traded goods in both the home and the foreign country.

4. Estimation and Results

We assume that in the representative agent's perception β the weight given to the last period's exchange rate, and (1-β) is the weight given to the equilibrium exchange rate. In addition it is assumed that higher liquidity in the period t (D_t) puts a downward pressure on the exchange rate. Adding a stochastic error term to account for other sources of variation, the expected exchange rate for period t+1 may be written as

$$q^e_{t+1|t} = c + (1-\beta)(\alpha * Log(P^{NT*}/P^{T*}) - \alpha Log(P^{NT}/P^{T})) + \beta q_{t-1} + \delta D_t + \varepsilon_t$$

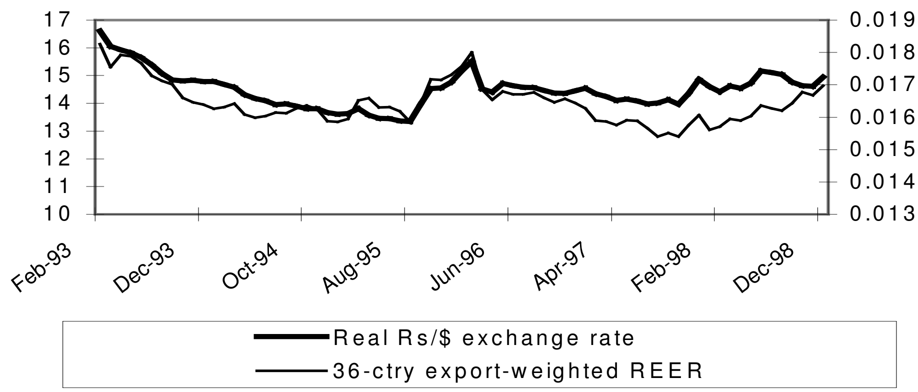
while the current exchange rate has been described as:

$$q_t = c + \delta q^e_{t+1} - \phi(r - r^*) + \varphi\Omega + \gamma\Pi + \rho_t$$

4.1. Data

The model specified above is estimated for the period January 1993 to December 1998. The model developed was a bilateral (rather than a multilateral) model with the US and India as the two countries.

Fig 5 Real exchange rate



Not only is a large component of our trade and capital flows dollar denominated, the dollar is the intervention currency of the RBI. This has clearly been demonstrated not only in the 1993-95 episode when the value of the rupee was kept constant against the dollar for 16 months, but also later whenever there was a pressure on the rupee dollar rate, the RBI intervened to prevent appreciation of the rupee. The other rates in the market are determined broadly by the movement of the dollar against various currencies. Since it is the dollar and not the rupee that is a major currency in international markets, arbitrage ensures that the value of the rupee expressed in yen cannot be significantly different from what the dollar-rupee-yen rate would set it at (apart from some transaction costs). Consequently, a dollar-centric model was chosen as the rupee- yen, rupee-pound, rupee-mark, rupee-franc, rupee-lira etc. rates cannot diverge from the rate determined by international markets for dollar versus other currencies. . Figure 5 shows that the bilateral US India real exchange rate moves broadly with the 36 country real effective exchange rate index.

Since the expected future value of the exchange rate is unobserved, actual lead data is used to measure expected future values assuming that expectations are rational. As the prices of nontraded and traded goods are not published as such, most research in this area proxies these by the consumer and producer price indices. In the same tradition the prices of nontraded and traded goods in India are proxied by the consumer price index for industrial workers (CPI_IW) and the WPI respectively. Similarly, prices for the US are measured by the consumer price index (CPI) and the PPI. Liquidity is measured by reserve bank lending to the central government. Intervention by the central bank (Π) is measured by the net purchase of dollars by RBI in the foreign exchange market. Here we are missing out the component of intervention in the foreign exchange market that the State Bank of India undertakes on behalf of the RBI. No suitable measure for this variable is available as one cannot separate purchase of dollars for normal bank activity from that for the sole purpose of sale and purchase of dollars to influence the rupee.

The nominal interest rate in India is measured by the return on 364-day treasury bills. The foreign interest rate is measured by the one year LIBOR on US dollar deposits. Inflation is measured in terms of the percentage increase in the WPI or PPI for India and the US respectively.

The risk premium is measured by the import cover or the foreign exchange reserves with the Reserve Bank of India scaled by the relevant year's monthly average imports. The source of the data is various monthly bulletins of the Reserve Bank of India (RBI), International Financial Statistics (IMF), the website of the Bureau of Labour Statistics of the US and the Handbook of Statistics published by the Ministry of Industry, Government of India.

4.2. Estimation

The sample period is insufficient to reveal the long run relationship between price ratios in the home and foreign country that underlies the determination of the equilibrium exchange rate. The values of α and are assumed to be 0.5.[ii] The equation for the expected exchange rate is then estimated for the short run parameters. The two equations in the model may be estimated simultaneously or separately. Since simultaneous estimation may lead to compounding of errors we estimate them independently. A restriction is imposed on the coefficients of the 'equilibrium' and the lagged rates in that the sum of their coefficients is one. The equation is estimated using non-linear least squares.[iii]

4.3. Estimation results

Expected Exchange Rate

$$q^{e}_{t+1|t} = -0.14 + \ (1-0.72)(0.5 * Log(P^{NT*} / P^{T*}) - 0.5 * Log(P^{NT} / P^{T}) + 0.72 q_{t-1} \ + 0.07 * D_t + \varepsilon_t$$

(–0.6) (11.9) (11.9) (3.4)

Std. dev. of dep. var. = .039344
Sum of squared residuals = .032624
Std. error of regression = .022066
R-squared = .695475
Adjusted R-squared = .686385
LM het. test = .674047

Current Exchange Rate

$$q_t = 0.56 + 0.8 q_{t+1} - 0.0008 \ (r - r^*) - 0.006 \ \Omega + 0.000001 \ (\Pi) + \rho_t$$

(2.8) (11.45) (-1.25) (-2.9) (0.47)

```
Sum of squared residuals = .018637
Variance of residuals = .278165E-03
Std. error of regression = .016678
R-squared = .869375
Adjusted R-squared = .861577
LM het. test = 3.06098 [.080]
Durbin-Watson = 1.73584 [.050,.267]
```

where $\Omega = \dfrac{\text{Foreign currency assets}}{\text{Average monthly imports}}$

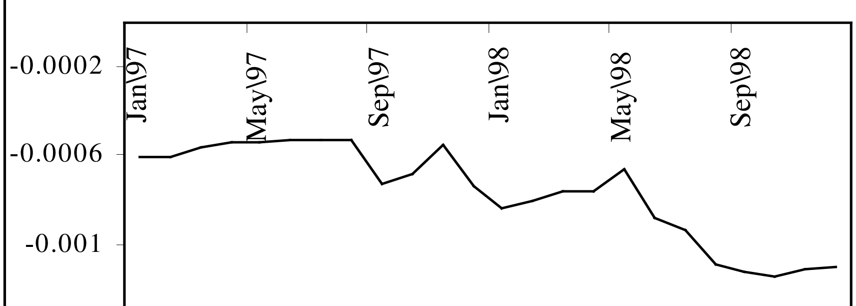
Π= net purchase of dollars by the RBI in the foreign exchange market

The estimation results for the expected exchange rate equation show that when the domestic price of non-traded goods increases, the domestic currency is expected to appreciate. Similarly, when the foreign price ratio of nontradables to tradables increases, the domestic currency is expected to depreciate. Both coefficients are fairly significant. The effect of the lagged exchange rate also has the expected positive sign and is found to be significant. Liquidity in the system is measured by reserve bank credit to the central government. This is also found to be positive and significant. As liquidity in the home country increases, the currency is expected to depreciate.

In the estimation results for the current period exchange rate equation we find that the expected rate is the most significant determinant of the current exchange rate. A high interest rate differential is expected to pull capital in and lead to an appreciation of the domestic currency. The results show the expected negative sign.

The correlation between expected returns on foreign markets and the domestic interest rate has increased due to financial reform in India that has led to greater integration of different segments of financial markets such as money and forex markets. If we estimate the equation recursively we find evidence of this increasing integration. The absolute value of the coefficient increases (note that the coefficient is negative) indicating the increasing importance of capital flows. Figure 1 shows the coefficient of the real interest differential when the equation is estimated recursively. It is first estimated from January 1993 to December 1996 and then the sample is extended month by month to include the period till December 1998.

Fig 1 Coefficient of interest differential (recursive)



The import cover proxies the country risk associated with the home country. Foreign exchange reserves with the central bank represent the country's capacity to import and honor its debt. International creditors such as banks and foreign portfolio investors often monitor the level of foreign exchange reserves available with developing countries to assess the risk of default on foreign debt. The foreign exchange crisis of 1991 in India, when India was on the brink of default reached its peak when reserves fell to only two weeks worth of imports. A comfortable level of reserves that allow a country a few months of import cover, and the capability to service debt represent reduced risk and hence increase confidence in its assets. A fall in reserves would be associated with increase in risk leading to an outflow of short-term capital and eventually a depreciation of the currency. Thus, if the import cover serves as a good proxy for the measure of risk and has a significant impact on the movement of capital and therefore on the short-term equilibrium exchange rate, the sign of the coefficient of import cover should be negative.

Our results suggest that when risk is measured by foreign currency reserves scaled by the average monthly value of imports for that year, the sign of the coefficient is both negative and significant. Thus, if there is a fall in reserves, confidence in the currency reduces, foreign capital, especially short term and portfolio investment, moves out and the rupee depreciates.

Central bank intervention in the foreign exchange market is expected to be yet another source of deviation of the exchange rate from its long run level. The government's objective, for instance, of trying to prevent loss of investor confidence in the currency may lead to attempts to prevent it from depreciating. As long as the pressure is not extreme, a central bank, by direct sale and purchase in the foreign exchange market can, in the short run, determine how the currency moves. In the period after January 1994 when foreign institutional investors were allowed to enter the Indian stock market, the increase in capital inflows put a sharp upward pressure on the rupee. Active intervention in the shape of purchase of dollars, however, kept the value of the rupee constant for sixteen months. Purchase of dollars is expected to increase the value of the dollar by raising its demand. We thus expect a positive correlation between intervention (measured by net purchase of foreign currency) and a movement of the exchange rate.

Estimation results do indicate a positive correlation. However, the coefficient of the intervention term is not significantly different from zero as indicated by its very low t-statistic.

5. Model Performance

A model may be evaluated or its "goodness" tested to see how well it emulates reality. Estimated individual equations can be evaluated by looking at the graphs of actual and fitted values and statistical measures like the R-square, adjusted R-square, etc and indeed, may perform quite satisfactorily. However, when these equations are put together in a model they may not track data very well.

Here the two equations estimated above are put together in a model where the equation for the expected exchange rate feeds into the equation for the current rate. Though the current exchange rate equation has been estimated recursively, for the purpose of the modelling exercise the coefficients are assumed to be constant at the level estimated for the sample ending December 1998. This is because one, the change in the coefficient estimated for the interest differential is very small, two, it is not a smooth function of time but of policy changes and three, it flattens out in the last year of the sample.

The mean errors, RMS error and comparison of actual and predicted data are within acceptable ranges.

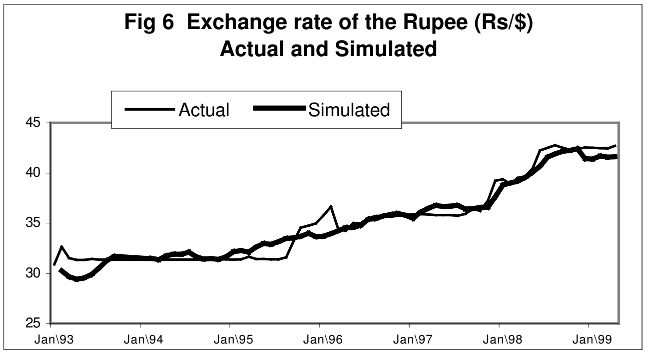
<u>COMPARISON OF ACTUAL AND PREDICTED SERIES</u>

Sample: 1993:2 to 1998:12
Correlation Coefficient = 0.96587
Correlation Coefficient Squared = 0.93291
Root-Mean-Squared Error = 0.94564
Mean Absolute Error = 0.68237
Mean Error = 0.10616
Regression Coefficient Of Actual On Predicted = 1.01635

The model can also be evaluated by comparing the actual and simulated values. When the above two equation model is simulated for the sample period it suggests that during most of 1994-95 the exchange rate was overvalued in comparison to its long run level

(Figure 6). To be in line with the long run equilibrium it should have depreciated. However, because of foreign portfolio capital inflow there was an upward pressure on the rupee. In this period the rupee was kept constant by the RBI. In 1995 the demand for rupees from FIIs reduced. But since the rupee was overvalued, trade deficit rose and put pressure on the rupee. Between May 1995 and May 1996 there was little intervention by the RBI since this time the pressure was downward rather than upward. When the rupee depreciated sharply, there was an overcorrection. For a few months it can be seen that the rupee was undervalued in terms of the long run equilibrium rate. The nominal value of the rupee soon adjusted and it became equal to the equilibrium rate. After this for a few months the rupee moved very little and did not depreciate at a rate that would have kept it at the level that would have ensured equilibrium in the output market. This was followed by another episode of overadjustment after the Pokhran nuclear test in May 1998. The economic sanctions imposed by certain industrial countries, suspension of fresh multilateral lending, downgrading by some international credit rating agencies and reduction in net foreign institutional investment led to a sharp depreciation of the rupee. The foreign exchange market again came under pressure in August 1998, reflecting the adverse sentiment with the deepening of financial crisis in Russia and the fear of devaluation of the Chinese renminbi. Both events were followed by measures by the RBI to stabilise the rupee. The Resurgent India Bonds (RIB) scheme was also launched in August 1998. The RIB scheme was designed to offset the disruption of normal capital flows to India and to counteract the possible adverse sentiments in the international markets due to downgrading of India's sovereign rating. This led to a pressure to appreciate and in contrast to cumulative sales by the Reserve Bank amounting to US $ 2,502 million during May-July 1998 to defend the rupee, the subsequent period from August 1998 to March 1999 witnessed cumulative purchases of US $ 4,143 million. Following that the exchange rate remained until now, by and large, fairly stable.

As the Figure 6 shows the model captures the behaviour of the exchange rate rather well. The rate generated by the model appears to be the underlying rate that determines the movement of the rupee as there is a tendency for the observed exchange rate to return to the path it follows. As expected the market does not move instantly to the output market equilibrium rate as adjustment in the output market is slow. Current account deficit can mount, financed by a draw down of reserves and capital flows.



4.4. Response Characteristics

A structural model like the one presented here allows us to endognize exchange rate responses to changes in fundamentals. A number of factors are exogenous in the model. The model can be used for the purpose of examining the movement of exchange rate that would occur due to a change in these exogenous variables. It is therefore worthwhile to evaluate the response characteristics of the model. The following graphs show the percentage change in the exchange rate due to changes in the exogenous variables.

Figure 7 shows the impact on the exchange rate of the rupee that a 10 per cent increase in the domestic price of non-tradables would have. As expected the increase in the domestic price of non-tradables raises the domestic price ratio of non-traded to traded goods and leads to an appreciation. The exchange rate takes about a year to adjust and stabilises at a new level where the percentage change is just below 3 percent.

Similarly, Fig 8 shows an increase in the foreign price of non-tradables by 10 percent would have the appropriate impact and lead to a depreciation of the rupee. The adjustment takes about a year.

Figure 9 shows the impact of a 2 percent increase in real interest differential on the real and nominal interest rates. As the graph suggests, an increase in the interest differential leads to an appreciation of the rupee. Similarly Figures 10, 11 and 12 show the percentage change in the value of the rupee due to a change in liquidity, central bank intervention and country risk. It is assumed that RBI credit to the central government increases by 10 percent. Figure 10 shows the resulting depreciation in the Re/dollar rate. Fig 11 shows that the impact of net purchase of dollars by the central bank by an additional $10 billion. Fig 12 shows that the depreciation due to a fall in foreign exchange reserves worth 5 months worth of imports.

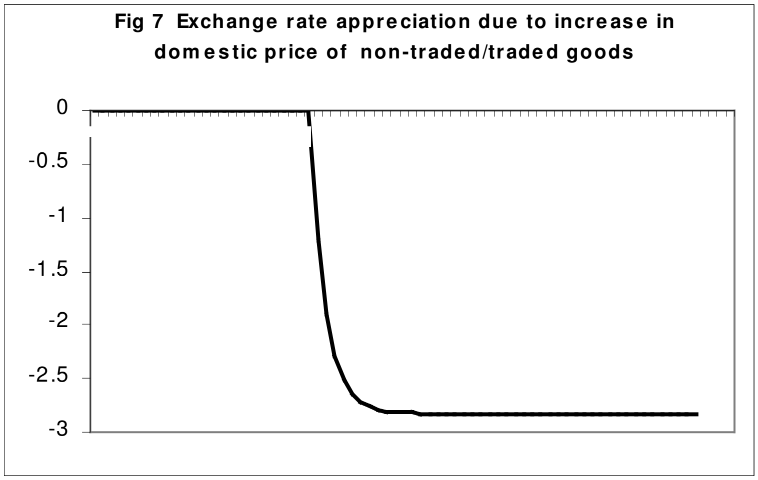


Fig 7 Exchange rate appreciation due to increase in domestic price of non-traded/traded goods
0
-0.5
-1
-1.5
-2
-2.5
-3

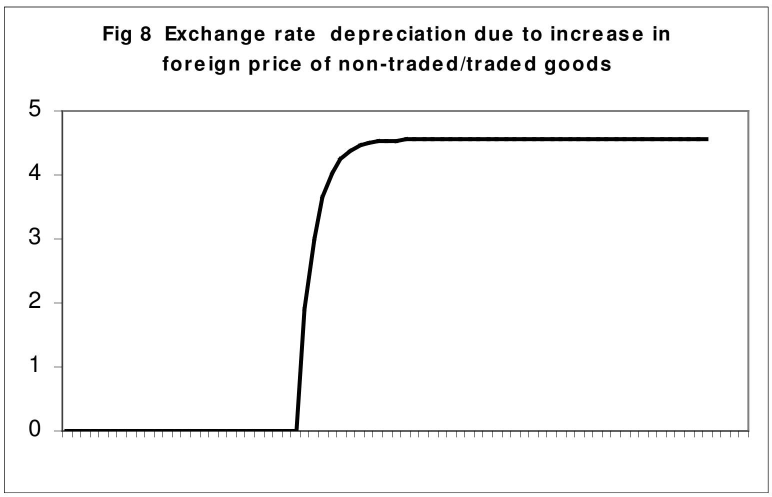


Fig 8 Exchange rate depreciation due to increase in foreign price of non-traded/traded goods
5
4
3
2
1
0

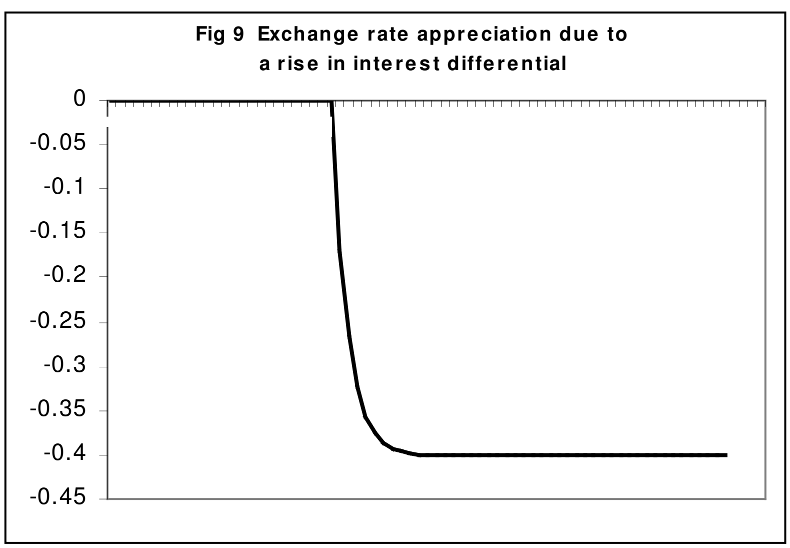


Fig 9 Exchange rate appreciation due to a rise in interest differential
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
-0.45

Fig 10 Depreciation of exchange rate due to increase in public debt

Fig 11 Exchange rate depreciation due to net purchase of dollars by central bank

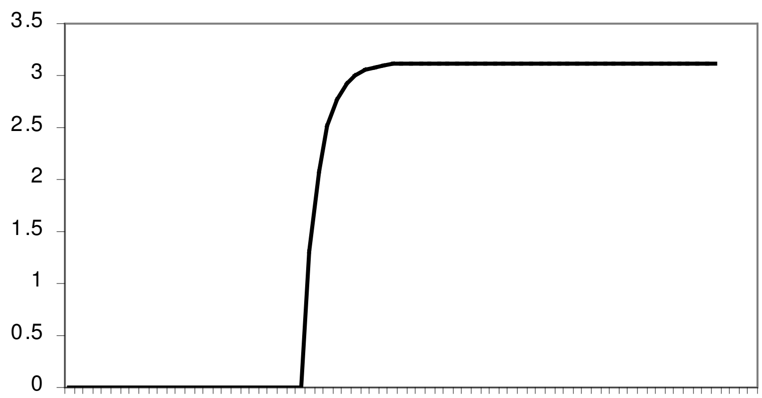
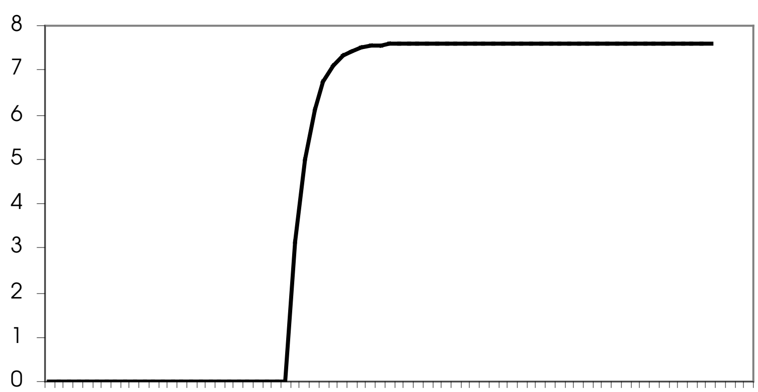


Fig 12 Depreciation of exchange rate due to an increase in country risk



6.Concluding Remarks

As markets are liberalised the rupee's value is increasingly determined by economic forces. Our results suggest that in the nineties the rupee was essentially determined by equilibrium in the output market. However, due to slow adjustments in this market, the exchange rate was not always at the equilibrium rate. Deviations from the output equilibrium rate were common. But despite periods when the rupee was overvalued or undervalued compared to the long run rate, usually in response to forces in financial markets, there appeared to be a clear tendency to revert to the output equilibrium level. Whenever the rupee became overvalued in response to capital inflows it did not take long for a mounting current account deficit to put pressure on it to depreciate.

Sometimes there was an overcorrection and the foreign exchange market witnessed a short spell when the rupee was undervalued. Usually this was short lived because even if this was followed by a period when the nominal exchange rate did not move as India's normally higher inflation rate vis-à-vis the US ensured that the real value of the rupee soon returned to the equilibrium path.

Financial reform has led to increased integration of domestic markets with international money markets. This is revealed by the increasing importance of interest differentials in the determination of the exchange rate. As the reforms proceed this variable is expected to become more important. This process has important policy implications as it leads to loss of monetary policy independence. As the vast theoretical and empirical literature on the European experience under the ERM shows pursuing a policy of managing the exchange rate within a band reducing the options available for monetary policy when the capital account is open. Conflicts may often arise between what are perceived to be the needs of the domestic economy and those arising from exchange rate considerations. Our results show that in India both liquidity conditions and interest differentials play a role in determination of the exchange rate. A recent example of the use of these instruments of monetary policy is the increase in the cash reserve ratio and bank rate in January 1998 to curb volatility in the forex markets despite the danger that tightening liquidity could hurt the real sector that was already facing recessionary conditions. With greater globalisation of financial markets there are likely to be more such conflicts in future.

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[i].Log approximation:

For small changes log (1+x)≈x ; x<<1; $\pi = \frac{P^e - P}{P} \cong \log[1 + \frac{P^e - P}{P}] = \log(\frac{P^e}{P}) = \log P^e - \log P$

[ii] Since we are trying to capture the component of *tradable* rather than *traded* goods, the ratio of export or import to GDP is not appropriate. For instance, only 30 per cent of manufactured goods may be exported but all may be tradable so 0.3 will not be suitable.

The following steps were followed to arrive at the value of domestic and foreign α- the proportion of income spent on non-tradables out of total income of a representative household used in the forecasting model.

i. α and α * were estimated using monthly data for the period January 93-April 99. They violated the theoretical restriction that they must lie between 1 and 0.

Since α and α * must lie between one and zero the model was calibrated over the values 0.1 to 1.0 for each of these. High values of α for US and low values for India gave better results. These were close to 0.87 to 0.9 for the US and close to 0.2 for India. This indicates that the proportion of income spent on non-tradables such as house rent/ mortgage and services is much higher in the US. In India a higher proportion of income is spend on tradables such as food, energy and manufactured products. However, since there were two variables α and α * calibrating the model over different values of the two variables and choosing the model that minimized the sum of errors did not give us a unique solution. This meant there would be a certain arbitrariness in the choice of the values of α and α *. To avoid a bias the values chosen were the mid-point of the theoretically feasible values. I.e. 0.5 that lies half way between 0 and 1 was chosen for both the variables.

[iii] Since the restriction has been imposed in a non-linear manner the estimation was using non-linear least squares. The equation may be rewritten and estimated even in a linear form imposing the restrictions that have been imposed viz. the sum of the coefficent of the equilibrium rate and the lagged rate is the same. Since both methods minimize the sum of squares the results are the same.