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Comparative Analysis of the Portfolio-balance Models of Exchange Rate Determination

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Karnikaa Bhattacharyya[1] and Kaveri Deb[1]

Abstract

The current study conducts a comparative analysis of Portfolio-Balance Models (PBM) developed by Branson, Kouri and Dornbusch to assess the role of expectations and time horizons in determining and forecasting the India–US exchange rate over the period 1996:Q2–2019:Q3. Notably, it improves the original models by integrating microstructure theory into their framework. The Autoregressive Distributed Lag Error-Correction Model (ARDL-ECM) is used to investigate both short run and long run behaviour of the models. Additionally, the study assesses out-of-sample forecasting accuracy of the modified models against the Random Walk Model (RWM) using the root mean square error metric. The estimation results reveal that models based on rational expectations are better than the static expectations model. Notably, the microeconomic determinant is counterintuitively significant only in the long run across all models. Furthermore, these modified models demonstrate superior out-of-sample forecasting abilities compared to RWM for alternative forecasting horizons. However, forecasting results over a 6-month period is better with short run models. Over 1-year and 2-year horizons, rational expectations models outperform the static expectations model. This study challenges the Meese–Rogoff puzzle, ensuring that PBM, when modified to incorporate microstructure theory, is valid and yields superior forecasting results compared to RWM.

JEL Codes: F31, F32, C22

Keywords

Portfolio-balance model, static and rational expectations, microstructure theory, ARDL-ECM approach, forecasting, Meese–Rogoff puzzle

[1] Indian Institute of Information Technology Guwahati, Assam, India

Corresponding author:
Karnikaa Bhattacharyya, Indian Institute of Information Technology Guwahati, Assam 781015, India.
E-mail: karnikaa.bhattacharya@iiitg.ac.in

Introduction

The evolution of exchange rate regimes has garnered considerable attention from economists and policymakers. In the early stages, fixed exchange rate regime was prevalent, where the exchange rate was maintained at a predetermined level by pegging it to gold or another currency. Under this arrangement, fluctuations in macroeconomic variables such as money supply, inflation or interest rates had limited influence over the exchange rate, as any pressure on the exchange rate was countered by making adjustments to the foreign exchange reserve. Previous empirical research conducted by Friedman (1953), Fleming (1962) and McKinnon (1963), as well as more recent work by Subacchi and Vines (2023), has emphasised that fixed exchange rate regime provides exchange rate stability but is susceptible to external shocks due to the restricted impact of macroeconomic factors. As a result of this susceptibility, the fixed exchange rate regime disintegrated, paving the way for the emergence of the floating exchange rate regime. Under the floating exchange rate regime, the exchange rate is determined by the changes in the demand and supply of foreign currency, prompted by macroeconomic variables. However, empirical investigations conducted by Boyer (1978), Henderson (1979) and McKinnon (1981) indicate that the floating exchange rate regime is more effective in managing output instability. Countries experiencing monetary and financial market disruptions may not deem this regime advantageous. The currency crises experienced during the 1990s highlighted the challenges associated with floating exchange rates. In response to this issue, an intermediate exchange rate regime with adjustable pegs and exchange rate bands gained popularity (Hausmann et al., 1999). This regime facilitated adjustments in exchange rates in response to market forces while simultaneously ensuring a measure of stability.

Hence, in light of the varied exchange rate regimes and their empirical outcomes, it remains inconclusive to assert definitively which exchange rate regime is optimal for a given country. Consequently, understanding the nuances of exchange rate regimes becomes imperative in determining the exchange rate of a specific country. The empirical research by Caramazza and Aziz (1998) and Fischer (2001) has indicated a consistent transition from intermediate to floating regimes during the late twentieth century, underscoring the critical role of macroeconomic variables in exchange rate determination. There are diverse approaches to exchange rate determination that consider macroeconomic variables as the determinants of exchange rates. Among these approaches, the portfolio balance approach has gained particular prominence due to its incorporation of a realistic assumption of imperfect asset substitutability. The pioneering work on the portfolio-balance model (PBM) was developed by Branson (1972, 1976). The model was then refined through theoretical adjustments by Dornbusch (1976) and Kouri (1983).

PBM was predicated on the idea that the exchange rate is primarily a macroeconomic phenomenon and shifts in the exchange rate arise as a result of macroeconomic fundamentals (Moosa & Bhatti, 2010). However, an empirical investigation by Meese and Rogoff (1983) has shed light on the limitations of these models for explaining and forecasting short run fluctuations in exchange rates. Meese (1986) rationalised this shortcoming by asserting that, contrary to what the conventional models assume, the exchange rate is not solely determined by macroeconomic fundamentals (especially in the short run). Thus, in light of this limitation, the decade of the 2000s witnessed the emergence of an alternative approach to exchange rate determination, recognised as the microstructure theory of Evans and Lyons (2002).

The microstructure theory emphasises the role of the micro behaviour of participants witnessed in the foreign exchange market along with the macro factors in determining the short run exchange rate. However, the model lacks a comprehensive assessment of macroeconomic fundamentals, as their analysis solely relies on interest rate differentials to represent all the macroeconomic changes (Moosa & Bhatti, 2010).

Therefore, given the inability of both approaches to solely explain the exchange rate fluctuations, the current study modifies the theoretical framework formulated by Branson (1972, 1976), Dornbusch (1976) and Kouri (1983) by integrating the role of the microstructure approach in determining and forecasting the exchange rate between Indian rupee and US dollar. The objective is to access the impact of expectation dynamics and time-frame considerations on the efficacy of these models. Branson (1972, 1976) model relies on static expectations, whereas both Kouri (1983) and Dornbusch (1976) models are grounded on rational expectations. Notably, Branson's (1972, 1976) and Kouri's (1983) models are designed as short run models, while Dornbusch's (1976) model is oriented towards the long run.

The rationale behind analysing the India–US exchange rate by using these models is rooted in India's notable surge in international financial flows and the growing positive interest differential vis-à-vis the rest of the world since 1991. Throughout this period, the Indian rupee has consistently experienced depreciation against the US dollar, marked by short-term fluctuations (Dua & Ranjan, 2010). Hence, understanding the determinants of the exchange rate is essential to comprehending the role of the exchange rate in India's economic interaction with the rest of the world, especially with the US, as the US is India's largest trading partner. However, given the fact that India follows a floating exchange rate regime monitored by the Reserve Bank of India (RBI), the role of the RBI in the foreign exchange market is incorporated into the considered models by means of a variable on capital control. Further, the role of imperfect asset substitutability is explicitly incorporated into the models through a variable on risk premium.

The preliminary data analysis of the current study recommends the usage of the Autoregressive Distributive Lag Error-Correction Model (ARDL-ECM) developed by Pesaran and Shin (1999) and Pesaran et al. (2001) to examine the objective. The model is suitable for analysing the behaviour of exchange rates in both the short run and the long run. The current study also attempts to compare the out-of-sample forecasting accuracy of the modified models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) with the Random Walk Model (RWM).

The current study makes three significant contributions to the literature. First, our analysis reveals that the role of expectations is important in the determination of the exchange rate. Rational expectations models demonstrate superior outcomes compared to models reliant on static expectations. Second, the results reveal an interesting insight into the microeconomic determinants, which, counter-intuitive to the existing literature, is significant only in the long run. Third, the conventional models of the 1970s, when modified to incorporate the microstructure theory, validate the PBM in explaining and forecasting the exchange rate. The findings indicate that the modified models outperform the RWM when predicting outcomes for all the forecast horizons, that is, 6 months, 1 year and 2 years. Hence, our findings with respect to the modified models contradict the observations made by Meese and Rogoff (1983), thus solving the Meese–Rogoff puzzle. Our results are robust to various alternative tests for model fitness.

The rest of the article is organised as follows: The theoretical framework of the three models is developed in the second section, and all pertinent literature is discussed in this section. The third section discusses the econometric techniques used in the current study. The secondary sources of data utilised for the analysis are listed in the fourth section. In the fifth section, we present and discuss the study's findings. The article is summarised and concluded in the sixth section.

Theoretical Framework and Discussion of Relevant Literature

Branson (1972, 1976) Model

The foundational work in the PBM was laid down by Branson (1972, 1976). Before analysing the model, Branson (1972, 1976) made three assumptions: first, that the domestic country is 'small', and hence, it cannot affect the foreign interest rate, which is considered to be exogenously given; second, that the model is based on static expectations as the empirical evidence on rational expectations is unavailable; and third, that the model exhibits short run behaviour, as an increase in the demand for foreign currency will immediately lead to depreciation of the exchange rate to clear the asset market.

Given these assumptions, Branson (1972, 1976) proposed that at a particular time period t, an investor of a domestic country holds their wealth (W_t) in the form of three assets: domestically issued money (M_t), domestic bonds (B_t) that yield a domestic interest rate (i_t) and foreign bonds (F_t) that earn a foreign interest rate (i_t^*).[1] In the short run, the exchange rate of a country is determined by the equilibrium in demand for and predetermined supply of these three assets.[2] Thus, the model focused solely on stock transactions in the capital account to explain changes in exchange rates.

Upon dropping the small-country assumption, according to Bisignano and Hoover (1982), the bilateral exchange rate would become a function of both domestic and foreign assets. The reduced-form equation for bilateral exchange rate determination, as derived by Branson et al. (1977) and Bisignano and Hoover (1982), and considered in the current study, is given by Equation (1):[3]

$$e_t = f\left(M_t, B_t, F_t, M_t^*, B_t^*, F_t^*\right) + w_t \tag{1}$$

In Equation (1), M_t^*, B_t^*, F_t^*, are the foreign money supply, foreign holding of domestic bonds and foreign holding of foreign bonds. W_t represents the random error term.

Later, in the context of foregoing model, Branson (1984) and Diebold and Pauly (1988) suggested the use of relative values in the analysis to avoid the loss in degrees of freedom arising from the inclusion of several variables into the model. Also, we may conjecture that relative values offer a better comparative framework than absolute values. Thus, upon considering relative values, Equation (1) becomes:

$$e_t = f\left(\frac{M_t}{M_t^*}, \frac{B_t}{B_t^*}, \frac{F_t}{F_t^*}\right) + u_t \tag{2}$$

Kouri (1983) Model

Although Branson (1972, 1976) developed the fundamental PBM, it relied on the simplistic assumption of expectations being static. This assumption limits the model's ability to explain exchange rate variations, as it focuses solely on the determinants of capital account flows. Kouri (1983) hence introduced the concept of rational expectations, suggesting that in the short run, exchange rates deviate from equilibrium due to unanticipated current changes or anticipated future changes in the determinants of the current and capital account balances, which represent the macroeconomic fundamentals of an economy. According to the model, the current account is determined by the past exchange rate, current and past values of incomes and price levels of countries.[4] The determinants of capital accounts are the current and past values of money supply and bonds of countries.

Branson (1984) and Diebold and Pauly (1988) modified the foregoing model to represent exchange rate as a function of unanticipated current or anticipated future changes in the exchange rate, relative money supply, relative price levels and relative income of both countries. Diebold and Pauly (1988), however, refrained from including the purchase and sale of bonds as a determinant of the capital account due to the high degree of unreliability associated with data on bonds. Further, they observed that separate inclusion of bonds need not be necessary as the interest income from bonds is a part of total income and hence a determinant of current account balance. Hence, following their arguments, the reduced-form equation for exchange rate determination in the short run is given by

$$e_t = f\left(e_{t-i}, \frac{M_t}{M_t^*}, \frac{P_t}{P_t^*}, \frac{Y_t}{Y_t^*}, + v_t\right) \tag{3}$$

In Equation (3), P_t and P_t^* represent the general price level of the domestic and the foreign nations, respectively. Y_t and Y_t^*, represent the gross domestic product or income of the domestic and foreign nations, respectively. e_{t-i} represents the lagged value of the exchange rate. v_t represents the random error term.

Dornbusch (1976) Model

Although the original model of Kouri (1983) and its subsequent modifications are based on rational expectations, they consider variables such as interest rates and price levels to be exogenously given. The overshooting model of Dornbusch (1976), however, addresses this issue by considering these variables to be endogenous.

The basic framework of the Dornbusch (1976) model relies on the assumptions of small domestic countries, perfect capital mobility, rational expectations, stable monetary conditions, swift adjustments in the financial market and slower adjustments in the goods market.

According to Dornbusch (1976), due to an increase in domestic money supply, there is an instant decline in the domestic interest rate relative to the foreign interest rate adhering to the uncovered interest parity (UIP) condition.[5] The interest rate, thus, acts as an endogenous variable in the money market. This decline in the domestic interest rate results in an immediate outflow of capital to the foreign nation, leading the domestic currency to depreciate and overshoot its long run equilibrium value. This depreciation arises as prices are sticky in the short run. Depreciation of the domestic currency in the short run results in increased demand for domestic goods in the long run. This increase in demand for domestic goods will increase the domestic price level relative to the foreign price level, partially offsetting the initial depreciation of domestic currency. Thus, price level acts as an endogenous variable in the goods market. An increase in price level is equal to the increase in the money supply following the quantity theory of money. Further following the purchasing power theory, the ultimate increase in the exchange rate is proportionate to the increase in prices. Hence, the domestic currency depreciates proportionally to the increase in money supply in the long run.

However, according to Frankel (1979), Dornbusch (1976) disregarded the impact of inflation. Frankel (1979) contends that the exchange rate does not remain constant in the long run, but rather changes over time. This change is expected to occur at a rate equivalent to the long run inflation differential. Moreover, Mossa and Bhatti (2010) challenged the assumption of a small domestic country and advocated for a bilateral analysis to facilitate exchange rate determination. In addition, Salvatore (2014) departed from the assumption of perfect capital mobility and introduced risk premium (RP_t) into the model. Therefore, in alignment with these critiques and modifications, the reduced-form equation for the determination of the exchange rate can be given by[6]

$$e_t = f\left(\frac{M_t}{M_t^*}, \frac{Y_t}{Y_t^*}, \frac{i_t}{i_t^* + RP_t}, \frac{\Delta p_t^{\,e}}{\Delta p_t^{\,e*}}\right) + z_t, \tag{4}$$

In Equation (4), i_t and i_t^* represent the policy interest rates of India and the US, respectively. $\Delta p_t^{\,e}$ and $\Delta p_t^{\,e*}$ represent the change in the general price level in India and the US, respectively. z_t represents the random error term.

Microstructure Approach to Exchange Rate Determination

One of the noteworthy observations about the PBMs developed by Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) is the reliance on macroeconomic fundamentals as a determinant of exchange rate. According to Meese (1986), PBM assumes that the exchange rate is necessarily a macroeconomic phenomenon, and any changes in the exchange rate are solely attributable to macroeconomic factors. However, Evans and Lyons (2002) have emphasised that because these macro factors remain constant in the short run, only macroeconomic factors do not affect the exchange rate. Thus, along with the macro factors, micro factors like behaviour, beliefs and preferences of individuals play a significant role in determining the exchange rate. The theory highlighting the micro behaviour of investors is known as the microstructure approach to exchange rate determination. The key determinants of microstructure approach are order flows, bid-ask spread and turnover in the foreign exchange market (Moosa & Bhatti, 2010). Order flow is the cumulative flow of transactions, which can be positive or negative depending on whether participants in the foreign exchange market are buying or selling when the foreign exchange transaction is first initiated. Order flows represent only actual signed transactions undertaken in the foreign exchange market. It does not consider booking and cancellation of foreign currency in the foreign exchange market (Moosa & Bhatti, 2010). Turnover, on the other hand, being an indicator of trading volume in the foreign exchange market, is a more comprehensive measure, as it considers all transactions associated with purchases, sales, bookings and cancellations of foreign currency or related products (Dua & Ranjan, 2010). Turnover also provides an idea about the bid-ask spread, as an increase in trading volume reduces the bid-ask spread due to falling transaction costs, asymmetries in knowledge and inventory holdings (Dua & Ranjan, 2010).

The microstructure approach, however, does not deny the significance of macro fundamentals in determining exchange rates (Evans & Lyons, 2002). In line with this idea, Evans and Lyons (2002) have created a hybrid model that incorporates interest rate differentials as a representation of macroeconomic determinants, and order flows as a representation of microeconomic determinants to explain fluctuations in exchange rates. However, their model was considered to be incomplete as it did not explicitly take into account all macroeconomic fundamentals like changes in income, money supply, money demand and so on (Moosa & Bhatti, 2010). Hence, in this article, accepting the importance of both macro and microeconomic factors as determinants of currency exchange rate, the considered models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) are modified to incorporate microstructure theory. The determinants of exchange rate in the PBM across all three models will signify macroeconomic fundamentals, while turnover in the foreign exchange market, being a more comprehensive measure of microstructure approach, will determine microeconomic fundamentals.[7]

Before proceeding with the estimation of the modified model, the existing exchange rate regime in India must be taken into account. The exchange rate in India is determined mainly by market forces but with careful intervention and monitoring of the RBI (Dua & Ranjan, 2010). RBI intervenes in the

Indian economy to reduce volatility from sudden surges or deficits in capital flows. However, a sudden surge in capital inflows will increase the supply of foreign currency, leading to an appreciation of the Indian rupee. Appreciation, however, is not preferred in a developing country like India, as appreciation may reduce exports and enhance imports, thus creating a deflationary situation in the economy. Hence, to avoid such a scenario, RBI carries out sterilised intervention by capping the government securities and corporate bonds to subdue the effects of capital inflows on the exchange rate (Raj et al., 2018). Such sterilised intervention is explained by the current study by considering a variable on capital control into all the models.[8]

Given the assumption of imperfect substitutability between domestic and foreign assets and the associated risks with foreign investments, a volatility index (VIX) is incorporated into the modified model to assess the effect of risk premium on exchange rate changes.[9]

The modified models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976), finally considered for analysis in this article, are thus represented by the reduced-form Equations (5), (6) and (7), respectively:

$$e_t = f\left(\frac{M_t}{M_t^*}, \frac{B_t}{B_t^*}, \frac{F_t}{F_t^*}, MB_t, CC_t, VIX_t\right) + u_t \tag{5}$$

$$e_t = f\left(e_{t-i}, \frac{M_t}{M_t^*}, \frac{P_t}{P_t^*}, \frac{Y_t}{Y_t^*}, MB_t, CC_t, VIX_t\right) + v_t \tag{6}$$

$$e_t = f\left(\frac{M_t}{M_t^*}, \frac{Y_t}{Y_t^*}, \frac{i_t}{i_t^* + VIX_t}, \frac{\Delta p_t^e}{\Delta p_t^{e*}}, MB_t, CC_t\right) + z_t \tag{7}$$

Expected Outcomes from Equation (5)

The expected effects of the considered variables on the spot exchange rate between Indian rupee and the US dollar are explained in the following paragraphs.

Following Moosa and Bhatti (2010), the effects of an increase in the Indian money supply (M_t) as a result of monetary policy of India can be explained in a general equilibrium model portfolio balance. An increase in money supply via open market purchase of domestic bonds will lead to a lower interest rate, given the money demand. Therefore, at each level of exchange rate, the interest rate will be lower in the money market. As the monetary authority purchases domestic bonds, the supply of bonds will also decrease in the bond market, given the demand. A decrease in the supply of domestic bonds leads to an increase in the price of bonds. As there is a negative association between price of bond and domestic interest rate, increase in price of bonds leads to a fall in the domestic interest rate. Thus, at each level of exchange rate, the interest rate will be lower in the domestic bond market. These changes in the money market and domestic bond market will lead to an increase in the exchange rate and a decrease in the interest rate in the general equilibrium model. The effects of an increase in money supply by the monetary authority via an open market purchase of foreign bonds have similar effects as the previous case, resulting in an increase in the exchange rate and decrease in the domestic interest rate in the general equilibrium model. Thus, overall, increases in money supply by the monetary authority lead to increases in the exchange rate in the short run.

An increase in the US money supply (M_t^*) as a result of the monetary policy of the US by means of similar tools will have similar effects on the US economy. Thus, an increase in the US money supply results in depreciation of the US dollar and simultaneous appreciation of the Indian rupee in the short run. Hence, the effect of relative money supply $\left(\frac{M_t}{M_t^*}\right)$ on the exchange rate could be dual in the short run.

In the long run, the balance of payment (BOP) must be in equilibrium. If there is a depreciation (appreciation) in the short run, it will eventually lead to a current account surplus (deficit). Thus, to balance the BOP, the current account surplus (deficit) must fall. A fall in the current account surplus (deficit) must be matched by a simultaneous rise in the capital account surplus (deficit), leading to an appreciation (depreciation) of the exchange rate in the long run. Therefore, the effect of relative money supply $\left(\frac{M_t}{M_t^*}\right)$ on the exchange rate will also be dual in the long run.

An increase in Indian bonds can lead to either an appreciation or depreciation of domestic currency depending upon the relative strength of substitution or wealth effect. The substitution effect arises when an increase in domestic bonds leads to a rise in domestic interest rate, encouraging further capital inflows and hence domestic currency appreciation. An increase in domestic bonds will also lead to an increase in the wealth of the people, which will further raise the demand for foreign bonds, resulting in an increase in foreign currency demand and therefore depreciation of the domestic currency. This is the wealth effect of an increase in domestic bonds (Moosa & Bhatti, 2010). Thus, given the wealth and substitution effect, the effect of relative Indian bond holding $\left(\frac{B_t}{B_t^*}\right)$ on the bilateral exchange rate will be dual in the short run. In the long run, the exchange rate may either appreciate or depreciate depending upon whether the domestic currency has depreciated or appreciated in the short run.

Depending upon the relative strength of the substitution and the wealth effect, an increase in US bonds can also lead to an appreciation or a depreciation of the domestic currency in both the short run and the long run. Hence, the effect of relative US bonds holding $\left(\frac{F_t}{F_t^*}\right)$ on the bilateral exchange rate will be dual.

The exchange rate may rise or fall in response to an increase in turnover in the foreign exchange market (MB_t). Increased sales of foreign currency will cause the Indian rupee to appreciate, while increased purchases of foreign currency will cause the Indian rupee to depreciate. The final impact on the exchange rate will be determined by the relative strength of foreign currency purchases over sales in the short run. Nevertheless, if there is depreciation (appreciation) in the short run, it will lead to a current account surplus (deficit). Thus, to balance the BOP, there will be an appreciation (depreciation) of the exchange rate in the long run.

The demand for and supply of foreign currency would decline if the RBI tightened controls on capital inflows and outflows (CC_t). A currency will depreciate (appreciate) if the decline in supply outweighs (fall behind) the decline in demand. The consequent impact on the exchange rate will thus depend on the relative fall in the supply and demand for foreign currency in the short run. In the long run as well, the exchange rate will appreciate if the fall in supply outweighs the demand for foreign assets in the short run, and vice versa.

The value of the volatility index (VIX_t) will rise with an increase in risk perception or economic uncertainty. This can lead to a decrease in demand for foreign currency as Indian investors become more hesitant to invest in foreign markets due to the increased uncertainty. Additionally, a decrease in income due to volatility in foreign markets can lead to a decrease in the supply of foreign currency as foreign investors have less money to invest in India. If the fall in demand for foreign currency is less (more) than the fall in supply, then there is depreciation (appreciation) of the Indian currency in the short run. Again, if there is depreciation (appreciation) in the short run, it will result in a current account surplus (deficit), leading to appreciation (depreciation) of the exchange rate in the long run.

Expected Outcomes from Equation (6)

If the lagged exchange rate (e_{t-i}) depreciates, there will be excess supply in the asset market and a simultaneous current account surplus, leading to an appreciation of the exchange rate in the short run. In the long run, however, the lagged exchange rate does not affect the current exchange rate. The reason is that, given rational expectation, the stochastic element present in the lagged exchange rate will be eventually anticipated by the investors. Therefore, the effect of the lagged value of the exchange rate is not included in our long run analysis.

An increase in the Indian money supply (M_t) will induce a current account deficit on the one hand and an increase in demand for foreign assets on the other. In both cases, the exchange rate will depreciate in the short run. In the long run, however, the ultimate effect on the exchange rate will depend upon the relative strength of current account deficit and the excess demand for foreign assets. Similar impacts on the US economy will arise from an increase in the US money supply (M^*_t). As a result, the changes in relative money supply $\left(\frac{M_t}{M^*_t}\right)$ may have a dual impact on the exchange rate, both in the short run and the long run.

An increase in the Indian price level (P_t) will increase the demand for imports given the exports, and therefore a current account deficit in the domestic economy. This will result in immediate depreciation of the Indian rupee vis-à-vis the US dollar in the short run. As the price level does not affect the asset market, given the current account deficit, the exchange rate will depreciate in the long run as well to maintain the BOP equilibrium. An increase in the US price level (P^*_t) will have similar effects on the US economy. Hence, the effect of relative price level $\left(\frac{P_t}{P^*_t}\right)$ on the exchange rate could also be dual in both the short run and the long run.

An increase in Indian income (Y_t) will also induce a current account deficit and an increase in demand for foreign assets. Therefore, the effects of increase in domestic income in both the short run and the long run can be analysed in a manner similar to the increase in domestic money supply. Similar repercussions on the US economy will result from an increase in US income (Y^*_t). Therefore, the exchange rate's response to the relative income $\left(\frac{Y_t}{Y^*_t}\right)$ may likewise be dual in both the short run and the long run.

The effects of turnover in the foreign exchange market, capital control and the VIX will be similar to the static model.

Expected Outcomes from Equation (7)

The expected effects of the relative money supply $\left(\frac{M_t}{M^*_t}\right)$, relative income $\left(\frac{Y_t}{Y^*_t}\right)$, are similar to the Kouri (1983) model, while turnover in the foreign exchange market (MB_t) and the capital control variable (CC_t) are similar to the Branson (1972, 1976) model of exchange rate determination, which has already been discussed in the previous subsection.

If there is an increase in the Indian interest rate (i_t), assuming all other variables to be constant, there will be an inflow of foreign capital to India. This will lead to the appreciation of the Indian rupee in the short run. Conversely, if the US interest rate compensating for risk-premium ($i^*_t + VIX_t$) is increased, there will be outflow of capital from the domestic country to the foreign country, resulting in depreciation of the Indian currency. Thus, the resultant effect of the relative interest rate inclusive of risk premium $\left(\frac{i_t}{i^*_t + VIX_t}\right)$ is dual in the short run. Again, if there is depreciation (appreciation) in the short run, it will result in a current account surplus (deficit), leading to appreciation (depreciation) of the exchange rate in the long run.

Finally, as a change in the price level is a long-run phenomenon, it will solely influence the current account flows. An increase in price level in India induces a current account deficit as people tend to import more from the US. Moreover, exports of India also fall given the price rise in India. This will lead to the depreciation of the Indian rupee. Conversely, a price level increase in the US yields the opposite outcome, leading to an appreciation of the Indian rupee. The resultant effect of the relative change in price level $\left(\frac{\Delta p_t^{e}}{\Delta p_t^{e*}}\right)$ is therefore also dual.[10]

We may thus summarise the expected outcomes from all three models in Table 1.

Table 1. Summary of Expected Outcomes.

Branson (1972, 1976) (Equation (5))		Kouri (1983) (Equation (6))		Dornbusch (1976) (Equation (7))	
$\ln\left(\frac{M_t}{M_t^*}\right)$	±	$\ln\left(\frac{M_t}{M_t^*}\right)$	±	$\ln\left(\frac{M_t}{M_t^*}\right)$	±
$\ln\left(\frac{B_t}{B_t^*}\right)$	±	$\ln\left(\frac{Y_t}{Y_t^*}\right)$	±	$\ln\left(\frac{Y_t}{Y_t^*}\right)$	±
$\ln\left(\frac{F_t}{F_t^*}\right)$	±	$\ln\left(\frac{P_t}{P_t^*}\right)$	±	$\ln\left(\frac{i_t}{i_t^* + VIX_t}\right)$	±
$\ln(MB_t)$	±	$\ln(MB_t)$	±	$\ln\left(\frac{\Delta p_t^{e}}{\Delta p_t^{e*}}\right)$	±
$\ln(CC_t)$	±	$\ln(CC_t)$	±	$\Delta\ln(MB_t)$	±
$\ln(VIX_t)$	±	$\ln(VIX_t)$	±	$\Delta\ln(CC_t)$	±

Econometric Methods

For analysis, the variables are transformed using natural logarithms to stabilise variance and achieve a more normal distribution. This enhances the reliability and interpretability of the model results. Additionally, to mitigate the impact of seasonality and prevent spurious correlations, the variables are seasonally adjusted using the moving average method in EViews before estimating the model.

To determine the order of integration of the variables, we use the augmented Dickey–Fuller (ADF) test. If the variables are integrated of mixed orders, that is, of orders 0 and 1, then the ARDL model will provide the best fit (Pesaran & Shin, 1999; Pesaran et al., 2001). However, this model will not be applicable if any of the variables are integrated of order 2. In the current study, we employ the ARDL technique since we found our variables to be integrated into orders 0 and 1.[11]

Equation (8) gives the general specification of the ARDL model, which is used in the current study:

$$y_t + \sum_{i=1}^{p}\gamma_{1i}y_t = \gamma_0 + \sum_{i=0}^{q_1}\gamma_{2i}x_{1t} + \sum_{i=0}^{q_2}\gamma_{3i}x_{2t} + \sum_{i=0}^{q_3}\gamma_{4i}x_{3t} + \sum_{i=0}^{q_4}\gamma_{5i}x_{4t} + \sum_{i=0}^{q_5}\gamma_{6i}x_{5t} + \sum_{i=0}^{q_6}\gamma_{7i}x_{6t} + \varepsilon_{1t} \tag{8}$$

In Equation (8), ε_{1t} is the disturbance term representing unobserved factors that affect the exchange rate, but are not accounted for by the included variables. The dependent variable is represented by y, while the independent variables are represented by $x_1, x_2, ..., x_6$ for Equations (5), (6) and (7). The lag length of the dependent variable is represented by p, while q_1, q_2, q_3, q_4, q_5 and q_6 represented the lag lengths of the independent variables. The lag lengths of the dependent and independent variables in the current study are selected by means of Bayesian information criterion (BIC). BIC is a statistical measure that balances the goodness-of-fit of the model with its complexity. The lag length that minimises the BIC is selected as the optimal lag length. According to Pesaran and Shin (1999), BIC performs better than the Akaike Information Criterion (AIC) when the sample size is small, which is the case in the current study. The BIC criteria indicate that the ARDL models (2,2,0,0,1,1,0), (2,2,1,0,0,1,0) and (2,2,2,2,0,1,1) are suitable for examining Equations (5), (6) and (7), respectively.

Since the ARDL model permits the examination of both short run and long run dynamics, it is important to assess whether the variables are cointegrated before estimating the model. The ARDL bounds tests for cointegration are used for this purpose. Cointegrated variables suggest the existence of a long run relationship among them. Non-cointegrated variables suggest short run behaviour of the model.

Our bounds test result reports the presence of cointegration among the variables.[12] Hence, we proceed by estimating the long run model presented in Equation (9) by means of Ordinary Least Squares (OLS), and obtaining the residual from it. The estimated residual is known as the error correction term (ECT). The first lagged value of the estimated residual (ECT_{t-1}) is then considered to estimate the ARDL-ECM model presented by Equation (10).

$$y_t = \pi_0 + \pi_1(x_{1_t}) + \pi_2(x_{2_t}) + \pi_3(x_{3_t}) + \pi_4(x_{4_t}) + \pi_5(x_{5_t}) + \pi_6(x_{6_t}) \tag{9}$$

$$\begin{aligned} \Delta(y_t) = \alpha_0 &+ \sum_{i=1}^{p}\alpha_{1i}\Delta(y_{t-i}) + \sum_{i=0}^{q_1}\alpha_{2i}\Delta(x_{1t-i}) + \sum_{i=0}^{q_2}\alpha_{3i}\Delta(x_{2t-i}) + \\ &\sum_{i=0}^{q_3}\alpha_{4i}\Delta(x_{3t-i}) + \sum_{i=0}^{q_4}\alpha_{5i}\Delta(x_{4t-i}) + \sum_{i=0}^{q_5}\alpha_{6i}\Delta(x_{5t-i}) + \\ &\sum_{i=0}^{q_6}\alpha_{7i}\Delta(x_{6t-i}) + \alpha_8 ECT_{t-1} + \varepsilon_{2t} \end{aligned} \tag{10}$$

The coefficient of ECT_{t-1} (α_8) in Equation (10) reports the speed of adjustment, which assesses how quickly the exchange rate returns to its long run equilibrium value. α_8 must be negative and significant to ensure a long run convergence of the variables. The other coefficients represent the short run association among the variables, and the consideration of log transformation of variables enables us to assess the elasticity of exchange rate due to changes in independent variables.

To account for any heteroscedasticity and autocorrelation in the data, all the models are estimated with a robust estimate of standard errors. We then test for the presence of autocorrelation, stability of the model and normality of the residuals using the Breusch–Godfrey LM test, Cumulative Sum of Recursive Residuals (CUSUM) Test and Jarque–Bera Normality test, respectively. The current study also checked for the endogeneity of the variables. According to Pesaran and Shin (1999), Nkoro and Uno (2016) and Jalil et al. (2011), endogeneity is less of a concern if the appropriate lag lengths for the variables are selected, and if the model is free from serial correlation. Nevertheless, we subject our model to the Ramsey RESET test to ensure there are no specification errors in our models. Ramsey RESET test is a general test of specification errors that considers omitted variables, incorrect functional forms and simultaneity issues while testing for specification errors (IHS Markit, 2020). Multicollinearity is less of a concern in our model, as, following Shabbir et al. (2019), the degree of data differencing used in the ARDL model tends to decompose model residuals and eliminate multicollinearity.

Following the estimation and the robust diagnosis of the modified models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976), the current study conducts out-of-sample forecasting on these modified models and compares it to the RWM with drift. The RWM with drift is a simple forecast model that assumes that current or future values of a variable (y_t) are primarily determined by their past values (y_{t-1}) and a random error term (ε_{5t}) (Gujarati & Porter, 2009). This model incorporates a linear trend or drift (α), which allows it to capture a gradual, long-term movement in the variable over time in addition to the random fluctuations.[14] The RWM with drift is represented in Equation (11):

$$y_t = \alpha + y_{t-1} + \varepsilon_{3t} \tag{11}$$

For forecasting, the dataset is split into two distinct time frames. The period from 1996Q2 to 2017Q3 is used for estimating the modified models and the RWM. The subsequent period, spanning from 2017Q4 to 2019Q3, is dedicated to forecasting using these models. The analysis includes three different forecast horizons vis-à-vis short-period, medium-period and long-period, specifically covering 6 months, 1 year and 2 years, respectively. The accuracy of these forecasts is measured using the root mean square error (RMSE) metric, following Meese and Rogoff (1983) and Moosa and Burns (2014). If the RMSE of the out-of-sample forecasts produced by the modified models is lower than those of the RWM, it signifies that the modified models demonstrate stronger forecasting capabilities.

The measure of RMSE is given in Equation (12):

$$RMSE = \sqrt{\sum_{i=1}^{n} \frac{(y_t - \hat{y}_t)^2}{n}} \tag{12}$$

y_t represent actual value of the exchange rate. $\hat{y}_t$ represent the predicted value of the exchange rate. n is the number of observations.

Data

The study uses quarterly time series data from 1996Q2 to 2019Q3. M3, GDP (at current prices) and policy interest rates are used to measure the money supply, income and interest differential, respectively, for both countries, while the consumer price index (with 2015 as the base year) is used to measure price level and change in price level. Data for these variables are obtained from the Federal Reserve Economic Data (FRED) database. Data on US holdings of US bonds have also been collected from FRED. Data on Indian holding of Indian bonds have been obtained from FRED and RBI. At first, data on general government gross debt for India are collected from FRED. Then, external debt of India, comprising of total government borrowing, is collected from RBI. Finally, the external debt comprising of total government borrowing has been deducted from the general government gross debt for India to calculate the Indian holding of Indian bonds. Data on Indian holding of US bonds and US holding of Indian bonds have been collected from the US Department of the Treasury. Turnover in the foreign exchange market and the rupee/dollar spot exchange rate data are taken from the Handbook of Statistics published by RBI. Capital control data are collected from the FKRSU dataset prepared by Fernandez et al. (2016). Data on VIX are obtained from the Chicago Board Options Exchange (Cboe).

Results and Discussion

Table 2 displays the ARDL-ECM representation of the estimated short run and the long run coefficients with associated p values for modified models of Branson

Table 2. The Estimated Short-run and the Long-run Coefficients of the Modified Models.

	Coefficient (p Value)		
Variables	Branson (1972, 1976) (Equation (5))	Kouri (1983) (Equation (6))	Dornbusch (1976) (Equation (7))
Short-run Estimates			
c	–0.548*** (<.0001)	0.306*** (<.0001)	–0.867*** (.0001)
$\Delta \ln(e_{t-1})$	–0.392*** (<.0001)	–0.192*** (.0013)	–0.372*** (<.0001)
$\Delta\ln\left(\frac{M_t}{M_t^*}\right)$	–0.717*** (<.0001)	–0.314*** (<.0001)	–0.311*** (<.0001)
$\Delta\ln\left(\frac{M_{t-1}}{M_{t-1}^*}\right)$	–0.437*** (<.0001)	–0.218*** (<.0001)	–0.172*** (.0005)
$\Delta\ln\left(\frac{Y_t}{Y_t^*}\right)$	–	–5.466*** (<.0001)	–5.888*** (<.0001)
$\Delta\ln\left(\frac{Y_{t-1}}{Y_{t-1}^*}\right)$	–	–	–1.926** (.0111)
$\Delta\ln\left(\frac{i_t}{i_t^* + VIX_t}\right)$	–	–	–0.004 (.1237)

(Table 2 continued)

(Table 2 continued)

Variables	Coefficient (p Value) Branson (1972, 1976) (Equation (5))	Kouri (1983) (Equation (6))	Dornbusch (1976) (Equation (7))
$\Delta\ln\left(\frac{i_{t-1}}{i^*_{t-1}+VIX_{t-1}}\right)$	–	–	–0.008** (.0171)
$\ln(MB_t)$	–0.020 (.1010)	–	0.008 (.3968)
$\Delta\ln(CC_t)$	0.357** (.0407)	0.330*** (.0081)	0.447*** (.0004)
ECT(–1)	–0.065*** (<.0001)	–0.151*** (<.0001)	–0.058*** (<.0001)
Long-run estimates			
$\ln\left(\frac{M_t}{M^*_t}\right)$	–0.762* (.0653)	–0.155 (.1243)	–1.133** (.0349)
$\ln\left(\frac{B_t}{B^*_t}\right)$	0.023 (.7224)	–	–
$\ln\left(\frac{F_t}{F^*_t}\right)$	–0.118* (.0969)	–	–
$\ln\left(\frac{Y_t}{Y^*_t}\right)$	–	–6.988*** (<.0001)	–8.895*** (.0001)
$\ln\left(\frac{P_t}{P^*_t}\right)$	–	0.511*** (<.0001)	–
$\ln\left(\frac{i_t}{i^*_t+VIX_t}\right)$	–	–	0.064** (.0247)
$\ln\left(\frac{\Delta p_t^{\ e}}{\Delta p_t^{\ e*}}\right)$	–	–	–0.032*** (.0090)
$\ln(MB_t)$	0.373** (.0256)	0.088** (.0373)	0.637*** (.0039)
$\ln(CC_t)$	–2.679 (.1623)	–0.602 (.3260)	0.239 (.8635)
$\ln(VIX_t)$	0.026 (.7015)	0.037* (.0781)	–
R-squared	0.859	0.928	0.939
Adjusted *R*-squared	0.849	0.923	0.932
F-statistic	86.708	184.103	126.042
Prob(*F*-statistic)	<0.0001	<0.0001	<.0001

Notes: ***Indicates significance at 1% level, **indicates significance at 5% level and *indicates significance at 10% level. Figures in parentheses represent the *p* values. A total of 92 observations are included after adjustments.

(1972, 1976), Kouri (1983) and Dornbusch (1976), as represented by Equations (5), (6) and (7), respectively.

In Table 2, the coefficient for the speed of adjustment parameter, ECT(–1), is highly significant (at the 1% level) and negative across all the models. This indicates the presence of a long run relationship among the variables. The value of the coefficients of ECT(–1) of modified Branson's (1972, 1976) model (Equation (5)) is –0.065, which suggests that approximately 6.5% of the deviations from equilibrium resulting from shocks in the previous quarter will be adjusted, leading the model to revert to equilibrium in the current quarter, respectively. The corresponding values for the coefficients of ECT(–1) from Equations (6) and (7) can be similarly explained.

The coefficient for the exchange rate across all the models demonstrates significance at the first lag, showing a negative association. Thus, a 1% increase in exchange rate changes from the previous period leads to 0.39%, 0.19% and 0.37% appreciations in the short run exchange rates for the three respective models.

The coefficients for macroeconomic variables considered in the PBM, based on rational expectations, are all statistically significant, whether in their current forms, lagged forms or both, in the short run. The static expectations model, however, in the short run generates significant coefficients for not all macroeconomic variables considered.

Interestingly, the micro variable, that is, the turnover in the foreign exchange market, is found to be significant in none of the models under study in the short run.

The capital control coefficient is found to be significant in the current period, with a positive sign in all the models depicting the importance of RBI's terilised intervention in the short run.

Noticeably, the difference coefficients of the variables whose optimal lag lengths are zero are not reported by EViews. Such variables in the modified Branson's (1972, 1976) model are relative holding of Indian bonds, the relative holding of US bonds and the VIX. In the modified Kouri's (1983) model, relative price level, turnover in the foreign exchange market and the VIX have zero optimal lag lengths. In the modified Dornbusch (1976) model, relative change in the price level has zero optimal lag length. However, the impacts of such variables are still reflected through the constant terms, which are found to be statistically significant across all the models.

Table 1 also reflects that in the long run, all the considered macroeconomic variables can explain the exchange rate for the modified model of Dornbusch (1976) only. For the other PBM models, some of the macroeconomic variables generate statistically insignificant coefficients.

Counter-intuitive to all existing literature, a positive association between turnover and exchange rate is found by the current study across all three models, which implies depreciation of Indian currency due to higher turnover, with the purchase of foreign currency exceeding sales.

In the long run, the influence of capital control is not significant for any of the modified models. The VIX is found to be significant only in the rational expectations models.

The goodness-of-fit results indicate that all the modified models are well-fitted. Upon conducting a comparative analysis among these models, it is observed that the R-square and adjusted R-square values for the rational expectations models (Dornbusch, 1976; Kouri, 1983) are identical and superior to those of the static expectations model (Branson, 1972, 1976). However, when evaluating the F-statistic for each model, it becomes evident that the modified Kouri (1983) model outperforms the other two models.

All the estimated models are found to be stable on the basis of both the CUSUM and CUSUM of Squares tests.

The models are also assessed for autocorrelation using the Breusch–Godfrey LM test, and the findings are presented in Table 3.

Table 3. Breusch–Godfrey LM Test for Autocorrelation for the Modified Models.

Lags	*F*-statistic	*p* Value of *F*-Statistic	*p* Value of Chi-Square
Branson (1972, 1976) (Equation (5))			
1	1.065641	.3051	.2655
2	1.704596	.1886	.1422
Kouri (1983) (Equation (6))			
1	1.921151	.1697	.1370
2	1.148456	.3225	.2638
Dornbusch (1976) (Equation (7))			
1	0.005839	.9393	.9321
2	0.377629	.6868	.6244

Notes: Null hypothesis: There is no autocorrelation up to lag 2. *** Indicates significance at 1% level, ** indicates significance at 5% level and * indicates significance at 10% level.

According to the information presented in Table 3, there is no autocorrelation in any of the models up to two lags. This is supported by the fact that both the F-statistic and the Chi-square statistic are not significant, indicating that our findings are not affected by endogeneity in the model.

However, as previously mentioned, we use the Ramsey RESET test to assess the possibility of specification errors that could result in regressor endogeneity. Table 4 reports the outcome of this test.

Table 4. Ramsey RESET Test for the Modified Models.

	Branson (1972, 1976) (Equation (5))	Kouri (1983) (Equation (6))	Dornbusch (1976) (Equation (7))
	Value (*p* Value)	Value (*p* Value)	Value (*p* Value)
t-statistic	0.349573 (.7276)	0.486873 (.6277)	0.203499 (.8393)
F-statistic	0.122201 (.7276)	0.237045 (.6277)	0.041412 (.8393)
Likelihood ratio	0.144022 (.7043)	0.279168 (.5972)	0.051471 (.8205)

Notes: Null hypothesis: There is no specification error. *** Indicates significance at 1% level, ** indicates significance at 5% level and * indicates significance at 10% level.

Table 4 shows that the coefficients for *t*, *F* and likelihood ratio statistics are not significant, indicating that all the models are correctly specified and do not have issues related to endogeneity. Lastly, Table 5 reports the outcome of the Jarque–Bera test, which tests for the normality of the residuals in the estimated model.

Table 5. Jarque–Bera Test for the Modified Models.

	Branson (1972, 1976) (Equation (5))	Kouri (1983) (Equation (6))	Dornbusch (1976) (Equation (7))
	Value (*p* Value)	Value (*p* Value)	Value (*p* Value)
Jarque–Bera statistic	0.575383 (.7499)	0.833383 (.6592)	1.440558 (.4866)

Notes: Null hypothesis: The residuals are normally distributed. *** Indicates significance at 1% level, ** indicates significance at 5% level and * indicates significance at 10% level.

According to Table 5, the residuals are normally distributed, which means that the inferences based on *t*- and *F*-statistics are reliable for all the models.

Table 6 reports the forecasting accuracy metrics for the RWM and the modified models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) across three different forecast horizons, specifically at 6 months, 1 year and 2 years.

Table 6. Comparing Forecasting Accuracy Metric.

	Root Mean Square Error			
Time Horizons	Random Walk Model	Modified Branson's (1972, 1976) Model	Modified Kouri's (1983) Model	Modified Dornbusch's (1976) Model
6 months	0.031	0.013$	0.013$	0.016
1 year	0.067	0.023	0.016$	0.022
2 years	0.072	0.031	0.014$	0.025

Note: $ represents the lowest RMSE.

It is evident from Table 6 that across all the forecast horizons, the modified models of Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) report RMSE lower than the RWM, and hence perform better than the latter. The findings hence suggest that all the models exhibit stronger forecasting capabilities in predicting exchange rates over short, medium and long terms. Furthermore, a comparative analysis of the three models highlights that for 6 months, the short run models (Branson, 1972, 1976; Kouri, 1983) have better forecasting abilities than the long run model (Dornbusch, 1976). However, for 1-year and 2-years horizons, the modified model of Kouri (1983) performs the best, followed by Dornbusch's (1976) and Branson's (1972, 1976) models. In effect, the rational expectation models have better predictive power than the static expectation models for longer forecasting horizons.

Summary and Conclusion

In the current study, we have made a comparative analysis of the PBM of exchange rate determination put forth by Branson (1972, 1976), Kouri (1983) and Dornbusch (1976) to evaluate its relevance in the contemporary context. However, certain modifications have been introduced in the original models to accommodate the recent developments in the exchange rate determination framework in the current study. The most significant modification of the current study is the incorporation of the microstructure approach to the exchange rate determination. The original models of portfolio balance approach are based only on the macroeconomic determinants of exchange rate. However, microeconomic factors may have greater influence than macroeconomic factors, particularly in the short run. Hence, we modify the original model by introducing heterogeneous microbehaviour of investors in the foreign exchange market in the form of turnover as a representation of microeconomic factor. Thus, our model significantly contributes to the literature by analysing both micro and macroeconomic determinants of exchange rate. To account for the floating exchange rate regime monitored by the RBI, a variable on capital control is further considered in our model. The risk associated with foreign investments is explicitly considered in our model by a VIX. We have analysed quarterly time series data from 1996 to 2019 to study the exchange rate. We use the ARDL-ECM approach, which enables us to ascertain both the long run and short run behaviours of our models. All the macroeconomic variables are found to be statistically significant in the Dornbusch (1976) model. Contrary to expectations, the microbehaviour of investors is found to have significant influence only in the long run across all models, which could result from the usage of quarterly time series data in our analysis. Daily data perhaps would have been more relevant to study microbehaviour of investors.[14] The capital control variable is also found to exert significant influence in the short run in all the models. Risk premium is not found to be significant in the static expectations model, both in the short and in the long run. The role of expectations is neglected by the static expectations model. Therefore, the model could not comprehend the unexpected behaviour that arises in the form of risk. However, risk premium is found to be significant in the rational expectations model of Kouri (1983) and Dornbusch (1976), but only in the long run. In the rational expectations model, any changes in the exchange rate will arise from an unanticipated behaviour, as people cannot predict any unanticipated behaviour of factors beforehand. As risk is an unanticipated factor, its effect will be reflected in the rational expectations model. However, given the significance of capital control in the short run, the effect of risk is neutralised in the short run. However, in the long run, the economy is eventually exposed to unexpected risks. Our results are robust to various alternative post-estimation tests. However, goodness-of-fit results reveal the superiority of Kouri's (1983) rational expectations model over the other models.

Upon testing the forecasting abilities of the modified models, it is observed that all the modified models perform better than the RWM over all the forecast horizons under consideration. According to Meese and Rogoff (1983), existing exchange rate models could not surpass the RWM at any forecast horizon.[15]

Our findings with respect to the modified models contradict the observations made by Meese and Rogoff (1983). A comparative analysis of the three models reveals that for the short term, the short run models have better forecasting abilities than the long run models. But for longer forecasting horizons, rational expectations models are better than the static expectations model.

On the basis of these findings, the rational expectations PBM of Kouri (1983) can be considered to be the best. However, given the fact that the Dornbusch (1976) model performs almost at par with Kouri (1983) and exhibits the following features: (a) based on long run and rational expectations, and (b) considers endogeneity of interest rate and price level, we may consider the model of Dornbusch (1976) equally reliable for determining and forecasting the exchange rate, particularly for longer time horizons. Hence, we may conclude by recognising that PBM based on rational expectations, when modified to incorporate microstructure theory, can effectively determine and forecast the movements in exchange rate between the Indian rupee and the US dollar.

Data Availability Statement

The data in a consolidated format can be made available from the authors upon request.

Declaration of Conflicting Interests

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ORCID iDs

Karnikaa Bhattacharyya https://orcid.org/0009-0003-9916-8662
Kaveri Deb https://orcid.org/0000-0002-0337-2091

Appendix A

Table A1. Augmented Dickey–Fuller Test for Stationarity of Variables.

	Augmented Dickey–Fuller Test					
	Level			First Difference		
Variables	SC Lag	*t*-Statistic	*p* Value	SC Lag	*t*-Statistic	*p* Value
$\ln(e_t)^{\$\$}$	1	–2.03	.5791	0	–6.87***	<.0001
$\ln\left(\frac{M_t}{M_t^*}\right)^{\$\$}$	2	–1.25	.8931	0	–7.37***	<.0001

(Table A1 continued)

(Table A1 continued)

Variables	Augmented Dickey–Fuller Test					
	Level			First Difference		
	SC Lag	t-Statistic	p Value	SC Lag	t-Statistic	p Value
$\ln\left(\frac{B_t}{B_t^*}\right)^{\$\$}$	0	–1.45	.8380	0	–8.79***	<.0001
$\ln\left(\frac{F_t}{F_t^*}\right)^{\$\$}$	0	–2.48	.3386	0	–10.53***	<.0001
$\ln\left(\frac{Y_t}{Y_t^*}\right)^{\$}$	1	–2.28	.1801	0	–6.36***	<.0001
$\ln\left(\frac{P_t}{P_t^*}\right)^{\$\$}$	2	–1.47	.8328	1	–4.84***	.0008
$\ln\left(\frac{i_t}{i_t^* + VIX_t}\right)^{\$}$	0	–1.48	.5403	0	–8.26***	<.0001
$\ln\left(\frac{\Delta p_t^{e}}{\Delta p_t^{e*}}\right)^{\$}$	0	–9.58***	<.0001	–	–	–
$\ln(MB_t)^{\$\$}$	0	–0.86	.9554	0	–9.83***	<.0001
$\ln(CC_t)^{\$}$	0	–1.79	.3852	0	–9.49***	<.0001
$\ln(VIX_t)^{\$}$	0	–3.32**	.0167	–	–	–

Notes: \$ represents model with intercept but no trend, \$\$ represents model with intercept and trend. ***p < .01, **p < .05, *p < .10. The SC criterion is used for appropriate lag selection in order to conduct the test. Null hypothesis: The variable is non-stationary.

Table A2. ARDL Bounds Test for Cointegration.

F-Bounds Test and *t*-Bounds Test for Modified Models						
	Critical Value at 1%			Critical Value at 1%		
F-statistic	Lower Bound Value, I(0)	Upper Bound Value, I(1)	*t*-statistic	Lower Bound Value, I(0)	Upper Bound Value, I(0)	Decision
Branson (1972, 1976) (Equation (5))						
8.44	3.15	4.43	–6.05	–3.43	–4.99	Cointegration
Kouri (1983) (Equation (6))						
5.08	3.15	4.43	–6.18	–3.43	–4.99	Cointegration
Dornbusch (1976) (Equation (7))						
7.15	3.15	4.43	–7.35	–3.43	–4.99	Cointegration

Notes: The lower and upper bound critical values are considered by Pesaran et al. (2001). If *F*- and *t*-statistics are below I(0), we cannot reject the null hypothesis, suggesting cointegration. If they are above I(1), we reject the null hypothesis, confirming cointegration. Results between I(0) and I(1) are inconclusive.

Notes

1. The foreign interest rate is fixed in the world market, given the assumption that the domestic country is small and cannot influence the foreign interest rate.
2. The supply of the assets is exogenously determined as they remain fixed in the short run.
3. For derivation of the equation of the model, please refer to Branson (1972, 1976), Branson et al. (1977) and Bisignano and Hoover (1982).
4. The current account is a function of past or lagged exchange rate, not the current exchange rate, because any anticipated current events do not affect the current exchange rate under rational expectation. Moreover, according to the definition of rational expectations, people make expectations about the future based on all the available information. Now, as the past exchange rate incorporates information about the stochastic elements of the previous year, lagged values of the exchange rate need to be considered.
5. The UIP condition in Dornbusch (1976) model is based on the assumption of rational expectations, which implies that the interest differential is equivalent to the discrepancy between the long run and current exchange rate.
6. For a detailed analysis of the Equation (4), please refer to Dornbusch (1976), Frankel (1979) and Moosa and Bhatti (2010).
7. The use of turnover is supported by Berger et al. (2005) and Dua and Ranjan (2010).
8. Variable on capital control is constructed by following Fernandez et al. (2016). Interested readers can refer to the same.
9. VIX captures the stock market's expectations of volatility based on S&P 500 index options. S&P 500 index represents a stock market index that tracks 500 publicly traded, large-cap US companies. According to Goyal (2019), VIX is the best measure of risk perception and uncertainty in the US and the global economy.
10. As the change in the price level affects only in the long run, it has no short run impacts.
11. The results for the ADF test are reported in Table A1.
12. Result of bounds test is reported in Table A2.
13. We have employed the RWM with drift because of the noticeable upward trend in the India–US exchange rate.
14. We did not use daily data in our analysis as the data on the price level, GDP, money supply and capital control are not available at a daily frequency.
15. Meese and Rogoff (1983) showed that short-term exchange rate forecasts based on the flexible-price monetary model of Bilson (1978), sticky-price monetary model of Dornbusch (1976) and the PBM of Hooper and Morton (1982) are worse than a naive RWM. This finding is commonly referred to as the Meese-Rogoff puzzle. Over the years, various literature, including works by Kilian and Taylor (2001), Neely and Sarno (2002) and Moosa and Burns (2014), attempted to address this puzzle by introducing other variables to the models, but none succeeded in outperforming the RWM.

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