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An overshooting model of exchange rate determination and forecasting: a threshold regression approach

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Abstract

Purpose – This study examines the impact of structural shocks and policy interventions on the India/US exchange rate post the 1991 economic reforms in India. The study aims to improve forecasting accuracy by incorporating macroeconomic and microeconomic factors into the analysis using the threshold regression model (TRM), a nonlinear approach to estimation.

Design/methodology/approach – Extending Dornbusch's (1976) overshooting model, the study incorporates micro factors, such as investor behaviour, beliefs and preferences, alongside traditional macroeconomic variables. Additionally, it introduces a capital control variable to assess monetary policy interventions. Using quarterly data from 1996Q2 to 2019Q3, TRM identifies two distinct economic regimes, providing a comprehensive understanding of India's exchange rate dynamics.

Findings – The study reveals that macro and micro factors have varying effects on the exchange rate across regimes, reflecting India's different economic conditions and policies. Furthermore, the TRM-based model achieves superior out-of-sample forecasting accuracy compared to the random walk model across all forecast horizons.

Originality/value – Unlike prior studies, where not all variables were deemed significant, our analysis demonstrates that all factors significantly influence the exchange rate. The innovative use of TRM deepens understanding of exchange rate behaviour, particularly in response to structural shocks and policy shifts. By identifying distinct economic regimes, the model offers insights into targeted policy measures tailored to India's economic conditions, a previously unexplored perspective.

Keywords Threshold regression model, Structural shocks, Forecasting, Exchange rate, Rational expectations, Overshooting model

Paper type Research paper

JEL Classification — F31, F32, C22

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1. Introduction

India's economy has become increasingly open over the last three decades, streamlined by the New Economic Policy of 1991. This period has seen significant growth in trade and capital inflows, positioning India among the top five destinations for private equity investment. However, among this trajectory of growth and liberalisation, the Indian economy has experienced several structural shocks necessitating policy interventions, with obvious impacts on the exchange rate. Given India's deepening global integration, it is crucial to understand exchange rate behaviour in the context of economic stability, structural changes due to global shocks and policy interventions.

To analyse the behaviour of the Indian exchange rate, it is necessary to investigate the theoretical models of exchange rate determinations empirically. Theoretical models, such as the purchasing power parity (PPP) model, monetary model, overshooting model and portfolio balance model (PBM), have been extensively analysed in the literature. Empirical studies by Hooper and Morton (1982), Driskill (1992), Nieh and Wang (2005) and Bhattacharyya and Deb (2024a) concluded in favour of Dornbusch's (1976) overshooting model and recognised its advantages: (1) when considering the risk premium, the model functions as a PBM, emphasising the importance of imperfect asset substitutability for a realistic portrayal of exchange rate dynamics; (2) it is grounded in rational expectations theory, which provides a precise representation of how individuals in the economy anticipate future variables, incorporating all available information, historical data and current economic conditions; (3) it accounts for both short-run and long-run relationships between the exchange rate and other variables; (4) it addresses endogeneity by determining variables, such as interest rates and price levels, within the model, a consideration often neglected by other theoretical models.

Existing studies have primarily applied a linear analysis to Dornbusch's (1976) model. However, given the intensity of structural shocks and associated interventions witnessed worldwide, specifically in India since 1991, examining whether exogenous variables behave differently under varying economic conditions is critical.

Hence, this study examines the India/US exchange rate through the lens of Dornbusch's (1976) overshooting model, employing the threshold regression model (TRM) introduced by Tong and Lim (1980). This approach enables the determination of the bilateral exchange rate after accounting for structural shocks and policy interventions in the Indian economy. TRM is well-suited for analysing economic fluctuations, as it examines variables that experience nonlinear changes at critical breakpoints through the nonlinear least squares method. Unlike traditional linear models, which assume consistent relationships, TRM pinpoints key thresholds where significant shifts occur, enhancing model robustness and predictive accuracy (Hansen, 2000). TRM also clarifies interpretation by identifying transition points, aiding decision-making processes and policy formulation. Additionally, TRM acknowledges the existence of heterogeneity within populations, thus offering a more comprehensive analysis of exchange rate dynamics (Hansen, 1999).

Following Bhattacharyya and Deb (2024a), this paper modifies Dornbusch's (1976) model to incorporate the significance of micro factors – such as investor behaviour, beliefs and preferences – alongside macro factors and the influence of monetary authorities in determining the exchange rate.

TRM identifies two distinct regimes in our data for the period 1996Q2–2019Q3. Upon closer inspection, the first regime represents a period of normalcy in the Indian economy, characterised by stable conditions and minimal external shocks. The second regime corresponds to structural changes driven by global shocks and policy measures implemented by the Indian government and the Reserve Bank of India (RBI).

To further evaluate model performance, the modified Dornbusch (1976) model is used for forecasting and compared with the random walk model (RWM).

The current study contributes to the literature in three significant ways. First, unlike previous studies, it demonstrates that all exchange rate determinants are significant. Second, the TRM results across the two regimes reveal how the effects of macro and micro factors on exchange rate behaviour differ between periods of stability and structural shocks. The results also highlight the impact of policy measures by the Indian government and RBI, an aspect not previously explored. Third, the model outperforms the RWM and even surpasses Bhattacharyya and Deb (2024a) in out-of-sample forecasting accuracy across all forecast horizons.

The paper is structured as follows: Section 2 outlines economic development and policies in India since 1991 to explain the use of TRM for our analysis. Section 3 develops the theoretical framework and reviews the relevant literature. The data sources are listed in Section 4. Section 5 details the econometric techniques used. Section 6 presents and analyses the findings. Finally, Section 7 concludes the paper.

2. The story of India

India's post-reform economic performance showcases significant strengths, with an average growth rate of approximately 6% from 1992–1993 to 2001–2002, positioning it as one of the fastest-growing developing nations in the 1990s (Ahluwalia, 2002). Reforms, including full convertibility of the current account in 1994 and capital account liberalisation, boosted India's appeal to foreign investors, resulting in increased exports and capital flows and promoting economic advancement.

However, a closer analysis reveals fluctuations in growth rates over sub-periods. While the economy grew robustly at 6.7% in the first five years post-reform, it decelerated to 5.4% in the subsequent five years, partly due to the 1997 Asian Financial Crisis (Ahluwalia, 2002). The crisis affected investor confidence, exports and capital inflows. India's limited exposure to volatile capital flows, diversified economy, prudent fiscal policies, strong domestic consumption and reforms since the 1990s ensured a relatively quick recovery compared to neighbouring nations.

The economic recovery was evident in the sharp rise of foreign portfolio investments, from US$2 bn in 2001–2002 to US$29 bn in 2007–2008. Foreign direct investment (FDI) also surged, reaching US$34.3 bn in 2007–2008, up from US$6.1 bn in 2001–2002. Simultaneously, Indian corporations expanded into global mergers and acquisitions, leading to some capital outflow. Consequently, two-way flows of portfolio and direct foreign capital grew from 12% of gross domestic product (GDP) in 1990–1991 to 64% in 2007–2008, marking a fivefold increase (Kumar and Vashisht, 2011).

The 2008 global subprime crisis disrupted growth in India due to its increasing integration with the world economy, which made it susceptible to global shocks. While India's banking sector remained largely shielded due to limited foreign operations and low subprime exposure, the crisis impacted India through other channels. Foreign direct and institutional investments reversed significantly, and export demand in key markets declined. The Indian rupee depreciated by 27% against the US dollar between April 2008 and March 2009 due to portfolio outflows and increased foreign exchange demand. Consequently, foreign exchange reserves fell by US$60 bn (Kumar and Vashisht, 2011).

In response to the 2008 crisis, India adjusted its fiscal and monetary policies. The government introduced measures such as employment guarantee schemes, farm loan waivers, commission benefit payments and increased subsidies for food and fertilisers. Meanwhile, RBI injected liquidity by lowering the cash reserve ratio (CRR), statutory liquidity ratio (SLR), repo rate and reverse repo rate (Kumar and Vashisht, 2011). RBI also implemented a forbearance policy, allowing banks greater flexibility in recognising and provisioning for non-performing assets (Department of Economic Affairs, 2021). These measures provided temporary relief and bolstered credit availability, facilitating economic recovery.

As these policies were implemented, India's economic conditions improved, restoring investor confidence. Capital inflows rebounded in 2009Q2, returning to pre-crisis growth. However, this surge was brief and had peaked by 2010Q3. Events such as the US credit downgrade and slowing global growth have led to risk aversion among investors (Muduli *et al.*, 2022). The 2013 taper tantrum worsened the situation, triggering capital outflows as India faced substantial external financing needs due to a growing current account deficit and weakening economic fundamentals (Muduli *et al.*, 2022). Economic growth slowed further after the forbearance policy ended in 2015, followed by structural shifts from demonetisation and the 2017 introduction of the Goods and Services Tax (GST).

Significant fluctuations mark the narrative of India's economic journey since 1991. A simple regression analysis may not adequately capture the complexities and impact of these fluctuations on the exchange rate. Hence, this study employs TRM to analyse each fluctuation and its effect on the exchange rate. This innovative approach enhances exchange rate determination as it sheds light on the policy measures undertaken by the government and RBI in response to these fluctuations.

3. Developing the theoretical framework and associated literature

Dornbusch's (1976) model or the overshooting model, implies that in the short-run, monetary factors exert a significant influence on the exchange rate, leading to overshooting of the exchange rate from its long-run equilibrium level. During this process, the good market remains relatively stable due to price stickiness. Conversely, in the long-run, monetary and goods market variables play pivotal roles in bringing the exchange rate back to its long-run level. The model is based on the assumptions of (1) a small domestic economy; (2) perfect capital mobility; (3) rational expectations; (4) stable monetary conditions; (5) swift adjustments in the financial market and (6) slower adjustments in the goods market.

Dornbusch's (1976) model is rooted in the uncovered interest parity (UIP) condition, which posits that the expected returns on deposits in two different currencies must be equal when expressed in the same currency. Symbolically:

$$\mathrm{i} = \mathrm{i}^{*} + \Delta \mathrm{S}^{e} \tag{1}$$

In Equation (1), i represents the domestic interest rate, i^* represents the foreign interest rate and ΔS^e is the expected change in the exchange rate (S). Furthermore, given the rational expectations, the interest rate differential $(i - i^*)$ is equal to the difference between the long-run exchange rate $(\bar{S})$ and the current exchange rate, i.e. $(\bar{S} - S)$. Thus, based on rational expectations and the UIP condition, Dornbusch (1976) posits that an expansion in the domestic money supply lowers the domestic interest rate relative to the foreign interest rate, making it endogenous in the money market. This decline triggers capital outflows, causing a sharp depreciation of the domestic currency beyond its long-run equilibrium due to short-run price stickiness. Over time, currency depreciation raises domestic income, stimulating demand for domestic goods and increasing domestic prices relative to foreign prices, partially offsetting the initial depreciation. The rising domestic price level aligns with the quantity theory of money and, following PPP, results in domestic currency depreciation in proportion to the increase in the money supply over the long-run. Therefore, in Dornbusch's (1976) model, exchange rate determinants include relative money supply, relative income and interest rate differential between domestic and foreign economies.

Dornbusch's (1976) model has undergone theoretical refinements by Frankel (1979), Dornbusch and Fischer (1980), Mossa and Bhatti (2010) and Bhattacharyya and Deb (2024a). Frankel (1979) integrated relative inflation rates, acknowledging that exchange rates evolve with long-run inflation differentials. Dornbusch and Fischer (1980) modified the UIP condition by incorporating a risk premium (RP_t) to compensate domestic investors for the additional risk of holding foreign assets. Moosa and Bhatti (2010) further refined the model by removing the small domestic economy assumption and adopting a bilateral approach that accounts for relative factors in exchange rate determination [1]. Furthermore, Bhattacharyya and Deb (2024a) emphasised the role of microeconomic variables, such as investor behaviour, beliefs and preferences, alongside macroeconomic determinants in shaping exchange rate dynamics. They also advocated including a capital control variable to highlight the role of monetary authorities in managing exchange rate fluctuations.

Drawing on these critiques and enhancements, expression (2) presents the reduced-form equation for exchange rate determination, as discussed in the literature:

$$e_t = f\left(\frac{M_t}{M_t^*}, \frac{Y_t}{Y_t^*}, \frac{i_t}{i_t^* + RP_t}, \frac{\Delta p_t^e}{\Delta p_t^{e*}}, MB_t, CC_t\right) + z_t \tag{2}$$

e_t represents the spot exchange rate.

M_t & M_t^* represent the money supply of domestic and foreign partners, respectively.

Y_t & Y_t^* represent the income of domestic and foreign partners, respectively.

i_t & i_t^* represent the policy interest rates of domestic and foreign partners, respectively.

Δp_t^e & Δp_t^{e*} represent the expected general price level change in domestic and foreign partners, respectively [2].

RP_t represents the risk premium.

MB_t represents the turnover in the foreign exchange market [3].

CC_t represents capital control.

z_t represents the random error term.

Various papers empirically have analysed expression (2); a brief review of the empirical literature is presented in Table A1 [4].

The models summarised in Table A1 [4] have been further evaluated for their forecasting accuracy by Meese and Rogoff (1983), Huber (2016) and Reikard (2023). Bhattacharyya and Deb (2024a) also evaluated the forecasting accuracy of their model. While most studies detailed in Table A1 found poor out-of-sample forecasting performance compared to RWM, Bhattacharyya and Deb (2024a) demonstrated superior forecasting accuracy across all forecast horizons.

This study identifies three main gaps based on the summary of the modified Dornbusch (1976) model's determination and forecasting results. First, previous studies predominantly use linear estimation methods, overlooking the possibility that variables may exhibit different effects on exchange rates under varying economic conditions. Second, none of the reviewed empirical studies found statistical significance for all the variables considered in their models. Third, except for Bhattacharyya and Deb (2024a), none of the models could outperform the RWM in any forecasting horizon. These gaps underscore the need for a more robust approach to modelling exchange rates.

To address these gaps, the current study applies TRM, a nonlinear estimation method, to the Dornbusch (1976) model, modified as in Equation (1), to examine the India/US exchange rate. Unlike linear models, TRM effectively captures how variables behave differently under distinct economic conditions. By identifying thresholds and regime shifts, TRM provides a deeper understanding of exchange rate behaviour, particularly during periods of stability and structural shocks, offering valuable insights into the observed patterns and enhancing the robustness of the analysis.

4. Data

The analysis relies on quarterly time series data from 1996Q2 to 2019Q3. Data were compiled from multiple sources to construct the necessary variables; a summary is provided in Table A2 [4]. Additionally, the summary statistics of the variables examined in this study are presented in Table A3 [4].

5. Econometric methods

Before model estimation, variables were log-transformed to stabilise variance and achieve a normal distribution. Additionally, seasonal adjustment was applied using the moving average technique in EViews to mitigate seasonality effects and avoid misleading correlations, following Bhattacharyya and Deb (2024a).

After performing log transformations and seasonal adjustments to the variables, we examined whether the variables exhibited a unit root. Following Hansen (1999) and Caner and Hansen (2001), all the variables and the threshold variable under study must be stationary. We therefore employed the augmented Dickey–Fuller (ADF) test for the stationarity of variables. The ADF test results indicate that all variables, except for the relative inflation rate, are non-stationary at their levels but become stationary at their first differences [5]. The relative inflation rate is found to be stationary at its level. Based on these findings, we proceeded with the first differences of all the variables, except for the relative inflation rate, to estimate the model [6].

Next, we conducted the TRM estimation in EViews following Hansen (1999, 2000). Since the threshold variable was initially unknown, we began by specifying the contemporaneous values of all the dependent and independent variables and the first lagged values of the exchange rate and relative money supply as the potential threshold variables [7]. We then ran various models, each using a different threshold variable, selecting the one with the least residual sum of squares (RSS). TRM employs two key specification methods: the Global L and Sequential L+1. The Global L method determines a universal threshold value by segmenting the dataset into regimes based on whether explanatory variables exceed this threshold, with separate regression models for each regime. The Sequential L+1 method iteratively tests various thresholds, selecting those that improve model fit and predictive power. If a threshold fails to enhance performance, alternative values or specifications are tested (Hansen, 2000). We used the Global L method, which was automatically selected by EViews based on the Schwarz criterion. Given the small sample size, this is a more stable and parsimonious model, avoiding overfitting and inconsistencies that may arise in Sequential L+1. The model was then estimated with robust standard errors to address heteroscedasticity and autocorrelation.

The model selection criteria suggested using the exchange rate in its contemporaneous form as the threshold variable [8]. Given that the dataset contains only 94 observations, a two-regime model was specified in EViews. Upon closer inspection, the identified regimes highlight two distinct scenarios for the Indian economy: the first regime signifies a period of normalcy in the Indian economy, and the second regime corresponds to structural changes driven by global shocks and policy measures implemented by the Indian government and RBI. Equations (3) and (4) represent TRM classified based on the two regimes and used in this study to determine the exchange rate of the Indian rupee vis-à-vis the US dollar:

$$\begin{aligned} e_t = {} & \beta_0 e_{t-1} + \beta_1 \frac{M_t}{M_t^*} + \beta_2 \frac{M_{t-1}}{M_{t-1}^*} + \beta_3 \frac{Y_t}{Y_t^*} + \beta_4 \frac{i_t}{i_t^* + VIX_t} + \beta_5 \frac{\Delta p_t^{e}}{\Delta p_t^{e*}} + \beta_6 MB_t + \beta_7 CC_t \\ & + \varepsilon_{1t}, \text{if}, e_t < \tau \end{aligned} \tag{3}$$

$$\begin{aligned} e_t = {} & \alpha_0 e_{t-1} + \alpha_1 \frac{M_t}{M_t^*} + \alpha_2 \frac{M_{t-1}}{M_{t-1}^*} + \alpha_3 \frac{Y_t}{Y_t^*} + \alpha_4 \frac{i_t}{i_t^* + VIX_t} + \alpha_5 \frac{\Delta p_t^{e}}{\Delta p_t^{e*}} + \alpha_6 MB_t + \alpha_7 CC_t \\ & + \varepsilon_{2t}, \text{if}, e_t \geq \tau \end{aligned} \tag{4}$$

τ is the threshold value of e_t corresponds to the data considered from 1996Q2 to 2019Q3. This threshold is used to estimate the regression equations for two different regimes [9].

In Equations (3) and (4), the null hypothesis (H_0) suggests that the considered explanatory variables do not have a significant relationship with the India/US exchange rate. The alternative hypothesis (H_1) corresponding to the association of each explanatory variable with the explained variable, is outlined below.

If the lagged exchange rate depreciates, excess supply in the asset market and a simultaneous current account surplus may appreciate the Indian rupee. Conversely, the rupee may depreciate if economic conditions remain persistently unfavourable or inflation rises, prompting investors to sell the domestic currency. The ongoing selling pressure may lead to depreciation. The lagged exchange rate influences market sentiment and can contribute to either the appreciation or depreciation of the current exchange rate.

An increase in India's money supply may depreciate the Indian rupee by lowering the Indian interest rate and widening the Indian current account deficit. Similarly, a rise in the US money supply could weaken the dollar while appreciating the rupee through a decline in the US interest rate and a widening of the US current account deficit. Lagged relative money supply may have similar effects. Thus, changes in the current and lagged relative money supply can influence the exchange rate, depending on the relative strength of changes in the money supply of the two countries.

An increase in India's income may depreciate the Indian rupee by widening the current account deficit and boosting Indian demand for US assets. Conversely, higher US income may weaken the dollar while appreciating the rupee through a US current account deficit and increased US demand for Indian assets. Thus, changes in relative income can influence the exchange rate, depending on the magnitude of changes in income in the two countries.

Assuming all else is constant, an increase in India's interest rate may appreciate the Indian rupee by attracting US capital inflows. Conversely, a rise in the risk-adjusted US interest rate could prompt capital outflows from India to the US, depreciating the rupee. Thus, changes in the risk-adjusted relative interest rate can influence the exchange rate, depending on the relative strength of interest rate changes in both countries.

Inflation in India may depreciate the rupee by increasing import demand, while inflation in the US may depreciate the dollar, leading to rupee appreciation. Thus, changes in the relative inflation rate can impact the exchange rate, depending on the magnitude of inflation shifts in both countries.

An increase in turnover in foreign exchange markets may have a dual impact on the exchange rate. The Indian rupee may appreciate with greater foreign currency sales and depreciate with increased purchases. The net effect depends on the relative strength of these transactions. Similarly, the lagged turnover is expected to have comparable effects.

If RBI increases controls on capital inflows and outflows, there will be a decrease in both the supply and demand for foreign currency. If the decline in supply exceeds (falls behind) the decline in demand, the Indian rupee will depreciate (appreciate).

The estimated TRM was tested for autocorrelation, heteroscedasticity, model stability and residual normality using the Breusch–Godfrey Lagrange multiplier (LM) test, White heteroscedasticity test, cumulative sum of squared residuals (CUSUMSQ) test and Jarque–Bera test, respectively. Additionally, the Ramsey regression equation specification error test (RESET) test was used to check for endogeneity, specification errors, omitted variables, incorrect functional forms and simultaneity errors (IHS Markit, 2020).

This study further evaluated the out-of-sample forecasting performance of the model by comparing its forecasted values with those of an RWM with drift. Given the upward trend in the India/US exchange rate, RWM with drift was chosen as the benchmark model, as it captures both long-term movements and random fluctuations.

The dataset was divided into two periods: 1996Q2–2017Q3 for model estimation and 2017Q4–2019Q3 for forecasting. The analysis considered three forecast horizons – short-term (six months), medium-term (one year) and long-term (two years) – following Bhattacharyya and Deb (2024a). Forecast accuracy was assessed using mean square error (MSE), mean absolute error (MAE) and root mean square error (RMSE) metrics.

6. Results and discussions

Before analysing the results, it is important to understand whether the regime shifts in our analysis based on the threshold value, τ, are indeed driven by structural shocks and policy intervention or simply by the magnitude of the external shocks. To illustrate this point, Figure A1 [4] presents a graphical representation of the India/US exchange rate from 1996Q2 to 2019Q3.

In Figure A1 [4], the first difference in the exchange rate is plotted to determine the threshold value, τ. The value of τ is ≥ 0.02 during 1997–1998, 2007–2009, 2011–2013 and 2017–2018, coinciding with major events, that is, the Asian financial crisis, the 2008 global subprime crisis, the taper tantrum of 2011–2013 and the Indian economic slowdown. These periods reflect structural changes driven by global shocks and policy responses by the Indian government and RBI, as discussed in Section 2. In contrast, lower values of τ correspond to periods of relative stability. The threshold value effectively segments the dataset into two phases: one of normalcy and the other of structural shocks and policy interventions, aligning with real-world events. Therefore, these regimes reflect not only the magnitude of external shocks but also the results of structural shifts in the economy, driven by crises and the consequent policy adjustments.

With this visual confirmation of the TRM, we now proceed to the estimation results. Table 1 presents the estimated coefficients and their corresponding *p*-values from TRM with the two regimes.

In Table 1, the first lagged exchange rate is negatively significant in the first regime, indicating that depreciation (appreciation) in the previous period leads to appreciation (depreciation) in the current period. This change may result from excess supply in the asset market and a simultaneous current account surplus driven by past depreciation, which improves the trade balance and strengthens the Indian rupee. This finding aligns with data for periods of economic normalcy, where trade balances improve in real time (Muduli *et al.*, 2022). However, in the second regime, the first lagged exchange rate is not statistically significant, likely due to structural shocks and policy reforms by the government and RBI, which may have offset its impact.

The current relative money supply and its first lagged value are negatively significant in the first regime, indicating that appreciation from an increase in the US money supply outweighs depreciation from an increase in India's money supply. As this regime reflects economic normalcy, RBI intervention is minimal, keeping India's money supply stable. The rupee

Table 1. Estimated coefficients from the threshold regression model

Variables	Regime 1 $\mathbf{e_t} < \boldsymbol{\tau}$ Coefficient	*p*-value	Regime 2: $\mathbf{e_t} \geq \boldsymbol{\tau}$ Coefficient	*p*-value
e_{t-1}	−0.121**	0.0344	−0.084	0.3152
$\frac{M_t}{M_t^*}$	−0.150**	0.0167	−0.330***	<0.0001
$\frac{M_{t-1}}{M_{t-1}^*}$	−0.138**	0.0275	−0.089	0.1897
$\frac{Y_t}{Y_t^*}$	−4.301***	<0.0001	−5.951***	<0.0001
$\frac{i_t}{i_t^* + VIX_t}$	−0.00002	0.9975	0.005***	0.0099
$\frac{\Delta p_t^e}{\Delta p_t^{e*}}$	0.001***	0.0007	0.003***	<0.0001
MB_t	−0.023*	0.0969	0.009	0.3502
CC_t	0.198	0.1308	0.375***	0.0005

R-squared = 0.932
Adjusted *R*-squared = 0.918
Jarque–Bera statistic = 0.883 (*p*-value: 0.643)

Note(s): *** indicates significance at the 1% level, ** indicates significance at the 5% level and * indicates significance at the 10% level. Ninety-two observations are included after adjustments. 15% data trimming is used. The value of τ is 0.01813466
Source(s): Authors' contribution

appreciates as greater US money supply lowers US interest rates, attracting capital inflows into India. In the second regime, the current relative money supply remains negatively significant, while its lagged value is not found to be significant. This result may be due to RBI's foreign exchange interventions during structural shocks, where it purchased US dollars, thereby increasing India's money supply. However, such interventions create inflationary pressures, which RBI offsets through open market security sales (Raj *et al.*, 2018). As a result, India's money supply has a limited impact on the exchange rate, with the rupee appreciating mainly due to US monetary changes. This result aligns with RBI's policy patterns during structural shocks (Kumar and Vashisht, 2011). The insignificance of the lagged value in the second regime may stem from investors' rational expectations, as the effects of RBI's policies are already anticipated, thus diminishing their relevance.

Relative income is negatively significant in both regimes, indicating that appreciation from higher US income outweighs depreciation from India's rising income. This pattern mirrors the effects of relative money supply, as discussed earlier. This similarity arises because increased money supply stimulates domestic income by lowering interest rates, encouraging investment and boosting economic activity. Thus, the rupee's appreciation is driven by both income effects and policy-driven changes in the money supply. As a result, the policy implications for relative income and money supply align, contributing to currency appreciation in the current period.

The risk-adjusted relative interest rate is significant only in the second regime, with a positive sign. This regime, characterised by volatile capital flows, witnessed RBI lowering interest rates (Kumar and Vashisht, 2011). The reduction in India's rates heightened the impact of US interest rates on the exchange rate, explaining the positive significance. In contrast, the risk-adjusted relative interest rate remains insignificant in the first regime, likely due to RBI's minimal intervention, consistent investor behaviour and the limited influence of external interest rates amid stable economic conditions and fewer external shocks.

The inflation rate shows a significant positive impact on both regimes, indicating that the depreciation caused by inflation in India outweighs the appreciation from inflation in the US. Since inflation is a long-run phenomenon, its effects remain consistent across both regimes. Any crisis-related shocks are already anticipated under rational expectations, rendering their immediate impact null and void. Hence, the relative inflation rate will continue to have significant positive effects on the exchange rate even in periods with structural shocks.

The turnover in the foreign exchange market has a significant negative impact on the exchange rate in the first regime but is insignificant in the second. In the first regime, investor confidence in economic stability leads to greater investment in Indian assets, increased foreign currency sales and appreciation of the rupee. In contrast, during the second regime, investor uncertainty reduces market activity, weakening the influence of turnover and rendering the variable insignificant. These findings align with real-world trends in the Indian economy, where turnover rises during periods of stability but contracts during structural shocks (Kumar and Vashisht, 2011).

The capital control variable is significant, with a positive sign only in the second regime, implying that the fall in the supply of foreign currency exceeded the fall in demand for foreign currency due to capital control. This result can be attributed to volatile capital inflows during the second regime, which exerted downward pressure on the exchange rate. To safeguard exports, RBI implemented capital control measures to counteract inflows, leading to a greater reduction in supply than demand for foreign currency (Muduli *et al.*, 2022). In contrast, during the first regime, which was a period of economic stability, minimal regulatory intervention was needed, rendering the variable insignificant.

The Jarque–Bera statistic in Table 1 is not significant, indicating that the residuals are normally distributed. Hence, inferences based on t statistics are reliable.

As part of the post-estimation analysis, the study conducted a CUSUMSQ test (Figure A2[4]), Breusch–Godfrey LM test for autocorrelation (Table A6[4]), White heteroscedasticity test (Table A7[4]) and Ramsey RESET test (Table A8[4]). The results confirm the robustness of the model.

The forecasting result in Table A9[4] indicates that the modified Dornbusch (1976) model considered in this paper consistently exhibits lower MSE, MAE and RMSE values than the RWM across all forecast horizons. Consequently, it can be inferred that our model demonstrates superior forecasting performance over short-, medium- and long-term horizons. Furthermore, the model not only outperforms RWM but also surpasses the forecasting accuracy of Bhattacharyya and Deb (2024a) across all horizons. These findings highlight the enhanced predictive capabilities of the model, particularly when accounting for thresholds or regime switching, in the context of exchange rate forecasting.

7. Summary and conclusion

This study employs TRM to determine and forecast the India/US exchange rate using a modified Dornbusch (1976) model. The analysis integrates theoretical adjustments, such as long-run inflation differential, risk premium, bilateral exchange rate determinants, micro-behaviour of investors and capital control, based on the contributions of Frankel (1979), Dornbusch and Fisher (1980), Moosa and Bhatti (2010) and Bhattacharyya and Deb (2024a). By analysing quarterly time series data from 1996Q2 to 2019Q3, two distinct regimes depicting periods of normalcy and structural change in the Indian economy are identified.

The findings reveal that most exogenous variables impact the exchange rate differently across regimes. The risk-adjusted relative interest rate is significant only during structural changes following RBI interventions. The turnover in the foreign exchange market is significant only in stable periods, as investors hesitate to invest during crises. Capital control is significant exclusively in the second regime, reflecting the greater need for regulatory measures during structural shifts, whereas such interventions were minimal in the first regime. In contrast, relative money supply and relative income exhibit similar effects across both regimes, likely due to their policy-driven nature. Likewise, inflation consistently influences the exchange rate across regimes, given its long-term nature and market anticipation of crisis-related shocks under rational expectations. The modified Dornbusch (1976) model outperforms RWM across all forecast horizons, reinforcing the model's relevance. This study's novel contribution lies in identifying a regime-switching exchange rate model and applying a threshold modelling technique, which provides new perspectives for analysing exchange rate dynamics in India [10].

The findings suggest key policies for managing the India/US exchange rate under varying economic conditions. During structural changes or crises, strategic capital control measures and dynamic interest rate policies by the RBI can stabilise capital flows and mitigate risks. In periods of stability, monitoring turnover in the foreign exchange market and curbing speculative trading can enhance exchange rate stability. The consistent effects of money supply and income highlight the need for stable macroeconomic policies, while effective inflation targeting can address long-term depreciation pressures. Furthermore, a proactive crisis management framework with forward guidance and contingency planning is essential to managing shocks anticipated under rational expectations, ensuring exchange rate and economic stability.

The study is constrained by limited data, with the availability of only 94 observations restricting the depth of analysis of structural shocks and fluctuations. The availability of more extensive data in the future could facilitate the analysis of additional regimes, capturing specific global crises, such as the Asian Financial Crisis (1997) and the Global Financial Crisis (2008), along with the aftershock periods, growth phases and recessionary periods in the Indian economy since 1991. This additional data would enable the formulation of more comprehensive policies and a deeper understanding of exchange rate dynamics.

Notes

1. In the original Dornbusch (1976) model, as the economy is small, any changes in the domestic economy cannot influence the macroeconomic variables of the foreign economy. Thus, in the original model, the exchange rate is determined by the domestic macroeconomic variables and a given foreign interest rate.

2. Frankel (1979) represented the inflation differential by the expected relative price level. Given that the inflation differential is a long-run concept, the expected relative price level should match the actual relative price level in the long run, assuming rational expectations.
3. Turnover is a comprehensive measure of investors' micro-behaviour, as suggested by Bhattacharyya and Deb (2024a).
4. Please see it on the online Appendix.
5. The result of the ADF test is presented in Table A4.
6. Since the relative inflation rate is stationary at its level, we incorporate it in its absolute form when estimating the TRM model following Karia *et al.* (2013).
7. The model was tried with several lags for all the variables. However, when lags for all the variables were specified, a singular matrix error occurred in the regression model, suggesting perfect multicollinearity. Therefore, by elimination, we tried to reduce the lag length of variables and found that the model could be estimated without the problem of a singular matrix error if the first lagged values of the exchange rate and relative money supply were considered. This finding can be intuitively justified by the fact that these variables are policy-induced, and policy-induced variables often exhibit delayed effects due to implementation and adjustment lags.
8. Table A5 reports the model selection criteria.
9. The value of τ is 0.01813466.
10. Bhattacharyya and Deb (2024b) previously employed the NARDL-ECM model to determine and forecast the India/US exchange rate. They analysed how the positive and negative effects of exogenous variables affect the exchange rate in the short and long-runs. The current study, however, is the first to introduce a threshold modelling technique in this context.

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Supplementary material

The supplementary material for this article can be found online.

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