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# India's Foreign Reserves and Global Risk*


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**Abstract**

India accumulated a sizable stock of foreign reserves over the past two decades, in common with many other emerging economies. Its current reserves comfortably surpass conventional thresholds for adequacy used by the International Monetary Fund and others. An assessment of whether the stock of reserves is appropriate should depend on an evaluation of the benefits and costs of reserves looking forward. Reserves provide self-insurance against sudden financial outflows by non-resident investors or resident savers and liquidity for managing exchange rates. While India's reserves appear to be ample for meeting both these needs, additional reserves can reduce vulnerability to capital flow reversals that can be crisis inducing. The empirical analysis of India's external portfolio capital flows finds that reserves lower outflows in the event of global financial distress at the margin. Reserve holdings reduce the volatility of portfolio debt flows in response to relative policy interest rate shocks. The results indicate that additions to reserves reduce the economy's exposure to global financial risk. The precautionary benefits of reserves could well increase as India becomes further integrated to international financial markets. Estimates of the costs of holding reserves give evidence that increases in the reserves to output ratio reduce the risk premium on reserves, so that the sovereign interest rate spread overestimates the marginal cost of reserves.



**Keywords:** Foreign exchange reserves, foreign portfolio flows, precautionary reserves, global financial shocks.

**JEL Classification:** F31, F32, E52


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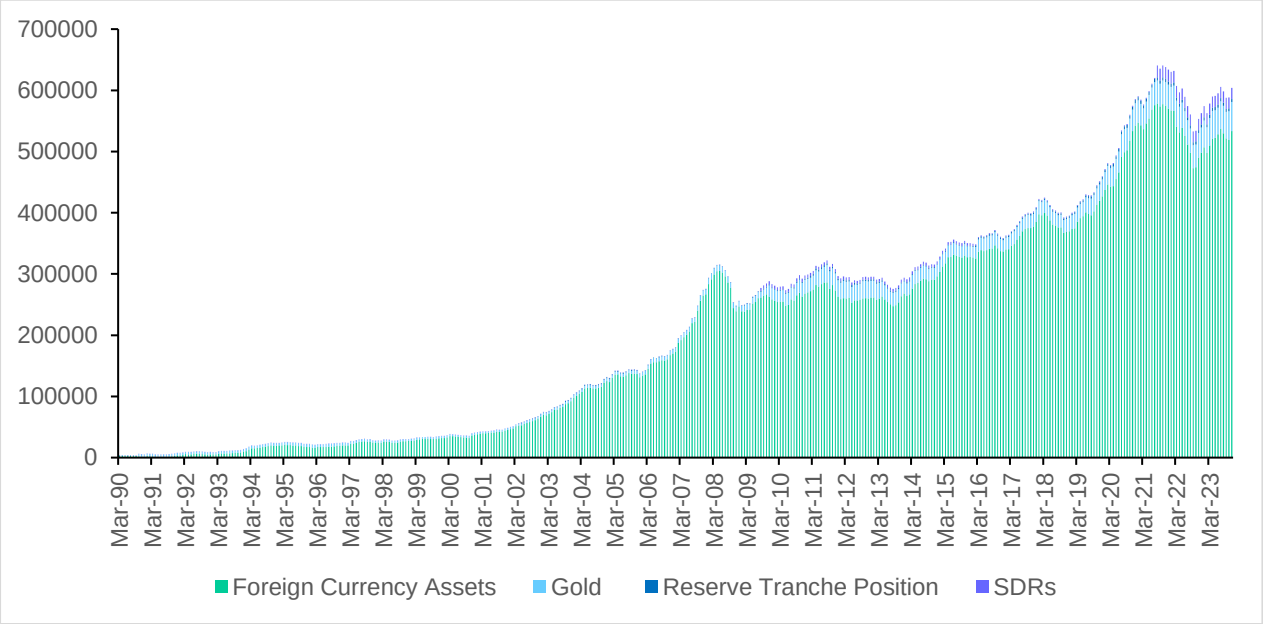
## 1. Introduction

Since the 1991 reforms, India has accumulated a substantial stock of foreign exchange reserves. This rise in reserves relative to GDP accords with the pattern of reserve accumulation by many large emerging market economies. The hoarding of reserves by the emerging markets has raised several questions about how these countries use their reserves, whether they hold adequate reserves for appropriate purposes, and if the marginal benefit of greater reserves outweighs the cost. In this paper, we concentrate on the third issue and analyze the impact of reserves on international capital flows over the global financial cycle and on the opportunity cost of holding reserves for India.

Figure 1 shows that in January1991, India's total foreign reserves were 6.4 billion U.S. dollars. In November 2023, they were 604 billion dollars.

**Figure 1: Foreign Reserves, India (million $)**




*Source:* RBI Database of the Indian Economy

There are three primary motives for central banks to hoard reserves. First, a stock of reserves provides self-insurance against runs on domestic financial markets and institutions by foreign and domestic asset holders. Reserves can be held as a precautionary measure against sudden capital outflows related to global financial or domestic shocks. Second, reserves are used for intervention in the foreign exchange market to reduce short-term exchange rate volatility. A third, mercantilist, motive concerns systematic purchases of reserves to maintain export competitiveness with a depreciated exchange rate.

Reserves provide international liquidity to central banks to intervene readily in times of financial turbulence to maintain stability. The prescription that a central bank should be ready to provide liquidity amply and quickly to stop a financial crisis is well known from the writings of Henry Thornton and William Bagehot in the 19th century.

Financially open economies face the risk of sudden reversals of foreign capital inflows or capital flight by domestic residents. Foreign reserves can further provide central bank liquidity against purely domestic runs when the credibility of home currency collateral assets fails as pointed out by J.M. Keynes. A financially closed economy is not subject to runs but can be short of trade credit to pay for imports. India faced this situation in 1991 prompting an effort by the RBI to build its foreign exchange reserves.

Determining the appropriate size of reserves to hold as a precaution against extreme capital outflows is an important topic of monetary policy in the official sector and academic research. The adequacy of precautionary reserves is typically defined in terms of the potential demand for reserve currency in the short run. The IMF includes a metric based on ratios of reserves to rule-of-thumb exposure of a country to sudden outflows or shortfall of inflows. For example, the Greenspan-Guidotti rule that sets a threshold of one year of external debt amortization is included. It also incorporates the conventional threshold of 3months of imports and the ratio of reserves to broad money. Adequacy metrics, however, are ad hoc measures of the national economy's exposure to global financial shocks and sudden stops.

Weighing against the benefits of having reserves are the opportunity costs of holding them. These costs are associated with the central bank's carry of foreign government debt against the national government debt. The interest differential between emerging market government debt and U.S. government debt, the sovereign spread, is usually used to estimate the cost of reserves.

India's reserves comfortably surpass IMF adequacy thresholds, as well as more fully articulated rules based on household welfare incorporating finite risk aversion and financial frictions. A natural policy question arises: when does the RBI have enough reserves? This may be the right policy question, but more needs to be known about the effects of reserves on risks and costs first. Additions to reserves beyond what is needed to cover potential sudden capital outflows and import needs can provide assurance to creditors and other market participants that the central bank will not hesitate to intervene as much and as long as necessary. Reserves may reduce the risks due to global and domestic financial shocks reducing the incidence of capital flow reversals and the risk premium on government debt whether denominated in domestic currency or foreign currency.

In the literature, historical data for capital inflows and outflows are used to estimate the volatility of capital flows, probabilities of crises, and the duration of extreme events. A large academic literature studies the relationship between global and national shocks and cross-border capital flows. New research, following Adrian et al. (2019), adopts an approach from capital-at-risk analysis. Quantile regressions are used to estimate capital outflows conditionally on global shocks and domestic shocks. Estimates provide a distribution of future capital outflows and inflows. These can then be used to estimate the effects of shocks and policies on capital flows. This might allow a better understanding of how policy interventions, frameworks, and reforms affect the probability and size of extreme capital outflows and inflows.

The quantile regression analysis does not allow an alternative for estimating reserve adequacy. Reserves held as a precaution against liquidity crises pointedly affect the probability of crises. The anticipation that reserves will be available to mitigate the effects of global financial shocks and to meet sudden outflows of foreign capital is likely to affect the amount and nature of foreign capital inflows. Self-insurance is purposed

toward financial stability and, hence, more efficient investment financing. Higher reserves that are seen to reduce financial fragility could improve the maturity structure of capital inflows reducing exposure to short-term capital outflows.

To quantify the impact of reserves on international capital flows over the global financial cycle, as in Patra, Behera, and Muduli (2022) and Gelos et al. (2022), we use quantile regressions for India to estimate the marginal effect of reserves as a share of GDP on gross capital flows across the distribution of external and internal shocks given global financial, growth, and monetary policy risks. We focus on (non-resident) gross capital inflows, which matter most for financial stability concerns, and amounted to about 1% percentage of GDP in 2023.[1] By interacting risks with reserve holdings, we demonstrate that additional reserves reduce large outflows of foreign-owned capital in adverse events. Higher reserves can reduce both extreme inflows and outflows of foreign capital. We analyze the effects for foreign portfolio debt and foreign portfolio equity flows separately. The estimates suggest that reserve accumulation continues to provide a precautionary reserve benefit for India.

We next look at the cost of holding reserves. These costs include the interest differential between Government of India and U.S. Treasuries, changes in the valuation of reserves, and the carry cost of foreign reserves. We estimate a model of the interest rate spread and find that spreads decline with the ratio of reserves to GDP. The marginal cost of reserves appears to be less than the interest rate spread.

The paper is organized as follows. The next section gives a selective review of the literature on reserve adequacy and the dynamics of capital flows to emerging markets. Empirical research on international capital flows concentrates on cross-country analysis. Our summary highlights the results for emerging markets collectively or selectively that can directly inform discussions of policy and prospects for India. The third section provides a narrative overview of Indian capital flows, reserves, and risks. Section four describes and reports the analysis of gross capital flows using quantile regressions. Section five discusses the cost of reserves and estimates the marginal effect of reserves on interest rate spreads. The last section is the conclusion.

## 2. International capital flows and emerging market reserves

The series of financial crises in emerging markets between 1980 and 2000 motivated advocacy by economists and multilateral financial institutions for central banks to raise reserve holdings as a buffer stock against sudden stops and avoid fixed exchange rates. By accumulating a sufficient level of reserves, emerging market economies would be able to sell reserves to accommodate sudden reversals of capital inflows. Such self-insurance could allow countries to avoid the sharp drops in output and domestic absorption caused by financial shocks. The Greenspan-Guidotti (1999) rule that reserves cover the short-term external debt exposure of a country provides a quantitative guide. The accumulation of a stock of reserves might also reduce the incidence of capital flow runs, for example when crises are self-fulfilling. In addition to

[1] Gross inflows are net sales of domestic financial instruments to foreign residents. Gross capital inflows arise when the economy incurs more external liabilities (inflows with a positive sign) or the economy reduces its external liabilities (inflows with a negative sign). See OECD (2018).

precautionary reserve holding, proposed and adopted measures include macroprudential policies and capital controls.

The notion of precautionary reserves leads to the question of determining the optimal level of reserves for a central bank. Heller (1966) argues that given the opportunity cost of holding reserves, the level of reserves should be determined by the tradeoff between this cost and the welfare cost of crisis risk. More recently, Jeanne and Ranciere (2011) derive a formula for optimal reserves to protect against sudden stops based on the idea that reserves replicate an insurance contract against sovereign default. An underlying concept is that the call on reserves and the holding cost should be discounted and priced using a stochastic discount factor in a forward-looking model. By the formula, optimal reserves equal the sum of the potential capital outflow and the output loss due the sudden stop discounted for the probability of a crisis and flow opportunity cost of reserves. Jeanne and Sandri (2020) take a similar approach to model optimal reserves for a country that is financially closed but open to trade. When calibrated for countries with very low private capital flows and low short-term external public debt, their model generates optimal reserves equal to 3.3 months of imports matching the conventional import cover rule very well.

Empirically, Jeanne and Ranciere show that the reserves held by emerging market central banks exceed the optimal level for precautionary reserves predicted. The empirical results of Aizenman and Lee (2007) and others find that reserves accumulated by East Asian countries after the 1998-99 crisis can only be partly explained as precautionary savings against external liabilities. Durdu, et al (2009) argue that financial globalization increases volatility leading to larger precautionary reserves. Their empirical analysis finds that the reserve growth can be explained by financial globalization and sudden stop risk, but not by domestic output fluctuations. Calvo, Izquierdo, and Loo-Kung (2013) find similar results.

Obstfeld, Shambaugh, and Taylor (2010) argue that international reserves can provide liquidity, often of higher quality, against capital outflows from domestic financial markets during periods of distress (an internal drain). They conclude that depth of domestic financial markets can contribute to an economy's risk exposure and motivate larger reserve holdings. They confirm the significance of M2 empirically for explaining emerging market reserves share of GDP. The inclusion of the reserves to M2 ratio in IMF evaluation of reserve adequacy reflects this. Financial account crises are often associated with the unwillingness of creditors to refinance maturing public and private debt. Hur and Kondo (2016) and Bianchi, Hatchondo, and Martinez (2018) model how rollover risk can motivate additional reserves for precautionary reasons. In these articles, reserve accumulation reduces the probability of a crisis in the presence of potential sovereign default.

The current account reversal in a sudden stop episode is the net outflow of capital. Bianchi and Mendoza (2020) estimate this to be around 3.7% of GDP for a typical sudden stop in emerging market economies over the period 1979 to 2016. These episodes are clustered around global financial events. The exposure of the economy to global shocks may be better measured by the dynamics of gross outflows and gross inflows than by net flows. Surges in capital inflows are associated with the accumulation of foreign liabilities and exchange appreciation that can create significant financial vulnerabilities, including asset price bubbles, raising the likelihood of banking, debt, and currency crises. In terms of gross flows, a sudden stop is characterized by a sharp

reversal of foreign inflows. Reserve accumulation provides liquidity to the central bank to act in the event of surge reversals and serves to counter real appreciation pressures. A large literature considers the role of gross flows for financial vulnerability of EMDEs and, hence, for precautionary reserve accumulation and macroprudential policies.

Forbes and Warnock (2012) and Broner et al. (2013) define capital flow regimes using data on gross capital inflows and outflows and identify factors that affect these flows. Gross flows can be very large and volatile, respond to global financial cycles, and are associated with emerging market financial crises. Negative global financial shocks typically lead to large outflows of foreign-owned capital (stops), and inflows of domestic-owned capital abroad (retrenchments). Global shocks induce gross flows that are much larger than the net flows. Forbes and Warnock show that global shocks drive gross flows but that domestic factors such as GDP growth do not. Gross flows are positively correlated with the global cycle. During periods of global financial volatility or uncertainty, foreign capital leaves and domestic assets return. Broner et al. show that the overall dynamics of gross capital flows holds for different types of flow (portfolio debt, portfolio equity, direct investment, and other flows) individually. Koepke (2019) surveys the empirical literature on the response of gross flows to shocks. Estimates of the effects of macroprudential policies on gross capital flows tend to be insignificant or inconclusive (Forbes and Warnock (2012), Beirne and Friedrich (2014), and Galati and Moessner (2018)).

A new approach to estimating the effects of shocks and policies on gross flows is proposed by Gelos et al. (2022). They use quantile regressions following the literature on value-at-risk to estimate the entire probability distribution of external portfolio capital flows using a panel dataset of emerging markets. We adopt this approach in our paper. The objective is to estimate how the future distribution of gross portfolio flows in short and medium runs varies with global shocks, country characteristics, policy frameworks, and policy actions. Of particular interest is the impact of global shocks on extreme capital flows in the tails of the distribution under alternative policies. In terms of country characteristics, they estimate how exchange rate regimes, institutional quality, monetary policy frameworks, and domestic financial depth affect capital flows. The findings indicate that more flexible exchange rate regimes are associated with more capital flow volatility in the short run and less in the medium run. Central bank transparency, stronger institutions, and deeper financial markets reduce the volatility of capital outflows in the medium-term. The authors find that macroprudential policies seem to reduce volatility while the imposition of capital controls in response to adverse global shocks exacerbates gross flows.

Eguren-Martin et al. (2021) use the same quantile regression approach using a cross-country panel. An innovation is the construction of global and domestic financial conditions indices from asset prices using high frequency data. Effects for foreign direct investment, portfolio equity flows, portfolio debt flows, and banking flows are estimated separately. They find that push (global) shocks affect portfolio and banking flows the most and foreign direct investment the least. Pull shocks affect each type of flows, but most strongly affect banking flows. The effects of global shocks diminish quickly. Capital controls on outflows do not change the distribution of flows, while control on inflows tend to reduce extreme inflows and outflows.

Most empirical analysis of capital flows and reserves for emerging markets relies on cross-country variation, often in panel datasets, for sufficient variation in country

characteristics and policies. The capital flows at risk approach is adaptable to a study of a single country. Quantile regressions suggest a way to estimate the risk of extreme capital outflows during global financial shocks or in response to domestic shocks and quantify the precautionary requirement for reserves. Precautionary reserve models and estimates are based on a measure of the potential portfolio capital outflows caused by adverse shocks. The outflows at risk can originate from both foreign and domestic holdings of domestic assets. Estimating the tails of a distribution of capital flows might more accurately measure the exposure that needs to be covered by reserves than balance sheet items.

One use of these regressions could be to estimate a value for setting a lower bound on precautionary reserves. Another is to estimate the effects of additional reserves on gross capital outflows and inflows in the presence of global shocks. If additional reserves reduce the risk of outflows during financial turbulence, then holding reserves in excess of the base amount needed to match outflows in the event should be beneficial. For example, Obstfeld and Gourinchas (2012) show empirical evidence that the frequency of banking crises, currency crises, and debt crises all fall with increasing reserve ratios.

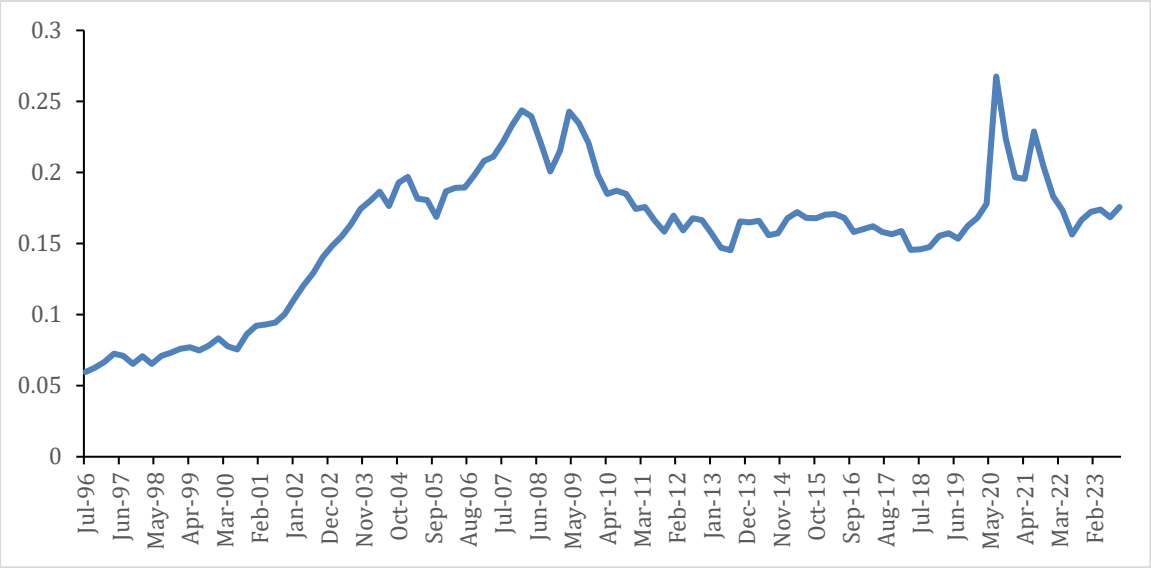
In our analysis, we use time series data to estimate the probability distribution of gross cross-border flows for India using conditional quantile regressions for India. The effects of reserves on gross capital flows at the margin are estimated using interactions with financial shocks and monetary policy changes. We examine whether reserves reduce the risk of extreme capital outflows, by how much, and how these effects vary across types of flows. Patra, Behera, and Muduli (2022) have already used the approach of Gelos et al. (2022) to analyze the distribution of capital inflows over global shocks. Their dependent variables are net capital flows so that extreme outflow events should be interpreted as current account reversals. We use gross capital inflows (increases in domestic assets owned by non-residents) and gross capital outflows (decreases in domestic assets owned by non-residents) separately as dependent variables. This approach follows Gaston et al. (2022). Our analysis of how reserves affect gross flows over the global financial cycle is new.

## 3. Reserves and Gross Flows for India

In common with many emerging market central banks, the Reserve Bank of India accumulated international reserves at a rapid pace over the first decade of the 2000s. The ratio of reserves to output (measured in USD) rose from about 20% in July 1996 to close to 100% in May 2009. India's reserve accumulation began a decade earlier following the currency crisis of early July 1991. In a speech before Parliament, then Minister of Finance Manmohan Singh noted that India's less than $1billion of foreign exchange reserves barely covered two weeks of imports in mid-1991.[2] The steady accumulation of reserves over the 1990s appears to have been a priority for monetary policy. Following the start of the Global Financial Crisis, the ratio of reserves to GDP declined until 2013, then growing in trend with nominal output until the Covid-19 lockdown**.** Figure 2 depicts the trends in reserves as a share of GDP.

[2] Presentation of the interim budget for 1996-97 on February 28, 1996.

**Figure 2: Reserves As a Share of GDP**




*Source:* RBI, IMF International Financial Statistics

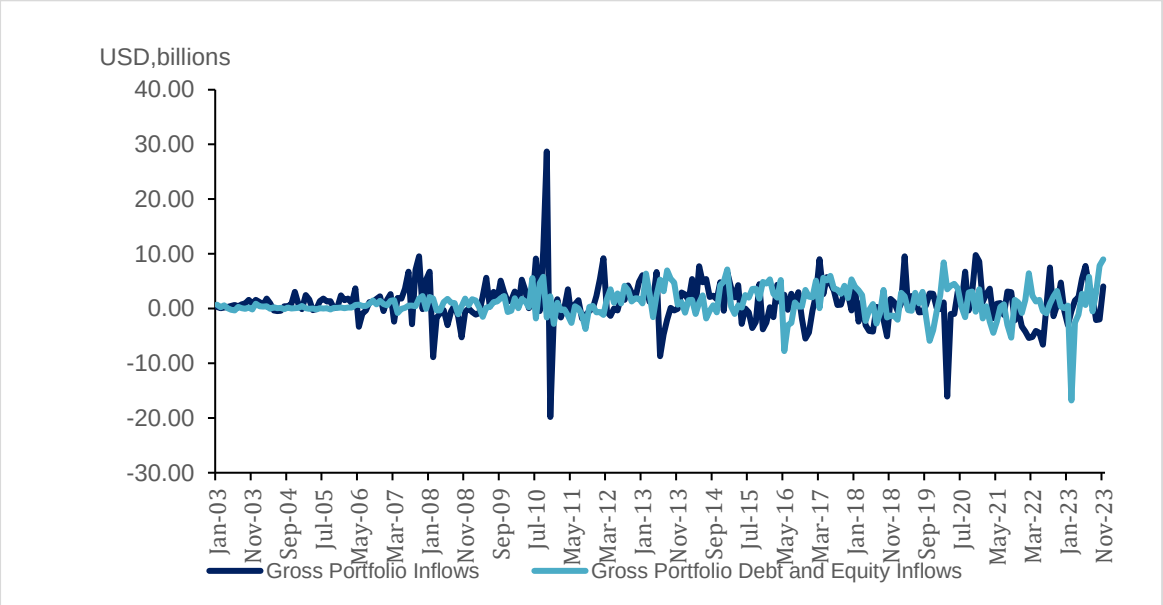
India's accumulation of reserves is strongly associated with the dynamics of gross portfolio capital inflows and foreign direct investment. Although current account surpluses were substantial up to 2004, net inflows of capital have broadly been negative since, with the exception of the pandemic. Gross capital inflows have been the primary contributor of resources funding the growth in reserve over the past twenty years.

One of the motives for holding reserves is the precautionary motive to provide liquidity against massive capital outflows and possibly to reduce the volatility of flows. The second use of reserves is to smooth cyclical exchange rate movements by intervening in the foreign exchange market. The RBI intervenes frequently for the ostensible purpose of "leaning against the wind" to reduce exchange rate volatility in the short-run. Leaning against the wind can provide a precautionary function by accumulating reserves during appreciations caused by surges of capital inflows and reducing capital outflows by selling reserves during depreciations. A third objective is mercantilism, seeking to inhibit secular appreciation to promote competitiveness.

Gross foreign portfolio inflows (FPI) to India tend to be very responsive to the global financial cycle and have experienced large reversals during global shocks. Sudden and large outflows of capital provide a basis for the self-insurance motive for maintaining a stock of reserves. The use of precautionary reserves should result in substantial large reserve outflows in times of large FPI outflows. Between 2004 and 2024, reserves fell annually in six events in the years 2008-09, 2011, 2013, 2018, 2020, and 2021-22. Each of these can be associated with a period of global financial turbulence facing emerging markets: the GFC, the European debt crisis, the Taper Tantrum, monetary tightening by the Federal Reserve (2016-19), Covid-19 lockdown, and the U.S. rate increases and Russian-Ukrainian War. Each of these episodes lasted from two to several months. Nath, et al (2024) provide detailed plots of daily foreign portfolio inflows and cumulative FPI flows, as well as time-series plots of global

volatility for each episode except the start of the lockdown. The monthly data for gross capital flows are depicted in Figure 3.

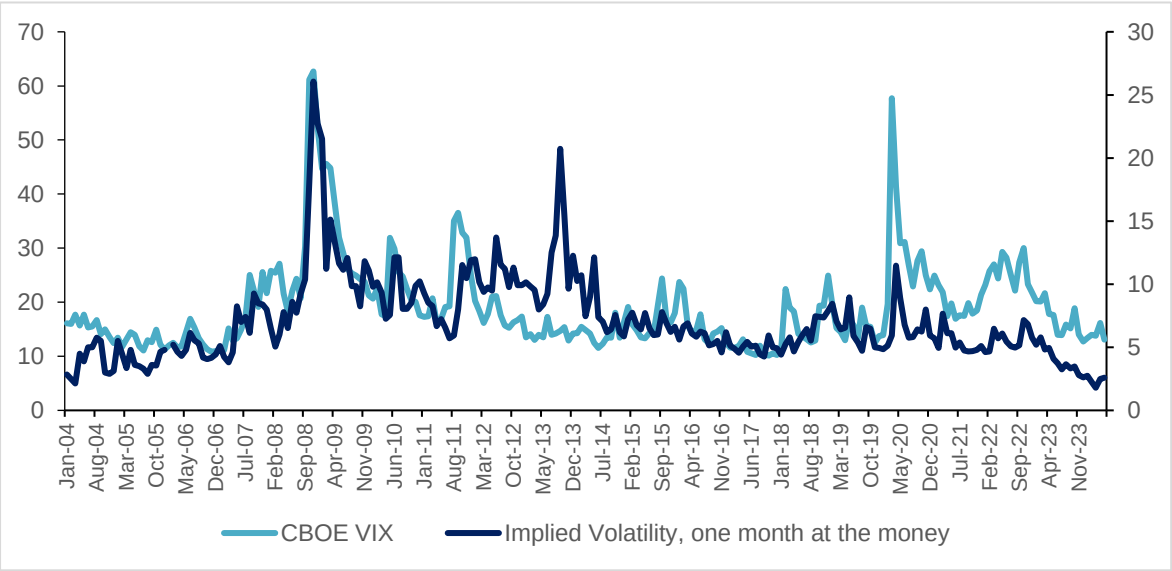
**Figure 3: Foreign Portfolio Inflows**




*Source:* OECD Monthly Capital Flow Dataset

Each of these events is associated with global financial shocks. The VIX index is a leading measure of global financial volatility, while implied volatility for the rupee-dollar exchange rate is a measure of the impact of global financial conditions on India. Shown together in Figure 4, with the exception of the Taper Tantrum (May 2013), significant financial shocks for India are global shocks.

**Figure 4: CBOE VIX and Implied Volatility Index**




*Source:* Federal Reserve Bank of St. Louis FRED, Bloomberg

Around the financial crisis, India experienced gross foreign capital outflow from May 2008 through March 2009 reaching a cumulative gross foreign portfolio outflow over $24 billion. This gross flow was 7.6% of reserves held by the RBI in May 2008. In the European debt crisis, FPI was negative for the months of September and October 2011. The cumulative foreign portfolio outflow was $1.5 billion despite substantial global financial volatility.

In the Taper Tantrum, FPI flows were negative from May to November 2013. The total outflow over these 6 months was over $15 billion, which was equal to 5.4% of reserves in May 2013. After the Federal Reserve began raising the federal funds rate, India had cumulative gross foreign portfolio outflows between April and November of 2018 reaching a peak cumulation equal to $18 billion. Sudden outflows at the beginning of the pandemic lockdowns were $16 Billion (USD) in March 2020 alone, followed by additional foreign portfolio debt outflows in April and May. The post-pandemic increases in U.S. rates and the Russian-Ukrainian war saw monthly outflows in excess of one standard deviation from December 2021 to June 2022.[3] The cumulative outflow over these 7 months was $33 billion, equal to 5% of total initial reserves. In this event, U.S. monetary policy was reflected by a sharp rise in long-term U.S. treasury yields, absent in each of the others. These numbers are summarized in Table 1 below.

**Table 1: Large Gross Foreign Portfolio Outflows (in USD Billions)**

| Event | Duration | Cumulative outflow (USD) | Fraction of reserves |
|---|---|---|---|
| 2008-09 | 11 months | $24.4 billion | 7.6% |
| 2011 | 2 months | $1.5 billion | 0.5% |
| 2013 | 6 months | $15.7 billion | 5.4% |
| 2018 | 7 months | $18.1 billion | 4.0% |
| 2020 | 3 months | $18.0 billion | 3.8% |
| 2021-22 | 7 months | $33.1 billion | 5.2% |

*Source:* Authors' Calculations

Gross foreign portfolio inflows respond most sharply to financial shocks and display much greater volatility than foreign direct investment flows. For India, gross domestic portfolio outflows are restricted by capital flow management measures and are dominated by portfolio equity outflows. These are small and do not quantitatively influence the demand for precautionary reserves. In comparison to middle-income emerging markets, capital flight and retrenchment do not feature in the Indian response to global shocks.

These portfolio capital outflows are substantially smaller than measures of reserve adequacy for India based on short-term external debt exposure. Nearly all of India's short-term external debt is denominated in foreign currency (primarily, U.S. dollars). For the third quarter of 2023, 97% of short-term debt exposure, reported by the World Bank, was denominated in foreign currency. External debt payments due within 12 months at the end of March 2023 were 44% of reserves, and original maturity short-term debt at the end of March 2023 was 22.2% of reserves.[4] The residual value

[3] The standard deviation is calculated for monthly flows from January 2000 to November 2023.
[4] Reserve Bank of India, "India's External Debt as at the end of June 2023", September 28, 2023.

exceeded the Greenspan-Guidotti rule by than 100%. The IMF metric for reserve adequacy (ARA) uses a weighted sum that includes the ratios of reserves to short-term debt, to 3-month import cover, and to 20% of broad money. The ratio of India's reserves at the end of the third quarter of 2023 to imports over the quarter also exceeded the traditional target by 3.4 times. Reserves were 21% of broad money (M3). These are depicted in Figures C.1-C.2 -C.3 in Appendix C.

By the Jeanne and Ranciere (2012) formula, reserve adequacy as a share in output should be bounded from above by the short-term external debt to output ratio plus the share of output lost in a crisis. The reduction applied to this sum depends on discounting at the world real interest minus the national real GDP growth rate. The opportunity cost of U.S. dollar- denominated external debt can be estimated by the sum of the real 10-year Treasury rate and the options-adjusted spread for bonds issued in dollars by corporations. For a twenty-year span from 2004 through 2023, this opportunity rate of interest averaged 4.1%.[5] Over the same period, India's real growth rate was 8%.[6] Since this difference is negative, such formulas are invalid. The real cost per unit of GDP of borrowing is negative.

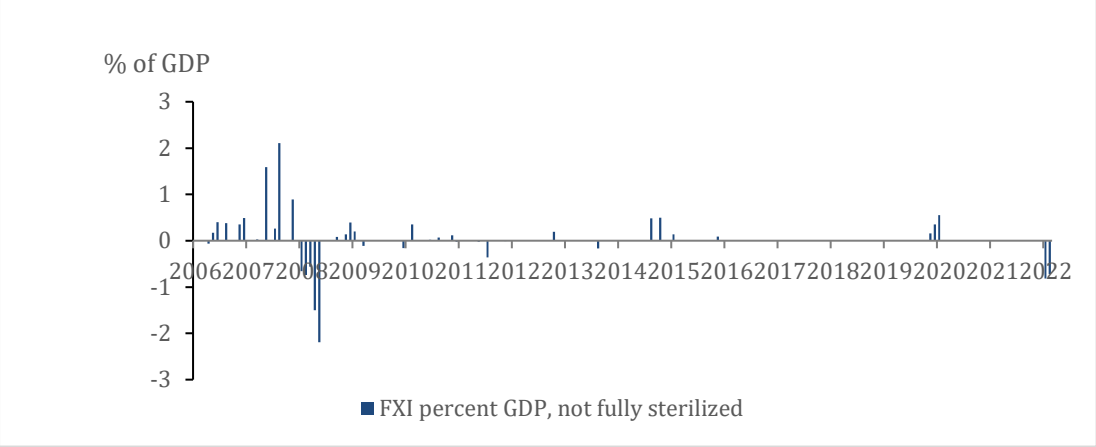
The duration and depth of extreme FPI outflows is informative, but it does not seem be a good guide for reserve adequacy. In particular, gross capital flows are only measured given the policy responses and the stock of reserves in place. Additional reserves on hand may reduce the vulnerability of the economy to extreme FPI outflows caused by either global or domestic shocks. Using the approach of Gelos, et al (2022), the next section provides an empirical analysis of this effect of precautionary reserves.

Exchange market intervention that leans against the wind seeks to move the nominal exchange rate. Although sterilized intervention can change relative interest rates through signaling, or possibly other channels, unsterilized intervention is more clearly related to efforts to limit the disturbance to domestic financial markets caused by global shocks. The RBI frequently intervenes in spot and forward exchange markets. Monthly intervention data reveal that intervention occurred in every month since 2000, but most interventions are sterilized.

An IMF database[7] provides the monthly data on foreign exchange intervention which includes a dummy variable recording whether the monthly intervention was fully sterilized or not fully sterilized. Over the recorded period (mid-2006 to mid-2022), incompletely sterilized interventions by the RBI are reported for just 35 months and are shown in Figure 5. These inventions are clustered and concentrated around the GFC. Foreign exchange rate purchases are positively correlated with an appreciation of the rupee against the dollar.

[5] Bloomberg and Federal Reserve Bank of St. Louis FRED.
[6] IMF International Financial Statistics.
[7] Data produced by the IMF using the methodology in Adler, et al (2021). Share of 3-year moving average of GDP. https://www.imf.org/en/Publications/WP/Issues/2021/02/19/Foreign-Exchange-Intervention-A-Dataset-of-Public-Data-and-Proxies-50017

**Figure 5: Unsterilized FX Intervention**




*Source:* IMF, Foreign Exchange Intervention Data and Proxies

## 4. Gross Capital Flows

In this section, following Gelos et al. (2022) and Patra, Behera, and Muduli (2022), we estimate the empirical distribution function of capital flows in India using a quantile regression approach. The main advantage of using quantile regressions is that one can model the entire conditional distribution of the dependent variable, thereby allowing the effects of the co-variates to differ across quantiles. Based on the estimated conditional distribution, the risks to capital flows can then be quantified by estimating the size of outflows for a given quantile (e.g. 5 %). The key departure from Gelos et al. (2022) and Patra, Behera, and Muduli (2022) in our paper, is that we analyze the role that foreign exchange reserves have for mitigating portfolio capital outflows at different quantiles. *Given* the current level of reserves, we are able to quantify the benefit of having more foreign exchange reserves.

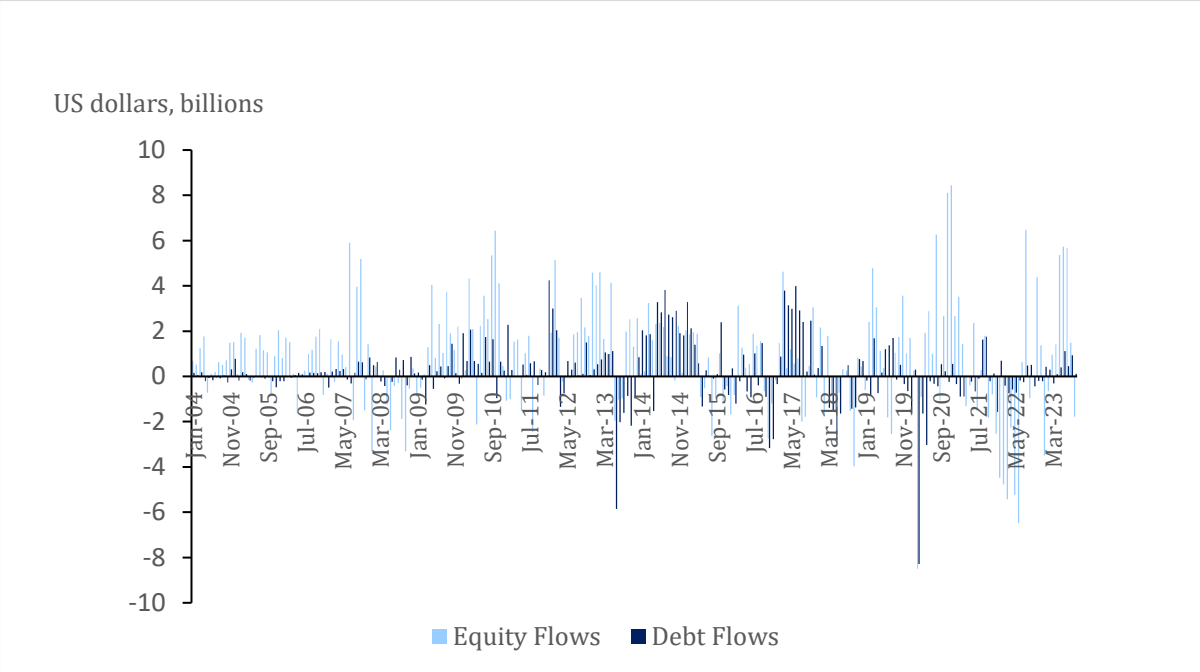
While a large literature has concentrated on *net* capital flows,[8] following Gelos et. al (2022), we use *gross* capital flows. More specifically, we use "non-resident" portfolio (debt and equity) inflows as our proxy for gross capital flows. We obtain gross portfolio debt and equity inflows (in USD) for India from the OECD Monthly Capital Flows Dataset (De Crescenzio and Lepers, 2024). Figure 6 plots portfolio equity (light blue line) and debt capital flows (dark blue line) into India between January 2004 to September 2023.[9] As pointed out in Gelos et al. (2022), non-resident portfolio inflows are the most volatile component of capital flows (compared to banking flows and FDI flows), and sensitive to external factors.[10] Hence, gross inflows are salient when it comes to financial stability considerations.

[8] Net capital flows are defined as the difference between in gross capital flows, i.e., the net purchases of domestic assets by foreign agents minus the net purchases of domestic assets by foreign agents. See Broner et al. (2013)

[9] Gross inflows are net sales of domestic financial instruments to foreign residents. Gross capital inflows arise when the economy incurs more external liabilities (inflows with a positive sign) or the economy reduces its external liabilities (inflows with a negative sign) See OECD (2018). https://www.oecd.org/daf/inv/Measurement-identification-of-capital-inflow-surges-technical-note.pdf

[10] Between January 2004 and September 2023, the coefficient of variation of equity flows is 2.96, for debt is 5.80, compared to 0.77 for FDI.

**Figure 6: Equity vs Debt Capital Flows India**




*Source:* OECD Monthly Capital Flow Dataset

More formally, for quantiles q ∈ (0,1) the quantile regression can be represented as

$$y^{q}_{t\_+\_h} = \beta_q X_t + \varepsilon^q_t \tag{1}$$

with horizon h and with the error term ε ~ N(0, σ). $Y_t$ refers to capital flows (total portfolio, debt, or equity inflows) and $X_t$ is a set of covariates.[11] To obtain empirical forward-looking probability density functions of capital flows, following Adrian et al. (2019) and Gelos et al. (2022, p.4), we fit a skewed t-distribution to the empirical distribution of predicted future flows. Azzalini and Capitanio (2003) provide the following skewed t-distribution:

$$f(y;\mu,\sigma,\vartheta) = \frac{2}{\sigma}\left(\frac{y-\mu}{\sigma};\vartheta\right) T\left(\theta\frac{y-\mu}{\sigma}\sqrt{\frac{\vartheta+1}{\vartheta+\frac{y-\mu}{\sigma}}};\vartheta+1\right) \tag{2}$$

with four parameters: the mean (μ), the standard deviation (σ), skewness (α) and kurtosis (ν) and where dT (.) and T(.) denote the probability density functions and cumulative density function of the skewed t-distribution. Because of the flexibility of the skewed t-distribution, it allows one to be agnostic about the shape of the distribution of future flows.[12]

[11] The list of co-variates that we use in our analysis are: CBOE VIX (FRED); Term Premium India (10 Year yield, Bloomberg minus WACR, RBI); India – US Spread (WACR – Fed Funds Rate, FRED); India – US Growth Differential (Monthly GDP Data, IFS Interpolated minus Brave Butters Kelly); Reserves/GDP lagged; and the interaction terms: (a) VIX * Reserves/GDP (lagged) (b) Spread * Reserves/GDP (lagged); (c)Growth Diff * Reserves/GDP (lagged). See Appendix A.

[12] See Gelos et al. (2022) for details.

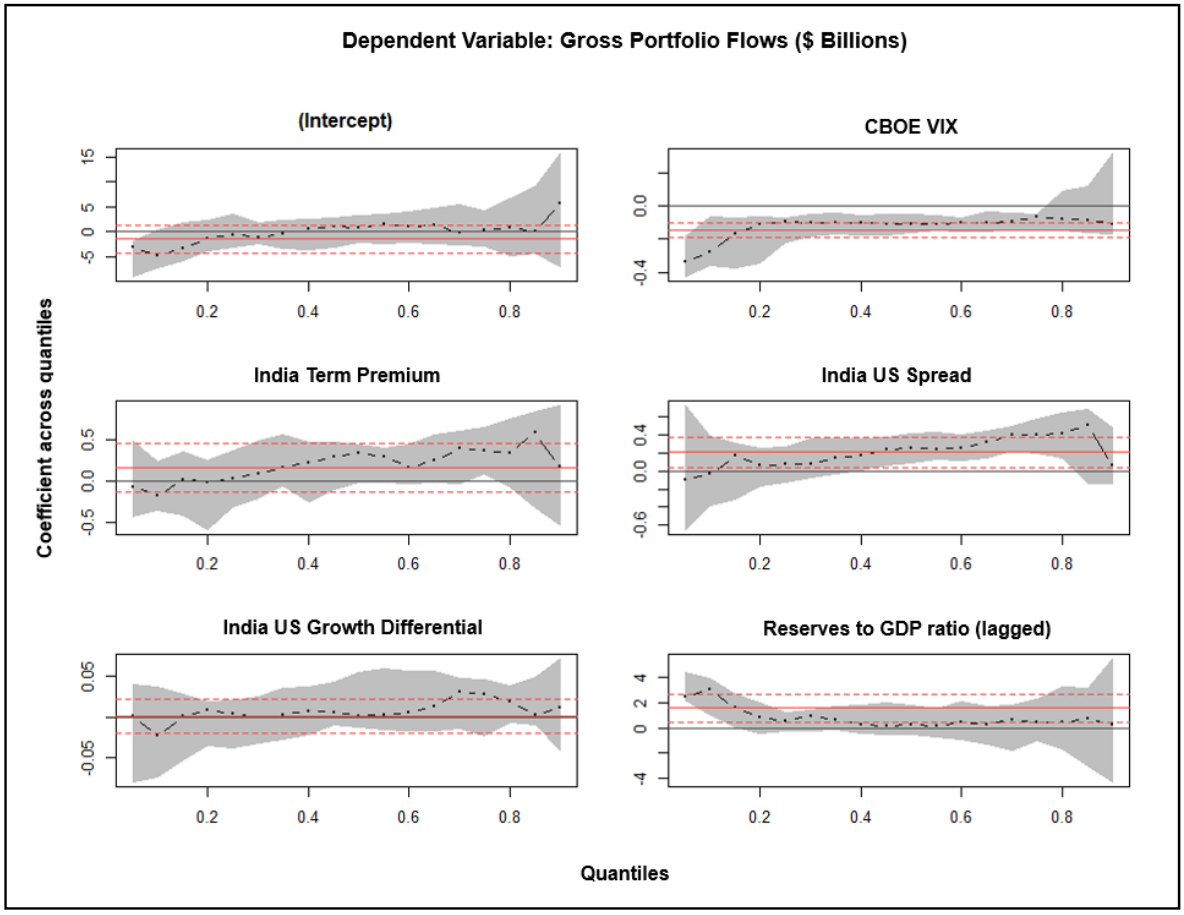
## Discussion of Data

A detailed discussion of the data and sources are in Appendix A. The time period for the analysis is January 2004 through September 2023.

## Empirical Results

The results of the baseline quantile regression in Equation (1) are shown in Figure 7 where total FPI flows are regressed on the VIX, Term premium for India (India 10-year G-Sec – weighted average call money rate (WACR)), the India US Spread (India WACR – US Fed Funds Rate), the India-US monthly real GDP growth differential, and the lagged (one period) reserves to GDP ratio (in USD Billions). The global uncertainty shock, VIX, impacts FPI inflows into India negatively, and is statistically significant at lower quantiles suggesting that the risk of capital outflows due a rise in global uncertainty (VIX) is particularly strong in bad states of the world. However, as can be seen in the coefficient plots for the ratio of reserves to GDP across quantiles in Figure 7, the coefficient on foreign reserves is positive and statistically significant at the lower quantiles. This suggests the stabilizing role of foreign exchange reserves in combating portfolio outflows in the left tail (bad states of the world).

**Figure 7: Baseline Quantile Regression Results - Dependent Variable = Gross FPI Flows.**




*Source:* Authors' estimates; data described in Appendix A.

Figures B.1(a) – B.1(d) in Appendix B plot the pre-shock and post-shock empirical conditional density functions based on the same quantile regression above, except that each independent variable in the quantile regression is shocked sequentially (the mean of the shocked variable is increased by a factor of 1.5). These regressions use the approach of Patra, Behera, and Muduli (2022).[13] In Figure B.1(a), a shock to global uncertainty, represented by a shock to VIX, shows that the conditional distribution of gross portfolio flows shifts to the left, with a fall in median flows. As seen in Figure B.1(a), the probability of (negative) outflows in the lower quantiles increases. The probability of (positive) inflows in the upper quantiles falls.

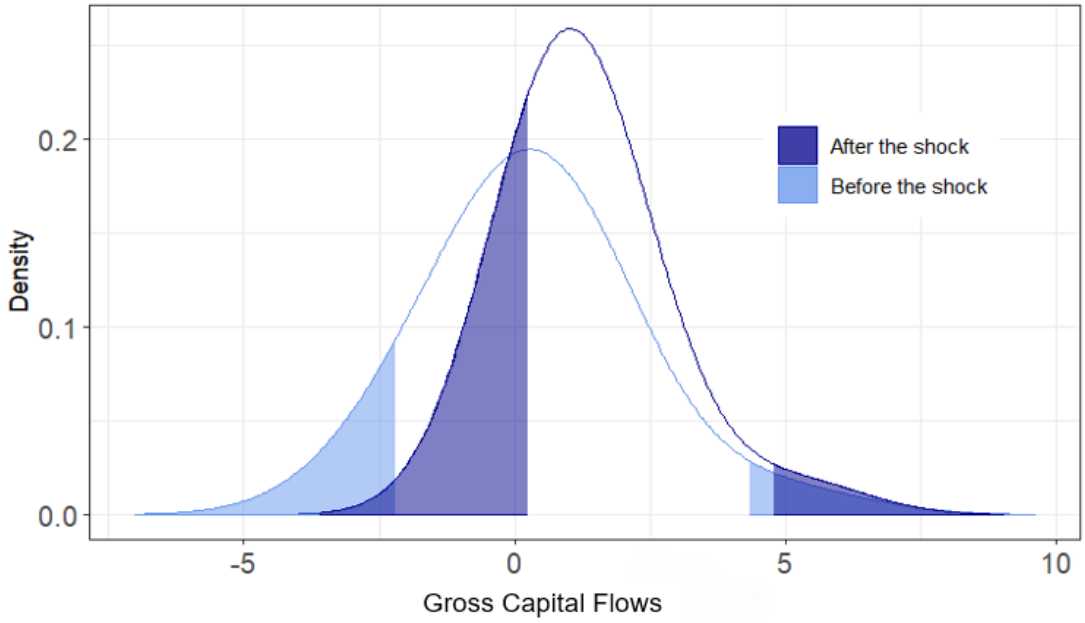
In contrast, a shock to the India term premium in Figure B.1(b), which corresponds to an increase in the steepness of the Indian yield curve (difference between the Indian 10-year G-Sec and the WACR) does not display a discernible impact on gross capital flows either at the tails or the median. However, a shock to the India-US spread (e.g., tightening of Indian monetary policy or loosening of US monetary policy), as seen in Figure B.1(c) leads to a small increase in median inflows. This is intuitive as a higher spread makes rupee denominated debt instruments more attractive relative to the US. This shows up in slight *rightward* shift in the empirical density function for gross flows. The probability of (positive) inflows in the upper quantiles (right tail) also increase.

Surprisingly, a shock to the India-US real GDP growth differential, has no discernible effect on gross flows either at the median or the tails.

A shock to reserves as a share of GDP, however, leads to a large rightward shift in the conditional distribution of gross flows as seen in Figure 8. While the probability of positive inflows increases, there is large reduction in the probability of a large negative flows (outflows). What we take away from this exercise is that foreign exchange reserves play a significant role in shifting the empirical distribution of gross flows wherein the probability of large (negative) outflows is substantially *reduced.* For an event at the 0.01 quantile (a bad shock), a 50% increase in mean reserves lowers estimated foreign portfolio outflows from $3.7 billion to $1.3 billion.

[13] The difference with respect to their results is that they do not include reserves in their analysis. We also consider additional variables (e.g., India-US Monthly Growth Differentials).

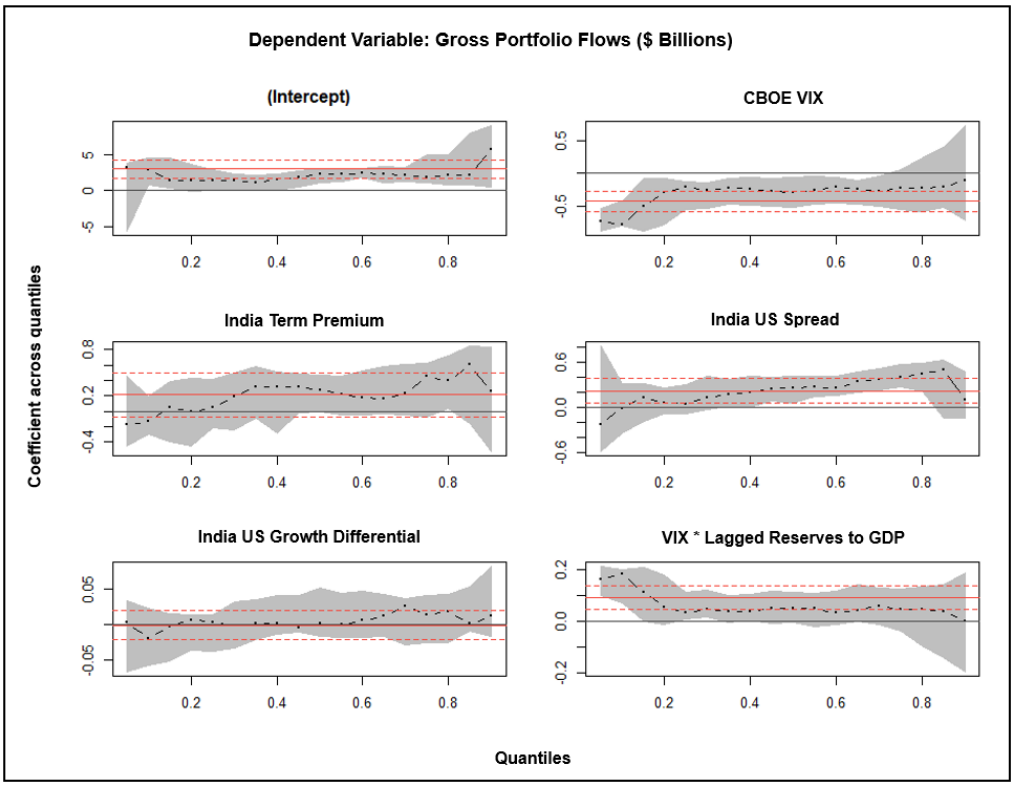
**Figure 8: An Increase in Reserves: Pre and Post Predicted Distributions**




*Source:* Authors' estimates; data described in Appendix A.

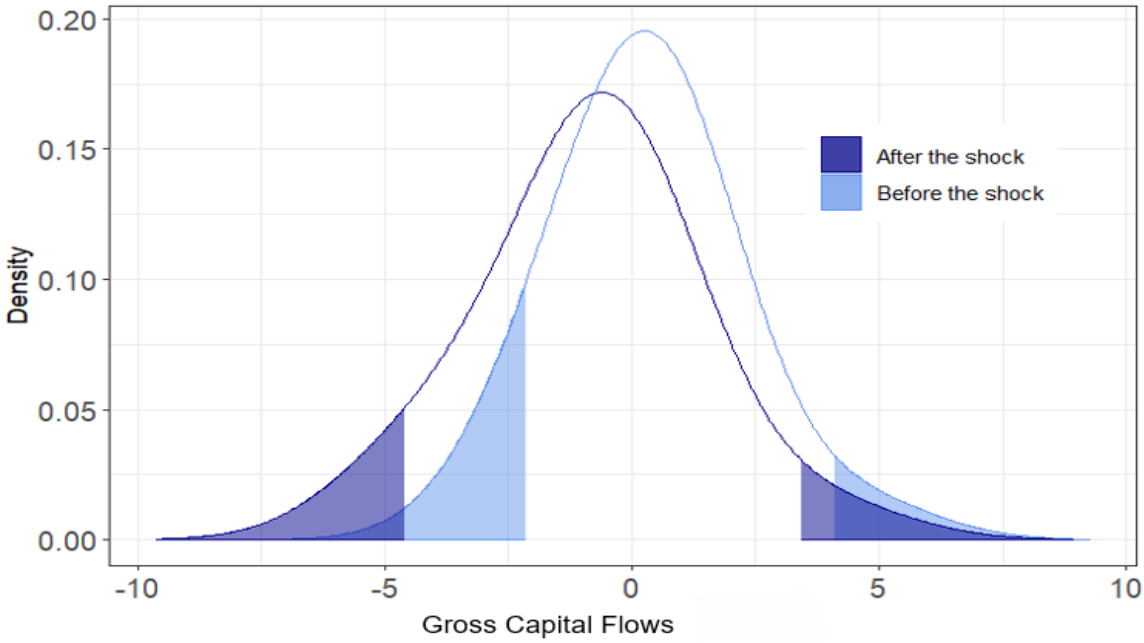
When we estimate the quantile regression in Equation (1) by replacing reserves to GDP with an interaction variable that interacts VIX with reserves to GDP, we see that global uncertainty continues to have a negative and significant effect on gross portfolio flows into India. These impacts are less at the lower quantiles compared to Figure 7 where there is no interaction and reserves are a standalone independent variable. Figure 9 displays the effect of a VIX shock on the predicted probability distribution of gross flows with reserves interacting with VIX. The coefficient on the interaction variable is significant with a positive sign suggesting that reserves counter the negative effects of VIX on outflows at the tail. Figure 10 illustrates the effect of a shock to VIX on the probability distribution of foreign portfolio inflows for our model interacting the reserves to GDP ratio with the VIX index. Figure 11 shows the effect of increasing the mean reserves to GDP ratio by a 50% (a multiple of 1.5). This leads to a large increase in the predicted median flows (by $1.1 billion), and a substantial reduction in the probability of large (negative) outflows in the left tail of the distribution. Foreign portfolio outflows at the 0.01 quantile fall from $4.0 billion to $1.1 billion.

**Figure 9: Quantile Regression Results - Dependent Variable = Gross FPI Flows. Reserves Interacted with VIX**



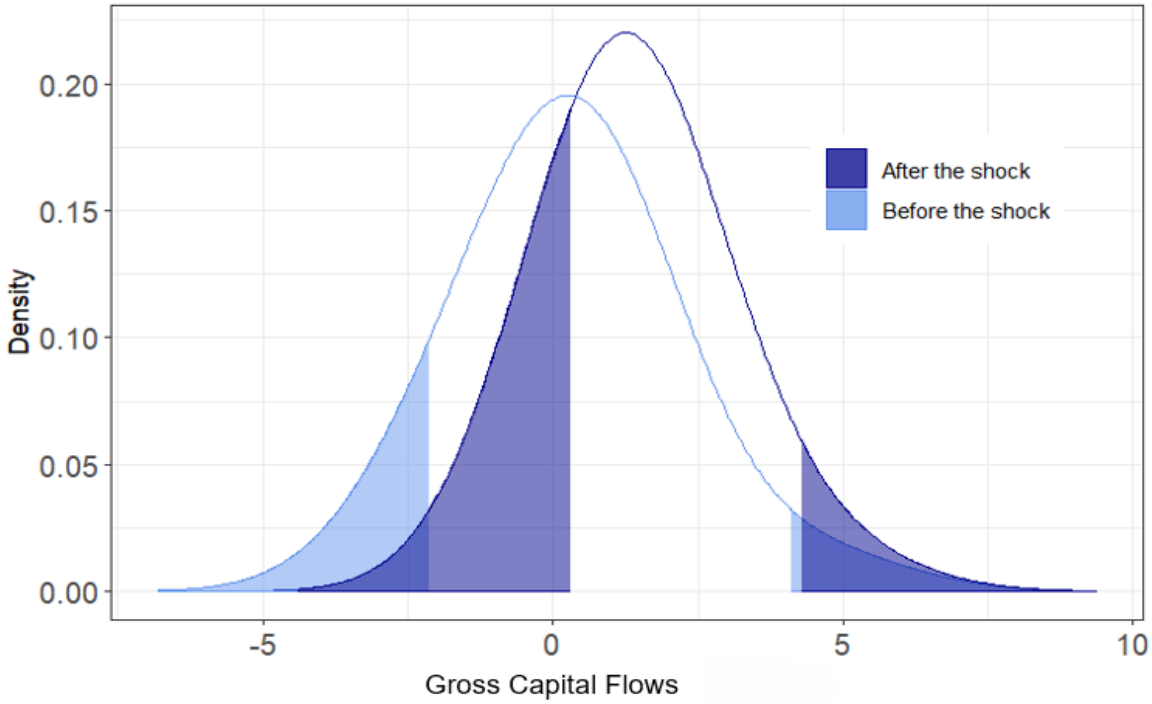

*Source:* Authors' estimates; data described in Appendix A.

**Figure 10: Interaction of Reserves and VIX: Pre and Post Predicted Distributions for a shock to VIX**




*Source:* Authors' estimates; data described in Appendix A.

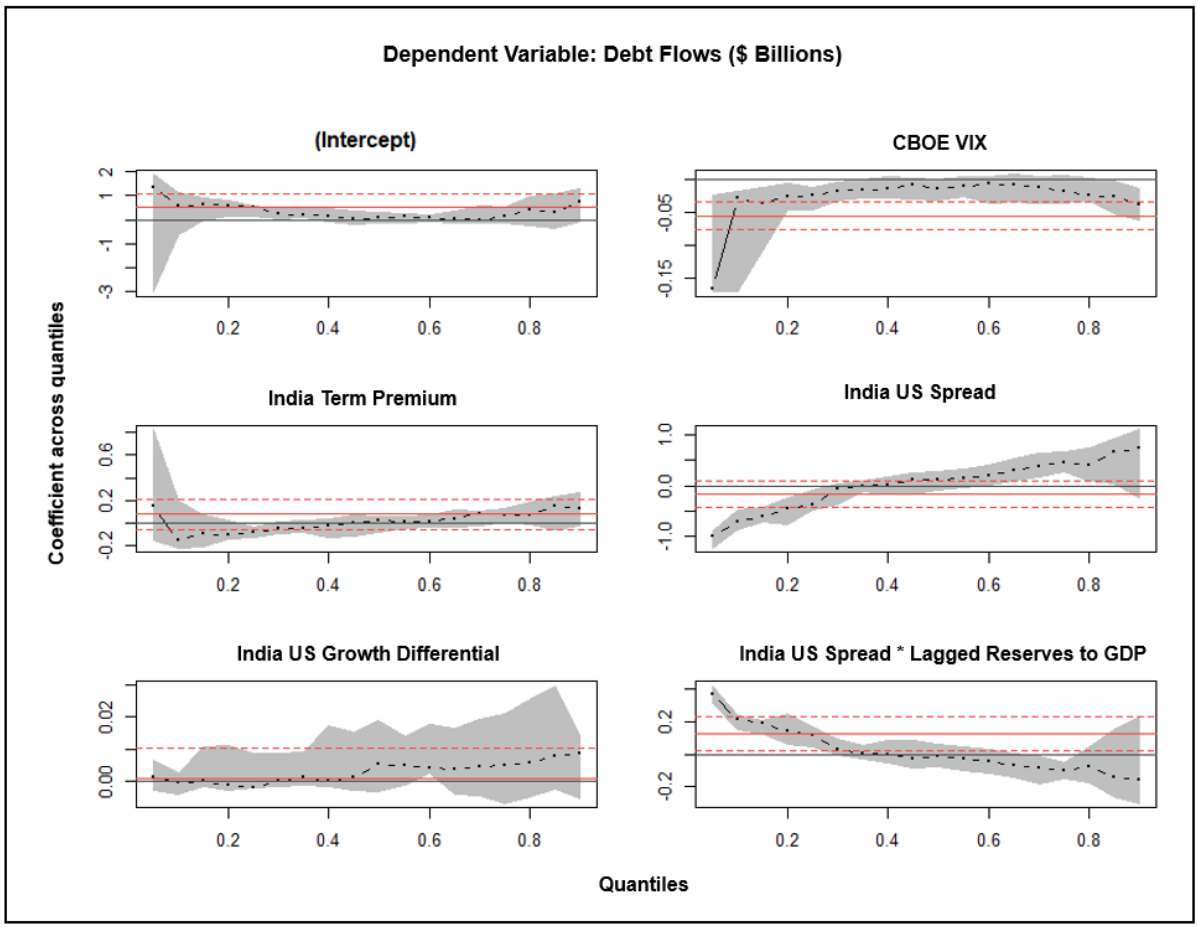
**Figure 11: Interaction of Reserves and VIX: Pre and Post Predicted Distributions for an Increase in Reserves**




*Source:* Authors' estimates; data described in Appendix A.

We next consider interactions between the India – US bond spread and ratio of reserves to GDP using portfolio debt and equity flows separately. The quantile coefficient estimates for this interaction is shown for gross portfolio debt flows in Figure 12. A shock to the difference between policy rates displays a negative effect by increasing debt outflows in the left tail, and a positive effect on debt inflows on the right tail. This suggests that an increase in the policy rate by India for a constant U.S. Fed Funds Rate raises the volatility of portfolio debt inflows. Figure 12 shows that the coefficient for the interaction term (India – US spread times reserves to GDP) is positive and statistically significant for low quantiles (negative debt inflows). This means that an increase in reserves reduces the incidence of portfolio debt outflows in the presence of a positive shock to the spread of the WACR over the U.S. Federal Funds Rate.

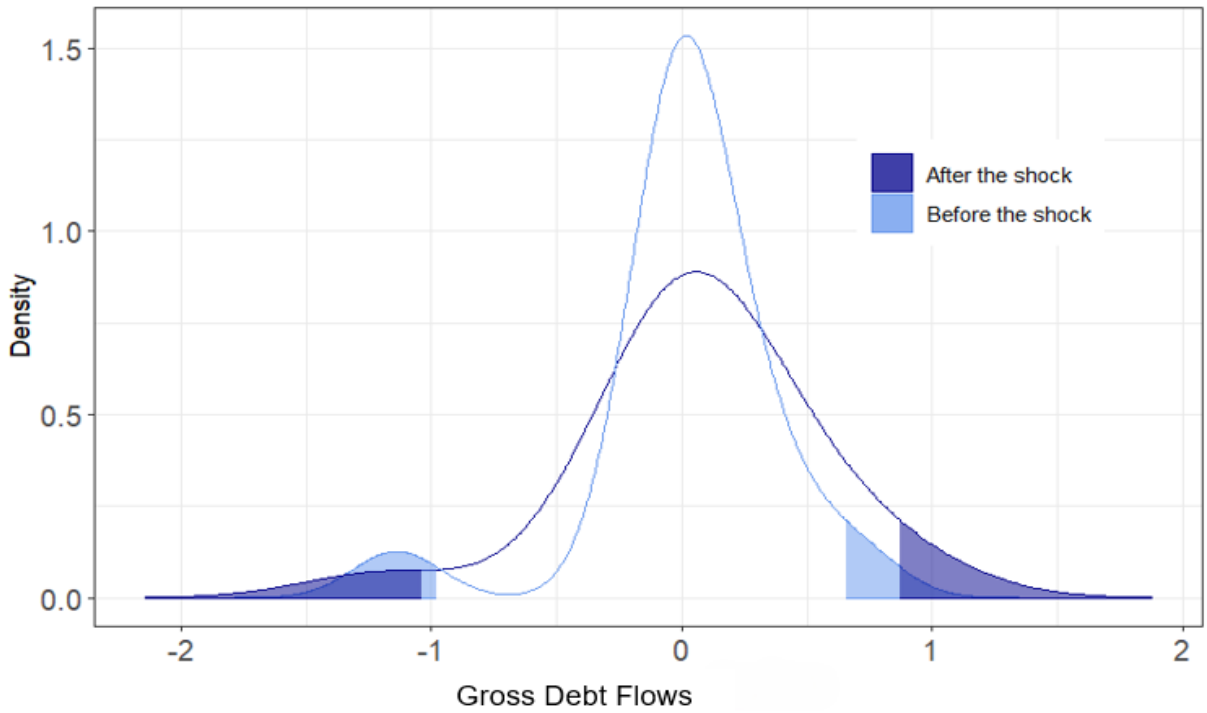
**Figure 12: Quantile Regression Results - Dependent Variable = Debt Flows. Reserves Interacted with India-US Spread**




*Source:* Authors' estimates; data described in Appendix A.

The effect of a shock to the India-US interest spread on the probability distribution of flows is shown in Figure 13. When shocks lead to negative debt flows, relative monetary tightening increases outflows. These are typically events in which global shocks are negative, and the U.S. tends to reduce the Fed Funds Rate. Increases in global uncertainty are associated with retrenchment of capitals flows back to the U.S. Conversely, in events in which portfolio debt inflows to emerging markets are high, increases in the weighted average call money rate (WACR) relative to the Fed Funds Rate should mitigate these inflows.

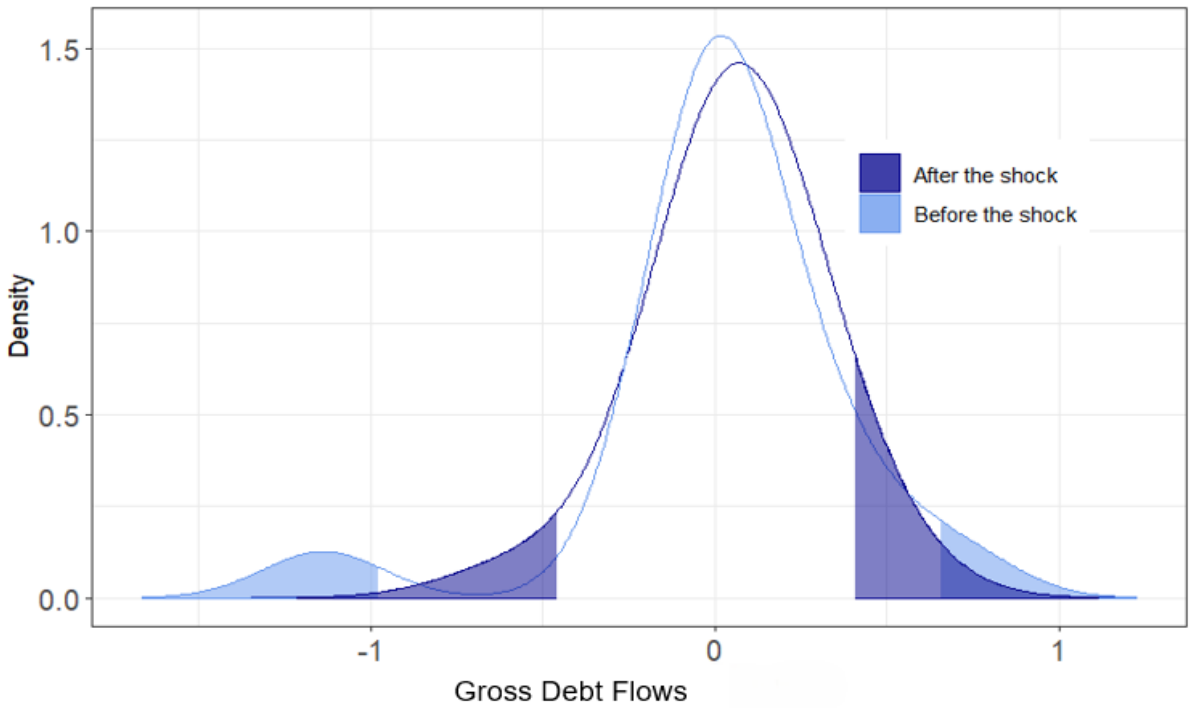
**Figure 13: Interaction of Reserves and India-US Spread: Pre and Post Predicted Distributions for a Shock to India-US Spread**




*Source:* Authors' estimates; data described in Appendix A.

Figure 14 shows that an increase of 50% in the mean of the reserves tends to reduce the volatility of foreign portfolio debt flows in response to relative tightening of monetary policy for India vis-à-vis the U.S. Both tails contract towards the median, compressing the distribution. Large debt outflows in bad times are reduced and sharp debt inflows in good times are also reduced. Increases in reserves stabilize portfolio debt inflows. Portfolio debt outflows at the 0.01 quantile fall from $2.4 billion to $1.8 billion.

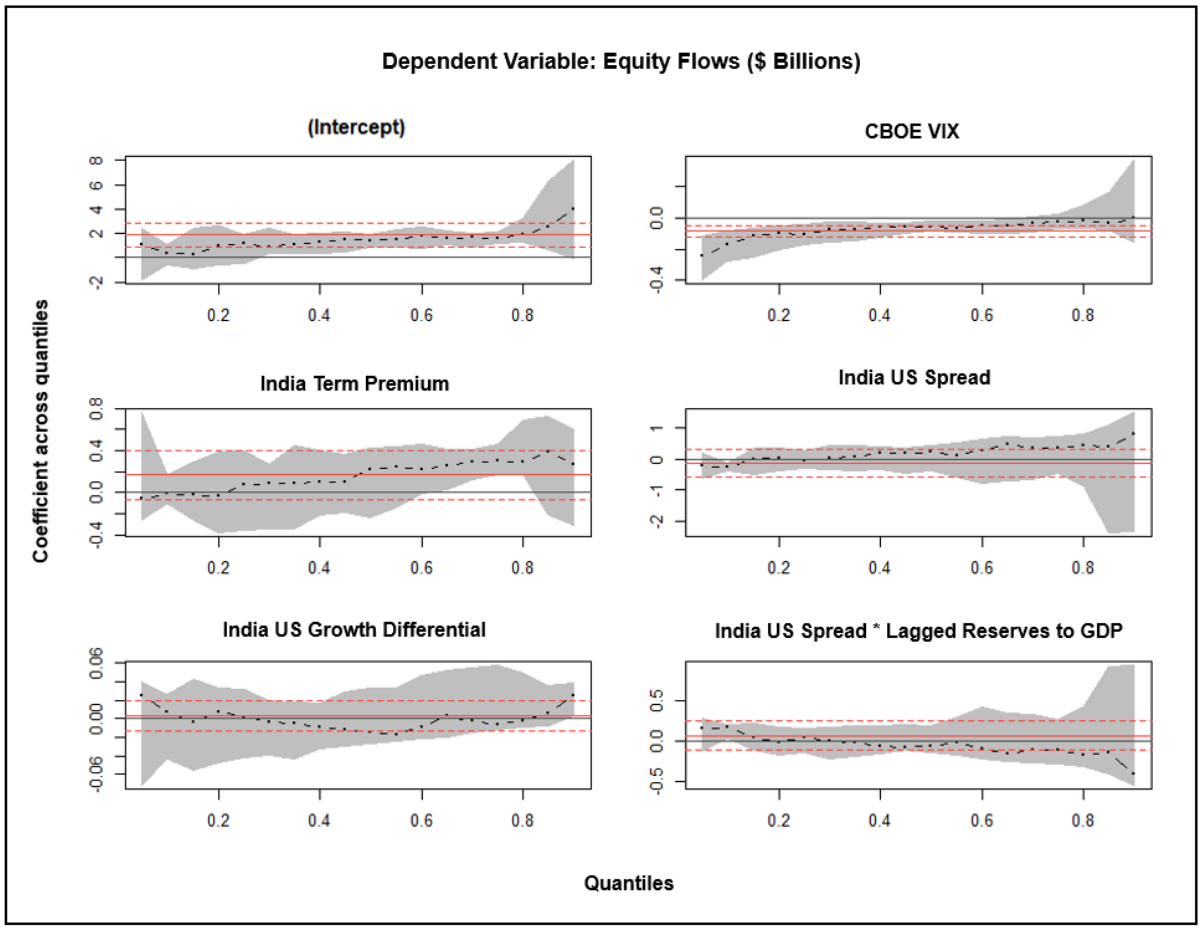
**Figure 14: Interaction of Reserves and India-US Spread: Pre and Post Predicted Distributions for an Increase in Reserves**




*Source:* Authors' estimates; data described in Appendix A.

The interaction effects between the India – US bond spread and the reserves to GDP ratio for gross portfolio equity flows are reported in Figure 15. The quantile coefficients for the spread and for the interaction of the spread with the reserves to GDP ratio are insignificant, except for the 0.1 quantile. This confirms intuition that debt flows are sensitive to relative policy rate changes but that equity inflows are much less so. Changes to VIX are significant for the low quantiles for portfolio equity inflows but not for portfolio debt flows.

**Figure 15: Quantile Regression Results - Dependent Variable = Equity Flows. Reserves Interacted with India-US Spread**

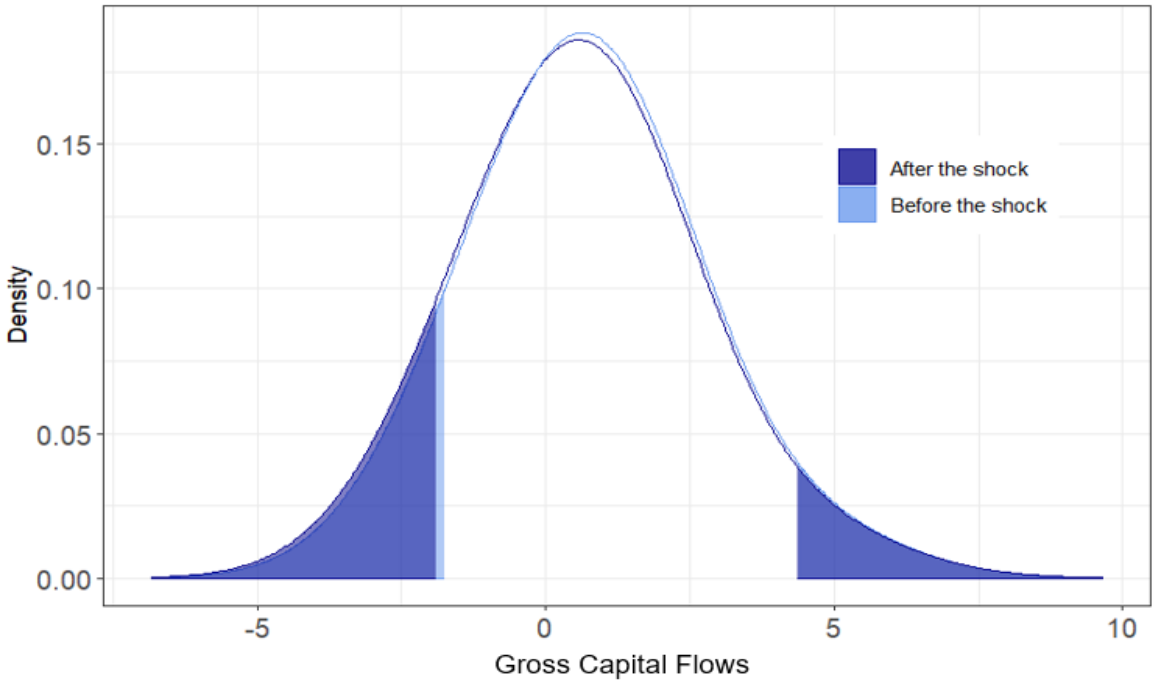



*Source:* Authors' estimates; data described in Appendix A.

Finally, we estimate the quantile regressions for shocks to the India 10-year bond to WACR term premium for all three dependent variables-- gross portfolio inflows, gross portfolio debt inflows, and gross portfolio equity inflows. The source of an increase in the term premium for India is ambiguous and could well differ qualitatively between events in the low quantiles and events in the high quantiles of gross portfolio inflows. An increase in expected inflation or in expected productivity growth can raise the term premium. A temporary decrease in the policy rate can increase the premium.

The regression coefficients are displayed in Figure B.2(a), B.2(b), and B.2(c) in Appendix B. For total foreign portfolio flows (FigureB.2(a)), the coefficient on the term premium is significant for high quantiles of gross inflows. However, Figure 16 shows that a shock to the term premium for India leads to small spread of the tails for gross portfolio flows.

**Figure 16: Pre and Post Shock Predicted Distribution Due to a Shock to the India Term Premium**




*Source:* Authors' estimates; data described in Appendix A.

The coefficient for the interaction term between lagged ratio of reserves to GDP and the India term premium is significant and positive in the lowest quantiles for (negative) capital outflows. Median gross portfolio inflows rise with an increase in reserves as shown in Figure B.2(b) in Appendix B by the shock to the interaction term as the entire distribution shifts to the right. There is a large reduction in the gross portfolio outflows in the lower quantiles and an increase in gross portfolio inflows in the upper quantiles (for large inflow states). An increase in reserves appears to increase the response of gross portfolio inflows to increases in India's term spread.

The effects of the India term premium on portfolio debt flows are displayed in Figure B.2(b). The coefficients for debt inflows on the term premium are qualitatively different from those for gross portfolio flows and for portfolio equity flows (shown in Figure B.2(c)). Shocks to the India term spread increase the absolute value of debt outflows at low quantiles (negative flows) and increase debt inflows at high quantiles (increase positive inflows). A rise in the term premium increases the volatility of portfolio debt flows. The interaction term is significant only for large portfolio debt outflows (low quantiles) indicating that larger reserves mitigate the impact of a higher term premium on portfolio debt outflows (Figure B.2(b)).

The effects of the India term premium on portfolio equity flows is shown in Figure B.2(c). The coefficients on the term premium and on the interaction term between lagged reserves to GDP and the term premium are insignificant at all quantiles. The quantile regression results in Figure B.2(c) illustrate the effect of an increase in reserves on portfolio equity flows.

## 5. Cost of Holding Reserves

While reserves provide benefits in terms of self-insurance and exchange market intervention, they are costly to hold. Conceptually, the cost of reserves equals the difference between returns to reserve assets and the opportunity return to investments foregone. The cost of reserves is typically estimated by comparing the interest paid on a country's sovereign debt and that received on reserve assets of similar maturity. This measure of the cost of holding reserves combines the sovereign risk premium with a term premium expressed in a reserve currency. The purposes to which reserves are used as well as how they are accumulated can matter and deserve consideration.

For reserves held as a buffer stock for insurance against the impact of global financial shocks and domestic financial crises, the marginal cost of holding reserves should be determined by the marginal opportunity cost of the debt implicitly issued to purchase reserves net of the returns on reserve assets. Reserves could be exchanged for outstanding government debt in a sterilized sale by the central bank. The quasi-fiscal cost of reserves is incurred when a central bank uses open market operations to sterilize the expansionary impact of reserve accumulation on the money supply.[14]

When government debt is issued in foreign currency, its marginal cost equals the sovereign risk premium plus the risk-free rate of interest. The yield on U.S. Treasury securities is frequently chosen as an appropriate proxy for the risk-free return. For government debt issued in domestic currency, as is the case for India, the quasi-fiscal cost of reserves must account for exchange rate risk. The effect of currency risk on *ex ante* sovereign spreads can be measured by the market exchange rate risk premium on government debt. Because exchange rate losses and gains are not realized until reserve assets are sold, the quasi-fiscal cost of reserves should include the central bank's net losses on what are essentially carry trades.[15]

Reserve assets tend to be of shorter maturity than domestic sovereign debt. For the purpose of self-insurance, reserves need to be readily available in ample supply in the event of a financial crisis. This means that precautionary reserves ought to be held in reserve currency debt that remains liquid in times of global financial turbulence. Short-maturity bond yields need to be adjusted by term spreads to match the average maturity for sovereign debt. Estimates of the cost of holding reserves ex ante use term premiums to adjust yields. Changes in the valuation of the reserve asset portfolio are additional quasi-fiscal costs or benefits.

The way in which reserves are accumulated should affect the opportunity cost of reserves. Reserves can be accumulated through unsterilized purchases, issuance of foreign currency- denominated debt, and sales of domestic currency government debt. Raising precautionary reserves by issuing foreign currency debt can increase the risk of currency and debt crises raising the exposure of the economy to extreme capital outflows and self-fulfilling runs. In contrast, domestic currency debt can be viewed as contingent on domestic economic performance and policies. India's government debt that effectively finances unsterilized reserve accumulation is issued in rupees. Levy-Yeyati and Gomez (2022) use balance of payments data to associate reserve increases

[14] The concept of the quasi-fiscal cost of sterilization is introduced by Calvo (1991).

[15] The cost of sterilized reserves discussed is sometimes labelled the direct quasi-fiscal cost. Indirect cost refers to possible real effects of sterilized intervention that delay real exchange rate and current account adjustment. The effects of sterilized intervention are beyond the scope of this paper.

with government and central bank debt issuance in foreign currency, with increases in domestic government debt, and unsterilized purchases. Sosa-Padilla and Sturzenegger (2023) apply this approach to ask how the currency composition of debt that funds reserve purchases by emerging market central banks affects spreads. They find that spreads rise when borrowed reserves are financed with foreign currency debt and fall with domestic currency debt financing.

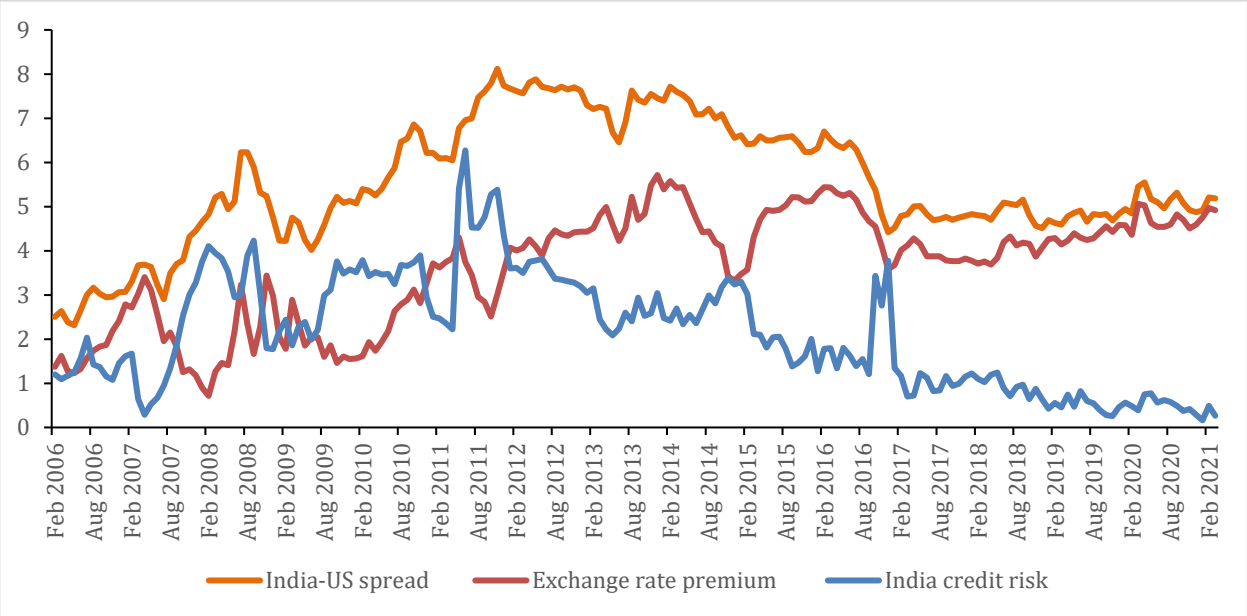
Managing the foreign exchange rate is the evident second motive for holding reserves for India. The RBI intervenes by exchanging reserves with either domestic currency changing the monetary base or with domestic currency debt. When a central bank is leaning against the wind by accumulating reserves in response to appreciation pressure, it takes a carry trade position long in foreign currency and short in domestic currency. The RBI is taking a trade in which it invests in the low interest rate currency and borrows in the high interest rate one. The cost of carry in sterilized intervention receives attention. A point, however, is that intervention countering exchange rate volatility results in positive or negative carry profits. The carry risk is an appropriate cost to consider for reserves held to "lean against the wind". The interest differential between foreign currency bonds and domestic currency bonds equals the forward premium. Deviations from uncovered interest parity can lead to positive or negative mean losses. Valuation losses tend to accumulate during appreciations and fall in depreciations. Expected valuation losses are a cost of holding reserves, as well.

We can apply the approach of Levy-Yeyati and Gomez (2022) to estimate the cost (ex ante) of holding reserves for India. Starting the precautionary reserve, we need to estimate the exchange risk at the maturity of securities held in reserves and issued by the central government. Holding a rupee- denominated bond involves two risks relative to holding a risk-free bond in dollars: exchange rate risk and credit risk. For example, the spread for a 10-year Indian treasury bond (G-Sec) equals the 10-year U.S. Treasury yield plus exchange rate risk and pure credit risk. The cost of carrying reserves in dollars is included in the term-adjusted spread. Forward markets exist only for short-maturity contracts. For longer maturities, cross currency swaps can be constructed by combining dollar-rupee cross currency basis swaps with interest swaps in each currency as proposed by Du and Schreger (2016). We use the updated database for Du, Im, and Schreger (2018) for yield spreads between treasury bonds in rupees for India and U.S. treasuries.[16] The India-US spread is the simple difference between yields in each currency. By subtracting the cross currency spread from this yield differential, Du and Schreger derive the rupee credit risk on central government debt. We use the series for India. They use this residual to study deviations from covered interest parity. Our assumption is to treat U.S. Treasuries as risk-free.

The India-US spread and India-US credit risk are shown in Figure 17. The decreasing trend in pure credit risk since 2011 is notable.

[16] https://sites.google.com/view/jschreger/CIP

**Figure 17: 10-year India-U.S. Treasury Spreads**




*Source:* Du, W. and Schreger, J., Calculations, Bloomberg

Carry profits can be illustrated by considering a simple one-month carry trade return using the Du and Schreger dataset and one-month ex post depreciation of the rupee against the dollar. The average carry return on the one-month trade for the last four years in the dataset (April 2017 through March 2021) was equal to 1.65%. Valuation changes are calculated by the RBI and published semi-annually, although reports do not consistently provide annual amounts. The average annual rate of return to reserves for the same four years was 0.84%.

The average 10-year spread for April 2017 to March 2021 was 4.9%. Of this, currency risk was 4.3% and credit risk was 0.7%. Although this spread is an opportunity cost of holding reserves, it may apply to the total stock of reserves. The vast majority of the stock of reserve qualified assets issued by the Government of India is held domestically. The premium on bonds held by private domestic entities is an internal transfer. The net cost equals the spread times the amount of government liabilities held by foreign creditors.

In our analysis, we ask whether adding reserves reduces the spread between India and U.S. 10-year treasuries. If so, then the marginal cost of holding reserves falls below the interest differential. To the extent that higher reserves provide more self-insurance against global shocks and sudden capital outflows, spreads should fall with the reserves to GDP ratio. A higher external debt to GDP ratio increases the exposure of the economy to the same shocks, and a higher fraction of external debt denominated in domestic currency may reduce risk exposure and spreads.

Following Devereux and Wu (2022), we use the Du, Im, and Schreger data to estimate the effect of reserves as a share of GDP on the 10-year spread, currency risk, and credit risk for India, as in Equation (3). In our regression, we control for global uncertainty shocks using the VIX index and the yield on U.S. 10-year treasuries.

Domestic controls are the rate of real GDP growth and domestic credit to GDP ratio. The amount of government debt held by foreigners is proxied by total external debt denominated in rupees as recorded by the World Bank. Private external borrowing also exposes the economy to global shocks and sudden gross foreign capital outflows. The measure used to capture this exposure is a ratio of private non-guaranteed external debt for both non-financial and financial corporations to GDP in foreign currency. The regression equation is

$$y_t = \alpha + \beta_1 \ln\left(\frac{Reserves}{GDP}\right)_{t-1} + \beta_2\, ln\left(\frac{Rupee\ external\ debt}{GDP}\right)_{t-1} + \beta_3\, ln\left(\frac{Priv\ external\ debt}{GDP}\right)_{t-1} + \beta_4 IndiaGDPgrowth_{t-1} + \beta_5\, ln\left(\frac{Domestic\ credit}{GDP}\right)_{t-1} + \beta_6 ln\, VIX_t + \beta_7 USyield_t + \varepsilon_t \quad (3)$$

The regression results are reported in Table 2 below. The time frame is January 2006 through March 2021. The first column reports the results of the regression when the dependent variable is the India-U.S. 10-year spread in percent. The coefficient estimate for the logarithm of the reserves to GDP ratio is negative and significant. It suggests that an increase of 1% in the reserves to GDP ratio reduces the spread by 0.03 percentage points. The coefficient for the India-U.S. bond spread on private external debt is significant and positive.

The coefficient for the reserves to GDP ratio on the exchange risk premium is also significant and negative, and both private external debt and rupee denominated external are significant and increase the exchange risk premium. The coefficient for reserves to GDP for pure credit risk for central government debt is significant and positive as well. The coefficient for private external debt (primarily foreign currency debt) and rupee denominated external debt are significant. While increasing foreign currency debt raises credit risk, rupee denominated debt reduces it. Paradoxically, global uncertainty is negative and significant for credit risk.

Increasing reserves appears to reduce the overall sovereign bond spread by reducing both currency risk and credit risk using the 10-year bond spread. The effect on currency risk is intuitive, but the effect on credit risk contradicts the panel data findings of Devereux and Wu (2022). Our result might be consistent with argument of Obstfeld, Shambaugh, and Taylor (2010) that reserves can mitigate the risk of domestic-sourced financial crises because domestic collateral instruments lose value in crises. Rupee denominated external debt may reduce pure credit risk as it raises currency risk.

**Table 2: The Impact of Foreign Reserves on Sovereign Bond Spreads**

| | India-US-Spread (%) | Exchange-Rate Premium (%) | India-Credit-Risk (%) |
|---|---|---|---|
| $\ln\left(\frac{Reserves}{GDP}\right)_{t-1}$ | - 2.889***<br>(0.422) | - 1.260***<br>(0.436) | - 1.786***<br>(0.603) |
| $ln\left(\frac{Rupee\ external\ debt}{GDP}\right)_{t-1}$ | - 0.045<br>(0.387) | 1.907***<br>(0.399) | - 1.871***<br>(0.553) |
| $ln\left(\frac{Private\ external\ debt}{GDP}\right)_{t-1}$ | 2.306***<br>(0.548) | 1.877***<br>(0.566) | 2.884***<br>(0.784) |
| $India\ GDP\ growth_{t-1}$ | 0.314<br>(0.233) | 0.278<br>(0.241) | 0.370<br>(0.334) |
| $ln\ VIX_t$ | - 0.005<br>(0.424) | 0.557<br>(0.437) | - 1.651***<br>(0.606) |
| $US\ 10year\ bond\ yield_t$ | - 0.440***<br>(0.083) | 0.018<br>(0.086) | - 0.224*<br>(0.119) |
| $ln\left(\frac{Domestic\ credit}{GDP}\right)_{t-1}$ | 3.394***<br>(1.151) | 0.474<br>(1.188) | 2.132<br>(1.645) |
| N | 182 | 182 | 182 |
| $R^2$ | 0.78 | 0.74 | 0.47 |

*Note:* Standard errors in parentheses. *, **, *** refer to significance at 10, 5, and 1 percent levels, respectively. Data sources are listed in Appendix A.

## Conclusion

The empirical analysis presented addresses the benefits and costs of additions to foreign exchange reserves held by the RBI. The quantile regressions provide estimates of the marginal effect of reserves on foreign portfolio inflows to India. Self-insurance motives for holding reserves concern the prospect of large sudden gross portfolio outflows. The role of precautionary reserves is not limited to providing the necessary liquidity for the worst events. It should include any deterrence effect, inhibiting run episodes, and mitigation effect, reducing the size of outflows induced by a shock. The quantile regressions can reveal how the probability and size of a sudden exodus of capital depend on global (push) and domestic (pull) shocks.

The results of our examination of how the ratio of reserves to GDP affects gross portfolio inflows shows that additional reserves continue to reduce gross outflows against adverse global financial shocks and interest rate shocks. They suggest that there are positive marginal benefits to accumulating reserves for financial stability functions. We find a significant and large effect of reserves for reducing foreign portfolio outflows in the event of shocks to global uncertainty. The results point to stabilizing effect of reserves in the case of monetary policy shocks as measured by the relative policy rate set in India to the U.S. For this case, an increase in reserves reduced portfolio debt outflows when gross inflows in sudden outflow (stop) events and reduced portfolio debt inflows during surges.

The counterpart of the benefit of reserves for reducing the impact of global shocks or the global financial cycle is the opportunity cost of holding a stock of reserves. The effect of reserves on sovereign spreads should be considered when estimating the cost of reserve hoarding. The estimation of the spread between Government of India and U.S. Treasury yields shows that the ratio of reserves to GDP reduces the yield differential. Our regressions test the hypothesis that India's reserves, at the margin, reduce the insurance premium. Thus, the significance of the negative coefficient on the reserves to GDP ratio shows that additional reserves reduce currency risk.

The marginal cost of holding reserves is estimated to be less than the sovereign spread. The decomposition of this spread is conceptually valuable and may be useful for understanding how monetary policy frameworks and reserves affect exchange rate risk in future work.

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## Appendix A: Data

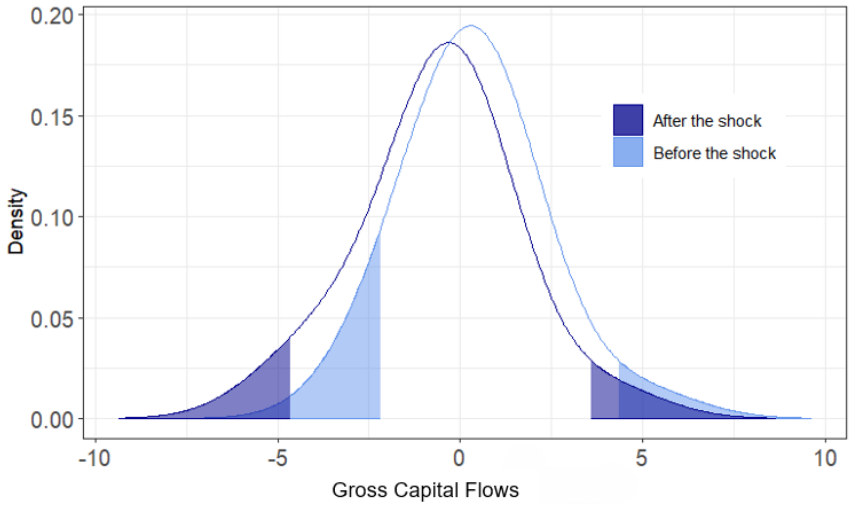
Table A.1: Data

| *Variable* | *Definition* | *Frequency* | *Source* |
|---|---|---|---|
| Gross Capital Flows (USD Billions) | Sum of Portfolio Equity and Debt Flows | Monthly | OECD Monthly Capital Flows Dataset |
| Chicago Board Options Exchange (CBOE) Volatility Index (VIX) | Near term volatility of stock index option prices | Monthly | FRED, St. Louis Fed Database |
| Weighted Average Call Rate (WACR) | India short term call money rate | Monthly | Reserve Bank of India, Database on Indian Economy |
| Fed Funds Rate (USFFR) | US Effective Federal Funds Rate (overnight interbank lending) | Monthly | FRED, St. Louis Fed Database |
| India 10-year bond yield | India long term government bond yields (10 year) | Monthly | Bloomberg |
| US 10-year bond yield | US long term government bond yields (10 year) | Monthly | FRED, St. Louis Database |
| India Foreign Exchange Reserves | India Total Foreign Exchange Reserves in USD (FCA, Gold, Reserve Tranche position, SDRs) | Monthly | Reserve Bank of India, Database on India Economy |
| India GDP | India GDP, Current Rupees | Quarterly; interpolated monthly | IMF, International Financial Statistics |
| India GDP growth | India Real GDP, domestic currency (growth rate) | Quarterly; interpolated monthly | IMF, International Financial Statistics |
| US GDP growth (Brave Butters Kelley Index) | Brave Butters Kelly Real GDP Annualised % change monthly | Monthly | FRED, St. Louis Database |
| India-US 10-year spread | Difference between 10-year India and U.S. treasury bond yields | Monthly | Du, Wenxin and Jesse Schreger, Calculated from Bloomberg |
| Exchange rate premium | Cross currency swap rate for 10-year India and U.S. treasury bond yields | Monthly | Du, Wenxin and Jesse Schreger, calculated from Bloomberg |
| India credit risk | India-US spread less cross currency swap rate | Monthly | Du, Wenxin and Jesse Schreger, calculated from Bloomberg |
| Private Rupee external debt | Gross external debt position, domestic currency, all sectors, all maturities, domestic currency, USD | Quarterly | World Bank Quarterly External Debt Statistics, SDDS |
| Domestic credit to GDP | Credit from all sectors to private non-financial sector at market value, domestic currency | Quarterly | Bank for International Settlements |

## Appendix B: Quantile Regression Results

Figure B.1(a)-B.1(d): Pre-and post-probability density functions plots of total flows after a VIX shock, an India term premium shock, an India-US bond spread shock, an India-US growth differential shock, and a reserves to GDP shock, respectively.

### Figure B.1(a): Impact of VIX Shock on Total Capital Flows




### Figure B.1(b): Impact of India Term Premium Shock on Total Capital Flows

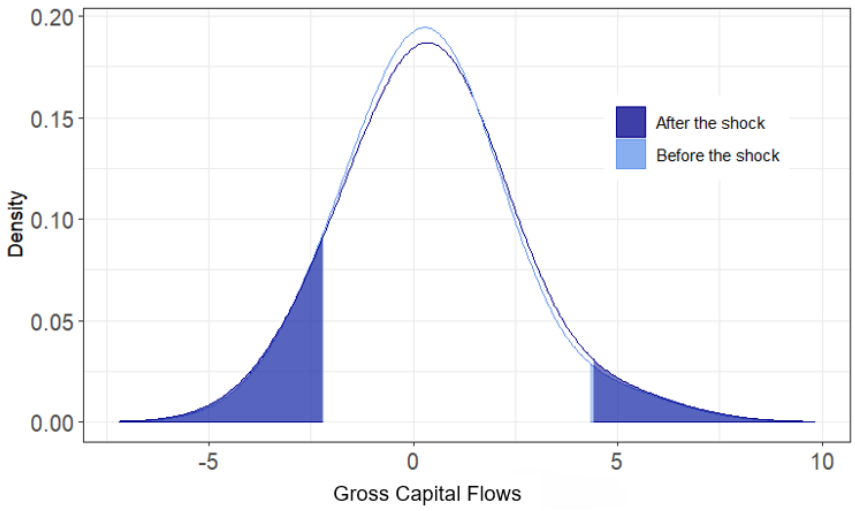


**Figure B.1(c): Impact of India-US Spread Shock on Total Capital Flows**

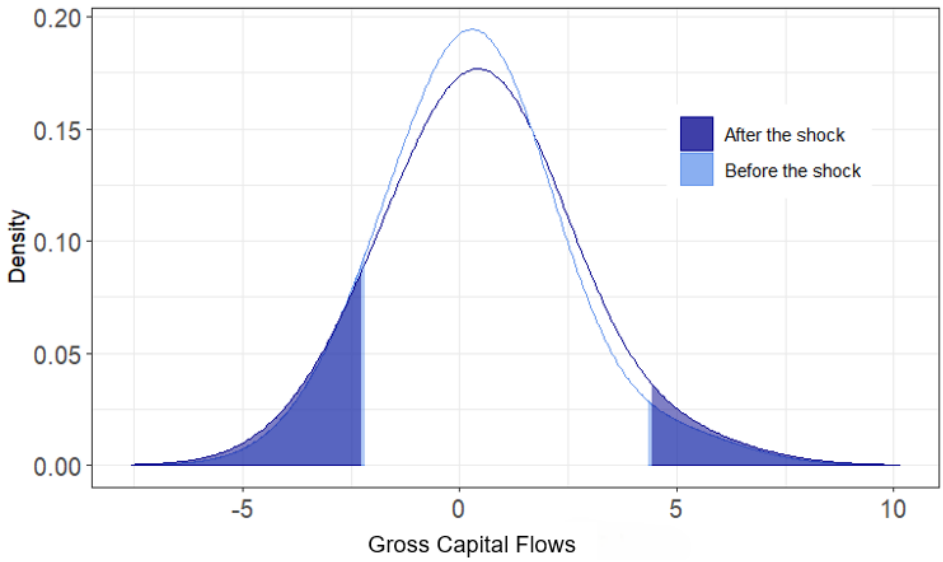



**Figure B.1(d): Impact of Growth Differential Shock on Total Capital Flows**

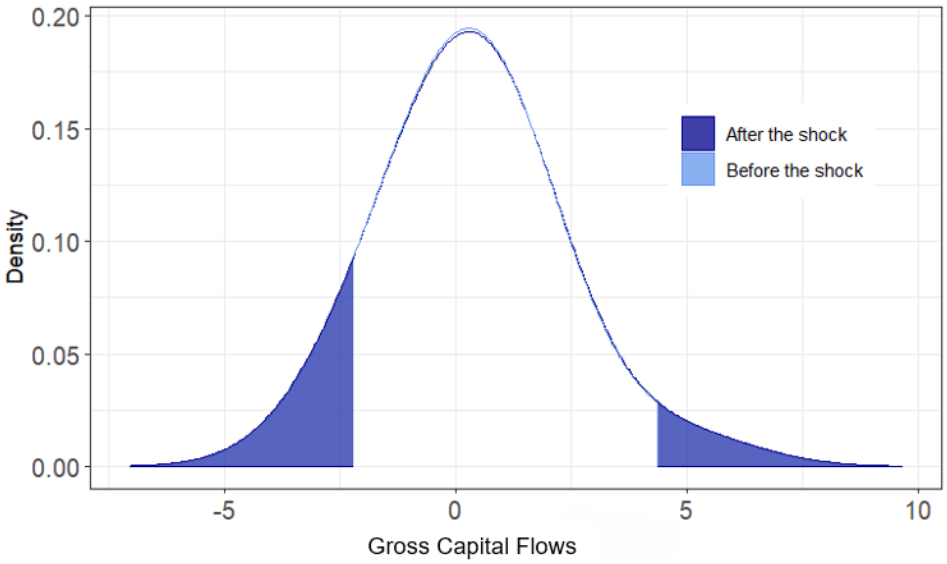
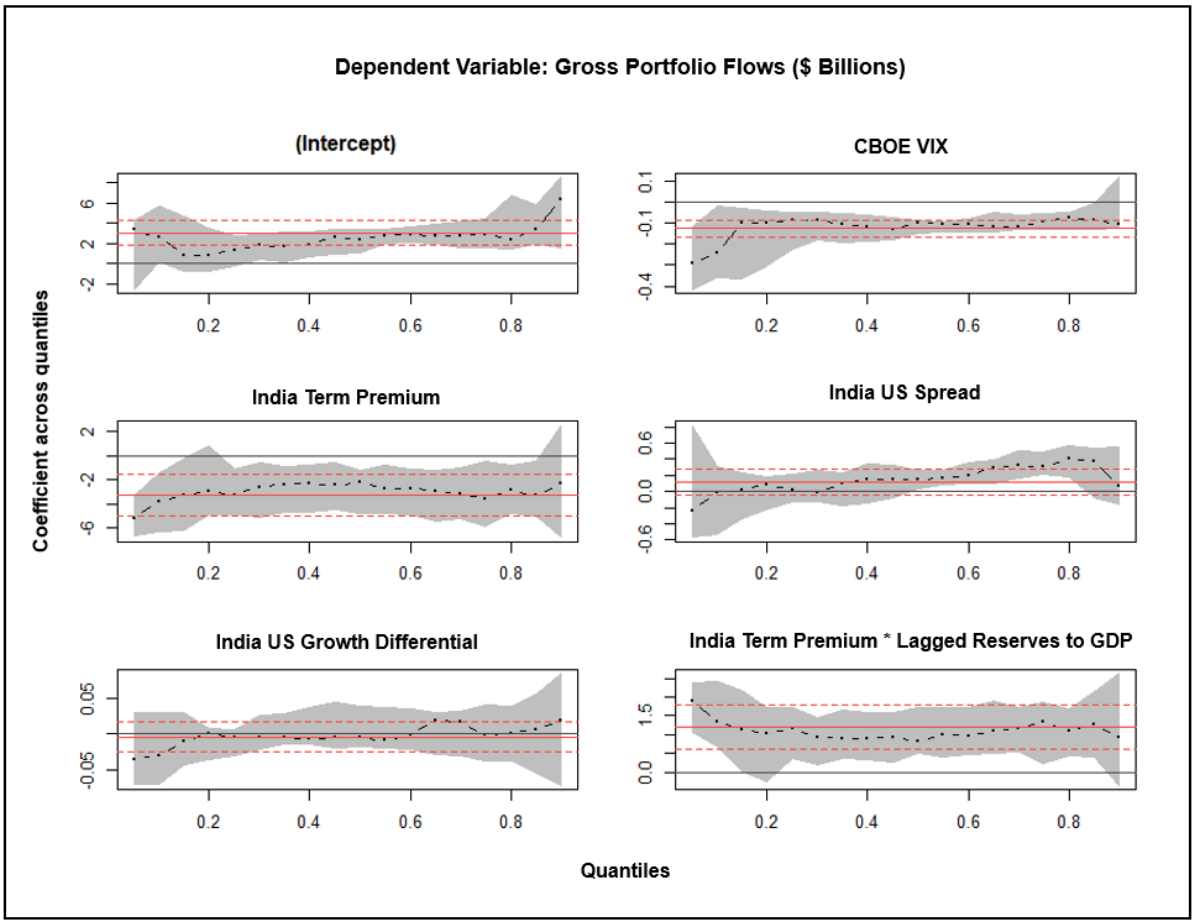
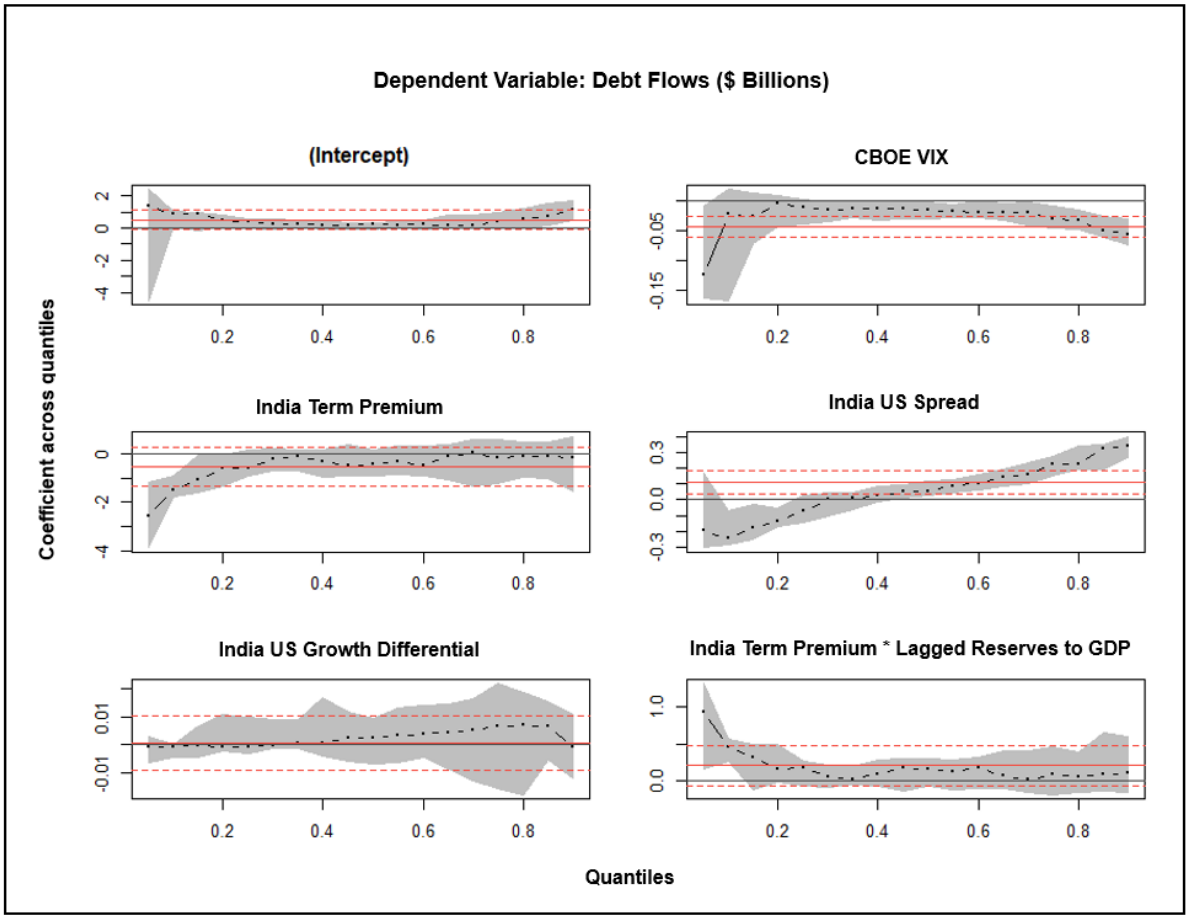


**Figure B.2(a): Quantile Regression Results - Dependent Variable = Gross Portfolio Flows. Reserves Interacted with India Term Premium**



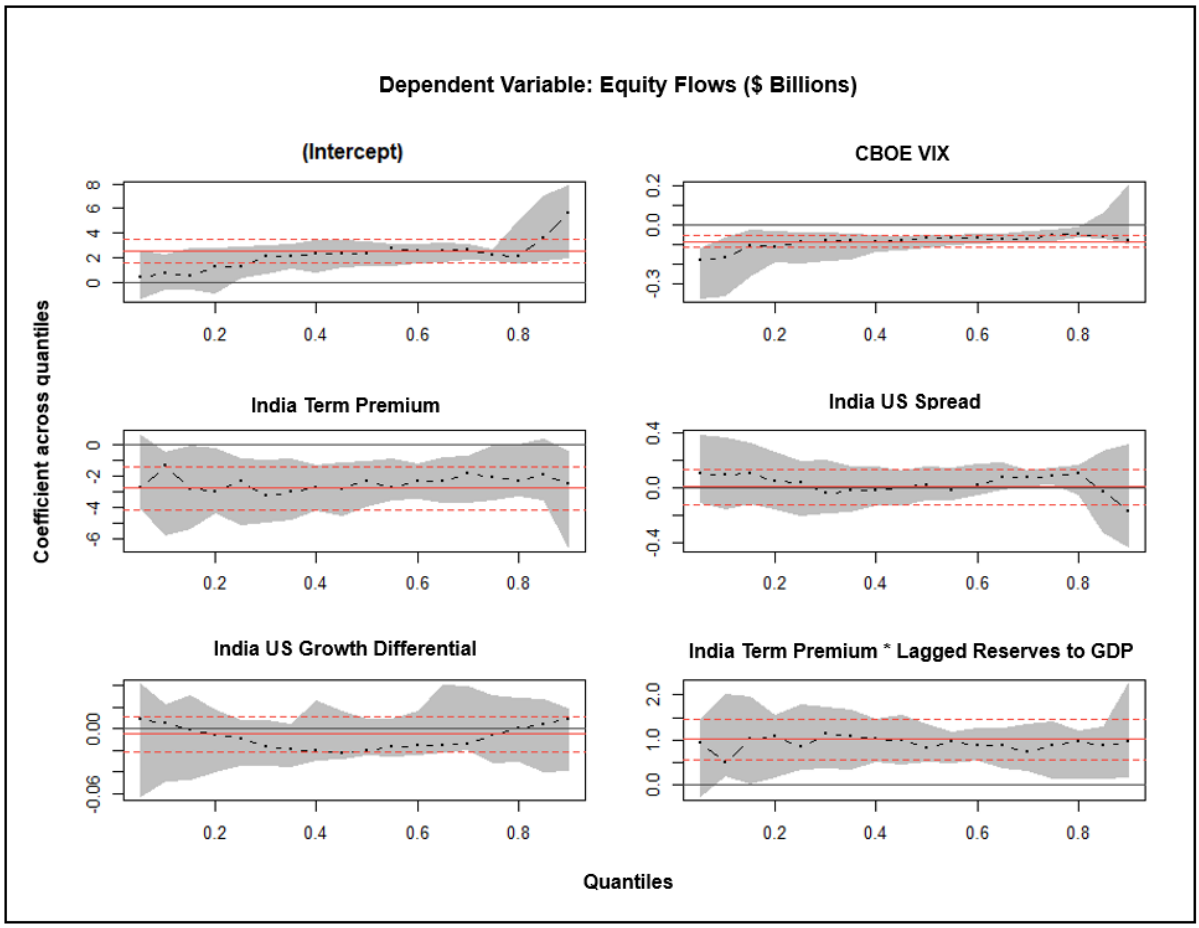

*Source:* Authors' estimates; data described in Appendix A.

**Figure B.2(b): Quantile Regression Results - Dependent Variable = Debt Flows. Reserves Interacted with India Term Premium**




*Source:* Authors' estimates; data described in Appendix A.

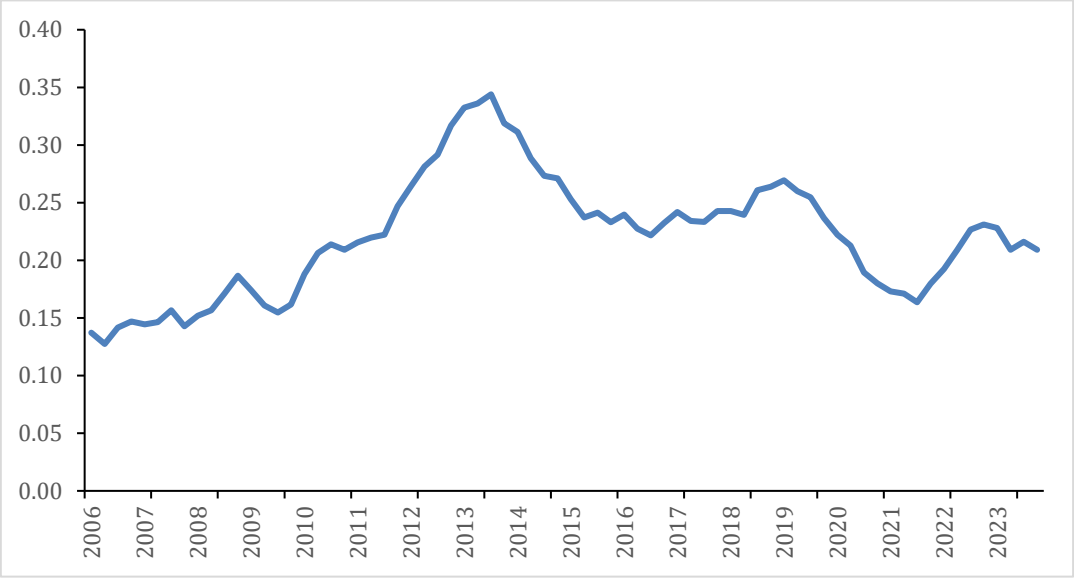
**Figure B.2(c): Quantile Regression Results - Dependent Variable = Equity Flows. Reserves Interacted with India Term Premium**




*Source:* Authors' estimates; data described in Appendix A.

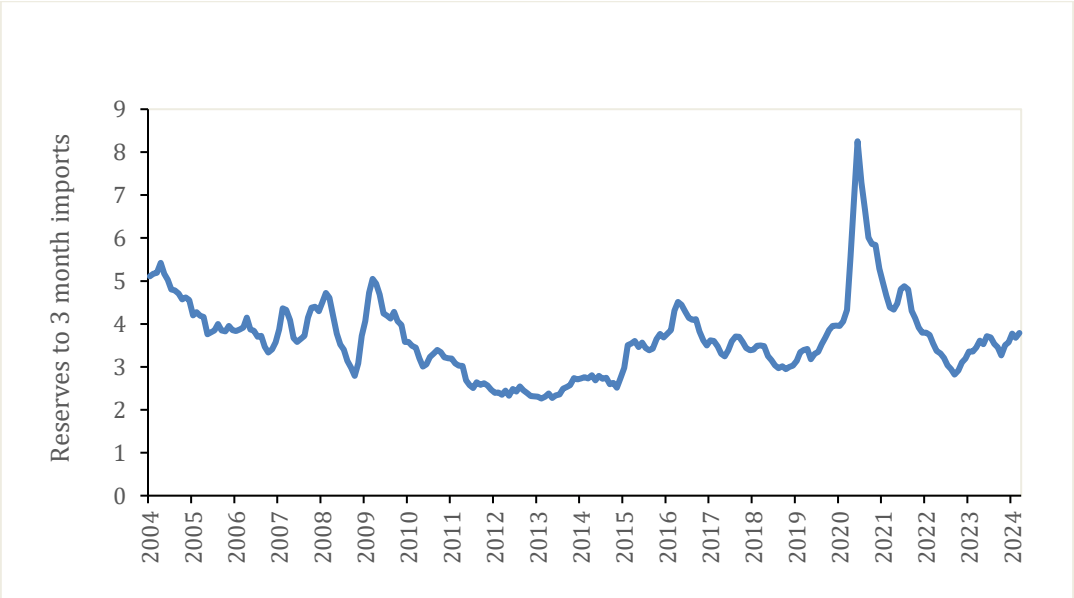
## Appendix C: Additional Figures

**Figure C.1: Short-term External Debt to Reserves**



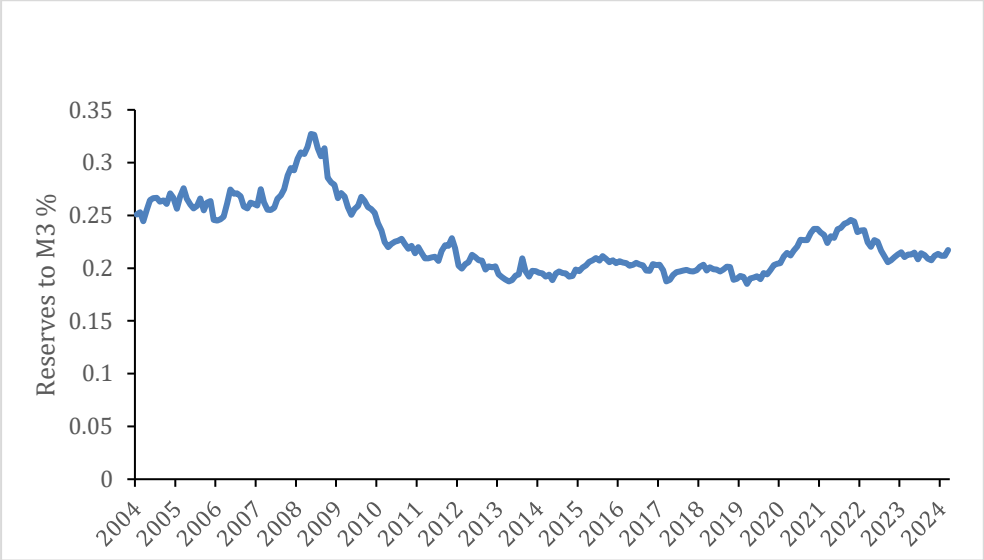

*Source:* World Bank, Quarterly External Debt Statistics, RBI

**Figure C.2: Ratio of Reserves to 3-months Imports in India**




*Source:* IMF International Financial Statistics, RBI

**Figure C.3: Ratio of Reserves to Broad Money (M3)**




*Source:* RBI

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