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Foreign Exchange Intervention Under the Integrated Policy Framework: The Case of India

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ABSTRACT: This paper analyzes the effectiveness of foreign exchange intervention (FXI) in mitigating economic and financial shocks in India by applying the Integrated Policy Framework (IPF). It highlights how FXI can be a complementary tool in mitigating the tradeoff between output and inflation, specifically under large economic shocks amid temporarily shallow FX markets. The paper indicates that while FXI can soften adverse impacts on domestic demand and output during severe risk-off shocks, its benefits under normal conditions with liquid FX markets are limited.

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WORKING PAPERS

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Prepared by Jesper Linde, Patrick Schneider, Nujin Suphaphiphat, and Hou Wang[1]

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I. Introduction

Foreign exchange intervention (FXI) has been an important part of the macroeconomic policy toolkit for many central banks, particularly in emerging markets (EMs), to mitigate ramifications from economic and financial shocks. The survey by the BIS highlighted that in recent years, many EM central banks used FXI to contain stressed trading conditions by keeping the exchange rate volatility in check and providing liquidity to the thin market. While spot market intervention is the most common instrument for intervention, many also engaged in the derivatives market and occasionally foreign exchange (FX) swap.

Various theoretical papers highlight the potential positive effects of FXI on economies through several channels, including the portfolio balance channel (Montoro and Ortiz, 2023), the signaling channel (Patel, Cavallino, 2019, Sarno, Taylor, 2001), and the information channel (Vitale, 2011). In each scenario, the channels underscore the significance of specific sources of friction, which may intensify during periods of financial stress. First, friction can emerge from the portfolio balance channel due to the imperfect substitution between domestic and foreign assets. Consequently, a sterilized FXI impacts risk premia by altering investors' relative endowments. Second, for the signaling channel, a sterilized FXI influences agents' expectations regarding future monetary policy and the exchange rate in line with the intervention. Finally, the information channel emphasizes the importance of micro-structural frictions that hinder the exchange rate from accurately reflecting its actual determinants.

On the other hand, empirical research on the effectiveness of FXI is inconclusive, partly due to existing challenges of endogeneity and limitations of FXI data. Despite these challenges, efforts have been made to address them. Blanchard et al. (2015) analyze a cross-country panel with quarterly data, using the closeness of a country's reserves to an optimal level as an instrument for FXI. The paper finds that consistent with the portfolio balance channel, larger intervention leads to less exchange rate appreciation in response to gross inflows. Daude, Yeyati, and Nagengast (2016) adopt a similar approach with monthly data, using the ratio of reserves to M2 as an instrument. Menkhoff et al (2021) consistently find evidence supporting the effectiveness of FXI, with impacts persisting for months. Fratzscher et al. (2019) find FX effectiveness, especially when interventions are announced and accompanied by verbal interventions. Filardo et al. (2022) highlight that the effectiveness of the intervention rises with the size of the misalignment and with the duration of one-sided interventions. Nonetheless, the paper notes that intervention is less effective in more liquid FX markets.

For India, the empirical evidence on the effectiveness of FXI is also inconclusive. Goyal et al. (2009) find that Reserve Bank of India (RBI) intervention is effective in influencing USD-INR exchange rate returns and reducing exchange rate volatility. On the other hand, Bhaumik and Mukhopadhyay (2000), Pattanaik and Sahoo (2003), Behera et al. (2008) do not find intervention to be effective in affecting exchange rate returns while Vadivel and Ramachandran (2013) do not find intervention to be successful in either of these objectives. Some studies also find an asymmetric impact of the FXI.

The IMF has developed an Integrated Policy Framework (IPF) to provide a systematic and friction-based approach for selecting an appropriate mix of policies to achieve macroeconomic and financial stability. Based on the framework, the use of FXI, as a complementary tool to other macroeconomic policy toolkit, depends on the nature of shocks and a country's characteristics and frictions, including FX market depth, FX mismatches, and risk of de-anchor of inflation expectations.

The motivation of this paper is to apply the IPF to India and demonstrate when FXI can be effective in mitigating shocks faced by the Indian economy. The paper will begin by documenting stylized facts on India's foreign exchange market, the RBI's FX policy, and FXI. Section III will highlight key features of the methodologies used for analyzing the effectiveness of FXI. Section IV will apply the IPF frictions in the context of India. Section V will provide appropriate policy tools based on two different scenario analyses.

II. Stylized Facts on India's Foreign Exchange Market, Policy, and Intervention

A. FX Market Development in India

The size of India's currency market has increased significantly in recent years. Average daily global Over-the-counter (OTC) FX turnover involving the Indian rupee reached $122 billion in April 2022 (net) compared to $114 billion in 2019, and $58 billion in 2016[1]. Offshore rupee transactions volumes accounted for over 60 percent of total OTC volumes in 2022, primarily driven by offshore forwards (NDFs),[2] which have nearly tripled in volume since 2016. Derivatives (forwards, swaps, options) accounted for a slight majority of total OTC volumes more generally, though the rupee swaps market is smaller on a relative basis compared to other emerging markets (Figure 1). Indian Rupees (INR) NDF trading is concentrated in London, accounting for 15 percent of total USD-based NDF volume, though other financial centers (New York, Singapore, Hong Kong) see significant volumes as well[3]. NDF contracts with 1 month or less maturity are the most liquid and actively traded, accounting for close to 70 percent of total contracts.[4] The largely OTC onshore market has a fairly liquid spot and forwards (predominately deliverable) market. The Indian rupee is notable among EMs (alongside Brazil) for seeing sizeable turnover in exchange-traded currency derivatives as well, with rapid growth in options in recent years, alongside futures more traditionally. Notional daily average turnover was $23 billion in 2022, up from $12 billion in 2019, which makes it the 4th[th] largest in the world (following US Dollar, Euro, and Brazilian Real)[5].

The presence of large offshore markets can lead to price fragmentation and complicate financial stability objectives. Several studies have found evidence of spillovers in both directions, though during episodes of market stress, price linkages tend to move from offshore NDF markets to onshore markets[6]. However, segmentation between markets has generally eased in recent years. The spread between onshore forwards and offshore NDF prices has shrunk, averaging about 5 forward points from 2020-2023, compared to 12 from 2015-2019, and 17 from 2010-2014 (Figure 2).

The authorities and relevant market participants have taken several steps to further develop local currency markets and better integrate the onshore and offshore markets. Since 2019, the authorities have lengthened domestic trading hours, simplified procedures, improved market infrastructure, and encouraged the development of new instruments[7]. As of June 2020, Indian banks with units in Gujarat International Finance Tec-City (GIFT)

[1] BIS Triennial Survey 2022, OTC turnover, net-net basis

[2] Compares all rupee transactions with rupee transactions in India

[3] Foreign Exchange Joint Standing Committee, Bank of England

[4] RBI Bulletin: Onshoring the Offshore

[5] BIS Exchange—Traded Derivatives Statistics

[6] IMF Working Paper 2020: Schmittman Chua; RBI Working Paper 2021: Behera, Behera, Chinoy, and Ranjan; RBI 2019 Report of the Task Force on Offshore Rupee Markets

[7] RBI Working Paper 2021: Behera, Behera, Chinoy, and Ranjan

City have been able to participate in offshore NDF markets (and with each other). This effectively also further extended trading hours for foreign exchange transactions beyond usual onshore market hours. More recently, in 2023, India began to allow domestic NDFs to settle in rupee, though volumes are low with the market still developing.

Figure 1. OTC FX Turnover: 2022
(US billions, daily average)

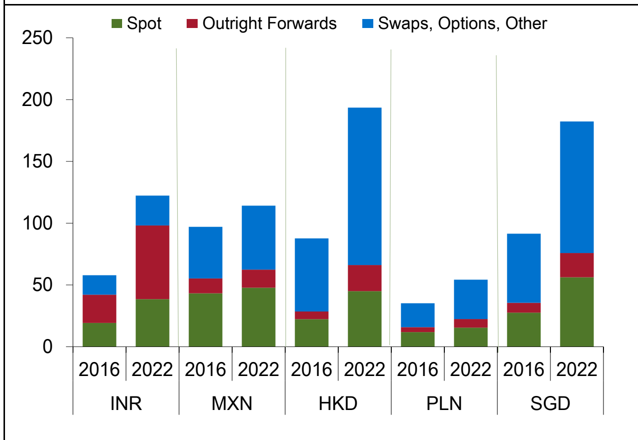
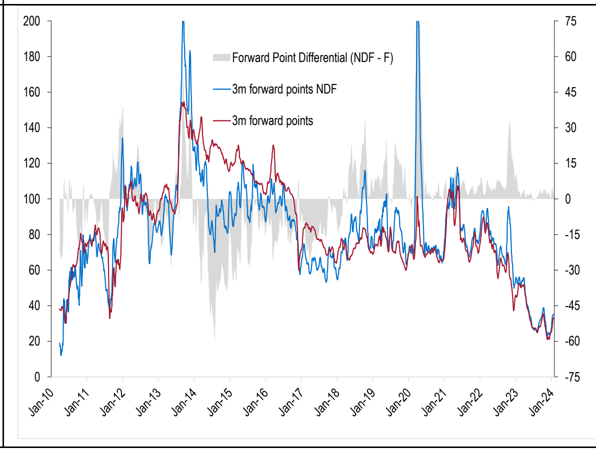


Figure 2. India Rupee: Forward Points and Offshore Premium



Source: Bis Triennial Survey, Bloomberg
Note: Forward points are defined in the difference between spot and forward exchange rate, with ‘1’ representing 1/10000 in the exchange rate quote. In Figure 1, decomposition by instrument for other Asian emerging market currencies is not available in the dataset. However, total OTC FX turnover in 2022 was approximately \$28 bn for Indonesian rupiah, \$31 bn for Thai baht, and \$14 bn for Malaysian ringgit.

B. Foreign exchange rate policy and the use of FXI in India

The RBI is responsible for foreign currency operations and formally intervenes only to curb excessive volatility in currency markets.[8] It intervenes through outright spot market transactions, forwards, and swaps, including so-called 'sell-buy' swap transactions. Assessing the scale of the RBI’s foreign currency interventions is somewhat challenging given the presence of large offshore and NDF volumes alongside a relatively deep domestic market, though it appears to have increased post-COVID. Official data show that the RBI's foreign currency purchases and sales have been directionally consistent with peer countries, albeit with several periods of relatively more aggressive intervention (as a percent of GDP).[9] (Figure 3). Total gross spot transactions have increased since 2019 both as a share of domestic turnover and in level terms to the highest in more than a decade, particularly compared to the previous three years (Figure 4 and 5).

[8] The RBI’s primary objective of monetary policy is to maintain price stability while keeping in view the objective of growth. Foreign exchange interventions and macroprudential measures are focused on minimizing exchange rate volatility and preserving financial stability.

[9] “Foreign Exchange Intervention: A Dataset of Public Data and Proxies” by Adler, Chang, Mano, Shao. The dataset incorporates and is consistent with official data published by the RBI.

Figure 3. EM FX Intervention Proxy
(Percent of GDP, 3m sum, major emerging markets)

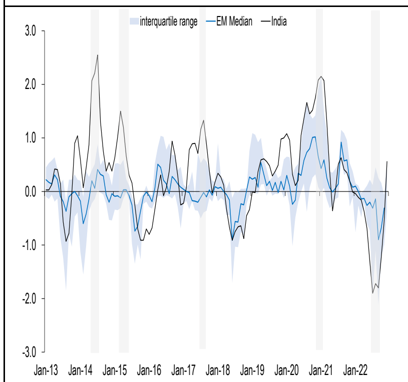


Figure 4. RBI FX Interventions
(US billions)

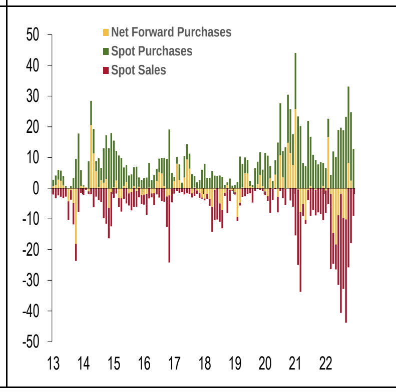
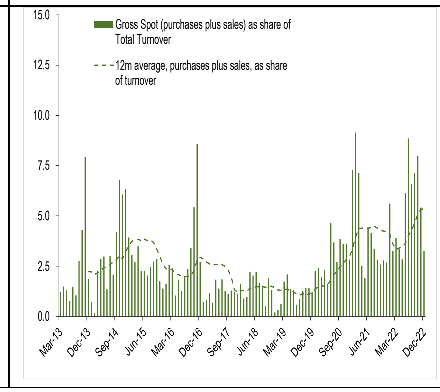


Figure 5. Gross Spot FXI as Share of Onshore Spot Turnover (%)



Source: "Foreign Exchange Intervention: A Dataset of Public Data and Proxies" by Adler, Chang, Mano, Shao

Note: Panel 1 uses cross country data on actual and FXI proxy data. Countries include Brazil, Colombia, Mexico, Hungary, India, Indonesia, Philippines, Poland, Thailand, Malaysia, South Africa, and Chile. For India the series closely correspond or are identical to official data. Panel 2 and 3 uses official data from the RBI. Turnover data is from the RBI and includes purchases plus sales of FX from both the interbank and merchant market.

III. Methodology and Data

A. Integrated Policy Framework – Key Summary

The traditional recommendations by the IMF for countries with inflation targeting regimes, when faced with economic shocks, have been to allow exchange rate flexibility to act as the first line of defense and to limit interventions *only* in the case of disorderly market conditions. The IPF provides a more granular guideline as to when FXI can be effective and should be used complementarily to a traditional monetary policy toolkit such as interest rate policy to stabilize the economy under shock scenarios (IMF, 2023). The framework provides general principles for the advice in countries with flexible exchange rates and sets out three use cases for FXI that are tied to specific frictions. According to the IPF guideline, considerations for FXI policy advice are subject to the nature of shocks and a country's characteristics and frictions.

Shocks

FXI should be used only if shocks faced by countries are large, posing significant risks to central bank objectives, and when the shocks are not caused by inappropriate domestic policy settings. This is because FXI incurs costs. For example, the direct cost includes sterilization costs from purchasing and holding on to FX assets. Furthermore, frequent usage of FXI could undermine or unwind countries' development of FX and hedging markets, and create moral hazard for corporates, preventing them from internalizing the exchange rate risk. Moreover, the inclusion of frequent FXI in a country's operational framework could lead to a loss of clarity regarding the primary objective of monetary policy and lead to confusion regarding the nominal anchor. Finally, if the level of exchange rate significantly deviates from fundamental levels, the use of FXI can lead to speculative attacks.

Specifically, FXI should be used when shocks can cause significant risks to central banks' price and financial stability objectives. This requires that the shock, such as a widening of uncovered interest parity (UIP) premia or a sharp change in the exchange rate, lies towards the tails of the distribution, thereby triggering frictions in a manner that is likely to cause significant risks to central bank objectives, including adverse macroeconomic impacts unless appropriate policy actions are taken.

In addition, where the shock is assessed as being caused primarily by inappropriate domestic policy settings, including excessive current account misalignment, inappropriate interest rate and monetary policy settings, and unsustainable public deficits that jeopardize fiscal sustainability, countries should not use FXI to substitute for the necessary adjustment of those macroeconomic policies as it could be costly, less credible, and deepens macroeconomic imbalances. Instead, policies should focus on correcting those domestic imbalances and restoring confidence.

Frictions: The IPF framework identifies three important frictions that could contribute to effective FXI.

A: Shallow FX market*:*

Capital flow shocks have the potential to trigger significant fluctuations in premia, introducing instability to macroeconomic activity and posing risks to financial stability. Sudden capital outflows can tighten financial conditions, while excessive inflows may result in the underpricing of risks and overly loose financial conditions. Shallow foreign exchange (FX) markets exacerbate the likelihood of overvaluation or undervaluation, making it more probable for shocks to lead to lower (higher) premia on local-currency debt and consequently causing overheating through excessive borrowing or credit crunch. In this case, the use of FXI becomes crucial in ensuring appropriate market functioning, with a primary focus on premia rather than the exchange rate itself.

It's important to note that FX markets may appear deep during normal times, but market liquidity can be state-dependent and the market could become shallow during financial stress. The model accounts for this scenario by incorporating the potential for a time-varying "Gamma" (Γ) in the balance sheet constraints of financial intermediaries. When estimating the quantitative model, one can also consider allowing for time-varying FX market liquidity by allowing the parameter Γ, which governs market depth, to fluctuate between low (indicating deep markets) and high (indicating shallow markets) values (see Section III B).

***B: FX* Mismatches**

An unusually large and unexpected depreciation of the exchange rate can lead to the realization of default risks if there are large unhedged FX exposures. When local currency (LC) assets are funded by unhedged FX liabilities, an exchange rate depreciation increases the value of FX liabilities in LC, while the value of assets remains the same, putting pressure on solvency. As the depreciation increases the debt service costs of unhedged borrowers in the short and medium run, firms may default on both FX and LC debt. Widespread defaults in turn can lead to broader macro-financial spillover effects, e.g., through decreased expenditure and investment (Aguiar, 2005; Kearns and Patel, 2016; Du and Schreger, 2022; Kalemli-Ozcan and others 2021; IMF, 2022c).

Using FXI to lean against a large depreciation can reduce solvency and liquidity risks from large preexisting unhedged FX debt. FX sales by the central bank would prevent the LC value of FX debt obligations and associated debt service costs from rising as high as they would otherwise, and thus the FXI would abate repayment pressures. This could also reduce the risk of fire sales of LC assets to meet FX repayment obligations. In reducing these risks, early and effective intervention in FX markets can help reduce the extent of adverse macro-financial feedback loops that might result from a reduced credit provision by domestic and external creditors.

C: Risk of de-anchoring inflation expectations

FXI can improve the policy trade-off faced by the central bank in the context of large exchange rate depreciations. In the presence of nominal frictions such as backward-looking expectations formation and price and wage indexing, the second-round effects of exchange rate depreciations on inflation may be strong, threatening price stability by de-anchoring inflation expectations and requiring a strong monetary policy response. However, raising policy rates sharply to counteract the effects of the depreciation on inflation may induce a slowdown in economic activity and increase the cost of stabilizing prices. FXI can limit the exchange rate depreciation and hence the passthrough to inflation and inflation expectations, complementing a monetary policy tightening, and thereby helping monetary policy meet challenges in containing such destabilizing effects.

The case for using FXI to maintain price stability is stronger when exchange rate movements induce inflation and output to move in opposite directions. When economic activity contracts following a large depreciation, the central bank could exacerbate the economic slowdown if it sharply raises the interest rate to prevent inflation from rising. Conversely, if economic activity is expanding amid a persistent appreciation, lowering interest rates to remedy persistently low inflation could further boost output and credit, increasing risks in the medium term. In these cases, trade-offs arise for the use of the monetary policy, and there may then be a bigger benefit of using FXI in addition to monetary policy.

B. Quantitative Integrated Policy Framework – Key Features

For the scenario analysis, we use a quantitative model by Chen and others (2023) extended with a supply side. The Chen and others (2023) model is an empirical small open economy formulation of the fully-fledged two-country model in Adrian and others (2021). Compared to the two-country model, the model by Chen and others (2023) makes several simplifying assumptions while augmenting the model with some additional shocks and features to enhance its empirical properties. For instance, following Christiano, Trabandt, and Walentin (2011), it is assumed that exporting firms use domestically produced goods as an intermediate input, which helps the model reconcile very volatile exports and imports with a relatively stable trade balance (as a share of GDP) from the data. The model is log-linearized around the steady state to facilitate Bayesian estimation.[10]

Chen and others (2023) estimate the model with Bayesian techniques using a set of standard macroeconomic time series for 12 emerging market economies (EMEs) and 5 small open advanced economies (AEs). The country-specific estimation results show different transmission of risk appetite shocks in some EMEs relative to the AEs. In particular, these shocks generate a sizeable tradeoff between output and inflation stabilization for some EMEs, reflecting the differences in their underlying economic structures and FX market depth. The results point to fairly deep currency markets in the group of five AEs, while evidence in favor of much shallower currency markets is found in nearly half of the EMEs. A regime-switching extension of the model provides some evidence of a time-varying FX market depth.

Building on Chen and others (2023), the model in this paper develops a supply side by introducing non-stationary technological progress. Not only is it important to capture the effects of supply-side changes due to economic convergence or reforms, but an additional benefit of this extension is that it also removes the need to pre-filter the data before estimation. The estimation can be based directly on the growth of quantity variables (e.g., output), as opposed to their deviations from trends derived from HP filters.

[10] Interested readers are referred to Appendix A of Chen and others (2023) for further details on the model.

The model is admittedly highly stylized to be able to parse out the various channels at play in propagating different shocks and understanding various policy scenarios. There are however two arguments why it should be of interest. First, it shares many features in common with the IMF's conceptual model (Basu et al., 2020) that underpins IMF's IPF policy advice. Second, our model has a similar level of aggregation as the Reserve Bank of India's policy model (see John et al., 2023). Still, an important caveat to keep in mind is that country modalities may differ for India in ways that are not fully captured by our model. Another important caveat that should be noted is that the model does not incorporate direct impacts of energy and food prices onto inflation expectations. Nonetheless, the model endogenously features time-varying inflation expectations, which should, at least implicitly, take second-round effects from food and energy price shocks into account in the estimated model.[11] For India, where food accounts for almost half of the CPI basket and food prices may have significant implications on household inflation expectations, it is important for monetary policy to target overall headline inflation rather than core inflation, while considering core inflation among the variables used to project near-term inflation trends.

C. Data

The model is estimated using a set of standard macroeconomic time series for India as well as for the U.S. The estimation proceeds in two steps. First, we estimate the foreign bloc (a closed economy formulation of the model with its own set of observables and shocks) on U.S. data. Next, contingent on the posterior mean parameters for the foreign economy, the domestic economy bloc is estimated. The observables and shocks for the domestic and foreign economies are summarized in Table 1. The data for India spans from 1996Q3 to 2022Q4 while the U.S. sample is 1984Q1-2022Q4. Considering that India is an emerging economy, we have examined the robustness of the estimation results for a shorter sample period (2009Q1-2022Q4). We do not obtain any notable differences in estimation results on the shorter sample.

The data for the domestic economy includes national account components (real GDP, real government expenditure, real imports, and exports), two measures of price pressures (core inflation, wage inflation), short- and long-term interest rates (the policy rate and 10-year government bond yield), real exchange rate, a measure of FXI, and labor force participation. Our wage measure includes both rural and urban population. All quantities are expressed as growth rates (log differences). All the nominal variables including interest rates and price and wage inflation are left untouched, and their sample means are matched by their model's consistent (calibrated) steady-state levels. Consistent with the stationarity assumption of the real exchange rate in the model, we measure it as a percent deviation from its sample mean. The real exchange rate is based on the bilateral exchange rate vis-à-vis the U.S. dollar. FXI is taken from RBI's published FX intervention and divided by trend

Table 1. Observables and Shocks Used in Estimation

Panel A: Domestic Economy		Panel B: Exogenous Foreign Economy	
Observables	**Shocks**	**Observables**	**Shocks**
Real output	Domestic demand shock	Real output	Domestic demand shock
Core inflation	Domestic price mark-up shock	Core inflation	Domestic price mark-up shock
Real exports	Export demand shock	Nominal wage growth	Wage mark-up shock
Real imports	Import demand shock	Policy rate	Interest rate policy shock
Real government expenditure	Government spending shock	Real government expenditure	Government spending shock
Nominal wage growth	Wage mark-up shock	Labor force participation	Permanent technology shock
Real exchange rate	Global risk appetite shock		Stationary technology shock
Policy rate	Interest rate policy shock		
Long-term interest rate	Domestic term premium shock		
Foreign exchange intervention	FXI shock		
Labor force participation	Import price mark-up shock		
	Permanent technology shock		
	Stationary technology shock		

[11] An updated version of the Q-IPF model incorporates commodity prices, which offers a useful framework for future research for India.

nominal GDP measured in U.S. dollars (calculated using an HP filter with the smoothing parameter λ set to 6400). None of the other series used as observables in the estimation of the model are pre-filtered; instead we include all quantity and price series in growth rates when we estimate the model. Employment per capita and the real exchange rate are observed in percent deviation from steady state, and interest rates in levels.

D. Model results for FX market depth for India

Below are the regime switching results when the market depth parameter Γ is assumed to follow a two-state Markov process following Davig and Leeper (2006, 2007) and Farmer, Waggoner and Zha (2011). The probability of switching between regimes is assumed to be exogenous and to not be endogenously related to the filtered state of the economy. For estimation purposes, the assumption that Γ switches exogenously is largely inconsequential as the purpose with estimation is to assess if there is evidence in favor of time-variation in FX market frictions. To implement the regime switching estimation, we use the toolbox RISE written by Junior Maih (see e.g. Maih, 2015).

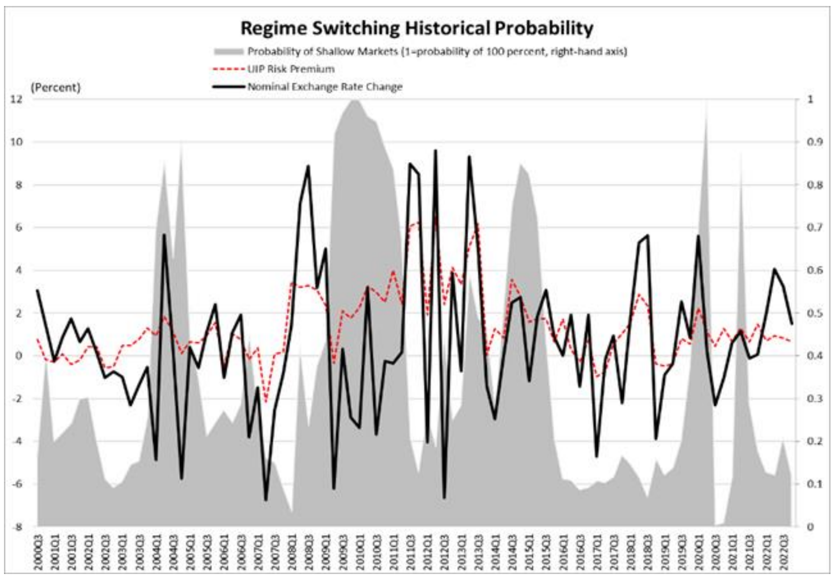
In Table 2, R1 denotes the regime where we center the prior for Γ to imply a deep FX market (Γ is low), and R2 represents a regime where the prior for Γ is set to imply shallower markets (Γ is higher). Uninformative priors are used for the transition probabilities between these regimes. The left columns in Table x summarize the priors for the two regimes. The columns to the right in Table x report the corresponding regime-switching estimation results. The first row in the table shows the posterior for Γ in the “deep” (R1) and “shallow” (R2) regimes, and the second row the corresponding transition probabilities between the deep and shallow regimes, that is p(R2|R1), and the transition probability from the shallow to the deep regime, that is p(R1|R2). The probability to remain in the deep and shallow regimes is simply 1- p(R2|R1) and 1- p(R1|R2), respectively. The third row reports the implied unconditional probability of a deep FX market (based on posterior transition probabilities). Although the prior is that the two regimes are equally likely, the posterior transition probabilities show that the economy often is best characterized as having deep FX markets, but occasionally FX markets become shallow. Figure 6 shows the model’s interpretation of the history—i.e., the probability of being in the shallow markets state against nominal exchange rate movements and a measure of the UIP risk premium. Periods around the global financial crisis, the taper tantrum, as well as the early times of the COVID-19 pandemic are identified by the model as having higher likelihood of being in a shallow-market regime.

India’s large presence of offshore markets can be indirectly accounted for with the IPF model by assuming the same ownership structure for financiers and portfolio investors. However, there are two important caveats. First, if the off/onshore market has been growing fast in the past, the estimated average FX market friction (Gamma parameter) in the model might be upward biased, because increasingly more important off/onshore markets effectively imply a deepening FX market overtime. Second, during times of market stress, offshore markets can spill risks over to onshore markets, which means that the large offshore markets do matter from an IPF point of view.

Table 2. Regime Switching Results

		Prior distribution				Posterior distribution	
		R_1: Deep		R_2: Shallow		R_1: Deep Markets (Low Γ) R_2: Shallow Markets (High Γ)	
Parameter	type	mean	std	mean	std	Deep	Shallow
Γ - FX Market Depth	beta	0.01	0.005	0.075	0.01	0.001	0.059
Trans. Probabilities. (R_1 to R_2 & R_2 to R_1)	beta	0.5	0.2	0.5	0.2	0.01	0.55
Probability of Deep FX Markets (quarterly)						0.990	

Figure 6. Regime Switching Probability



IV. The Use of FXI Under the IPF

A. Initial conditions[1]

Robust growth: India's economy remained strong supported by robust domestic demand. Headline and core inflation, which had been elevated in FY2021/22 due to a war-induced commodity price surge as well as the impact of pent-up demand, have eased and stayed mostly within the tolerance band of 2-6 percent in FY2022/23. Nonetheless, headline inflation remains volatile due to high fluctuations in food prices.

Prudent macroeconomic policy setting: India's macroeconomic policies have fostered macroeconomic stability and helped support strong growth. Fiscal policy is tightening, and the deficit is expected to narrow gradually notwithstanding a strong push in capital expenditure. Monetary policy has effectively helped mitigate inflationary pressures.

[1] This section refers to macroeconomic developments during FY2021/22 as the analysis covers data up to 2022Q2.

Ample international reserves: India faced strong external pressures beginning in March 2022 as advanced economies simultaneously tightened monetary policy in response to high inflation and global oil prices spiked following the war in Ukraine. These led to Rupee depreciation against the US dollar and a decline in FX reserves, partly reflecting foreign exchange intervention (FXI) by the Reserve Bank of India (RBI). As of end-June 2022, FX reserves stood at about $589 billion.

Global headwinds: India's economy is faced with global headwinds amid high uncertainty. Inflation could remain high and even rise on the back of further shocks, including from an intensification of the war in Ukraine and weather-related shocks. Global financial sector turbulence could return on the back of inflation surprises and expectations of further central bank rate hikes. These shocks could lead to a renewal of external pressures on India, as investors' risk appetite shifts toward safe havens. These downside risks, if materialized, could lower India's growth, elevate inflation, and potentially give rise to financial sector stress. To manage these consequences, macroeconomic policy management will have an important role and the policy mix will have to be carefully calibrated.

B. Identifying IPF frictions for India

B.1 FX market depth

In general, India's FX market appears deep, but it could turn shallow during large shocks. In most cases, India's FX market is relatively liquid, with high FX turnover and narrow bid-ask spread. The UIP premium has been largely low and stable. However, staff analysis points to episodes of destabilizing risk premia from arbitrage frictions in shallow FX markets, with FX volatility spiking during certain large outflow episodes, including the global financial crisis, the non-bank financial corporations (NBFC) crisis in 2018, and, to a lesser extent, the March 2020 COVID-19 outbreak. Nevertheless, FX market dynamics, including the extent of volatility, are hard to fully assess in the presence of FXI.

B.2 FX liability*:*

India's external borrowing is relatively small compared to its peers, with half of foreign currency-denominated borrowing hedged as of June 2023.[2] In 2020, the RBI rolled out measures that deepened its FX markets, such as longer trading hours, merging facilities for residents and non-residents, free cancellation and rollover of contracts, and relaxation of underlying asset requirements to facilitate FX transactions and develop onshore NDF markets which potentially help limit the exposure to FX risks (BIS, 2022). Despite the presence of a large offshore market, some domestic banks are allowed to participate in the offshore NDF market, which has helped reduce the spread between onshore and offshore rates that previously existed (Kumar and Rituraj (2020)).

B.3 Inflation expectation and exchange rate pass-through

India introduced a flexible inflation target framework in 2015. Long-term inflation expectations have been, on average, well -anchored. The exchange rate passthrough is relatively low, estimated to be around 7 percent based on RBI's quarterly projection model.[3] Nonetheless, some studies (e.g. Patra et al, 2018) find that the exchange rate passthrough can be asymmetric, non-linear, and time-varying.

[2] 46 percent of FX external currency borrowing, excluding foreign direct investment (FDI) borrowings from foreign parent companies, was unhedged in March 2023.

[3] RBI Bulletin February 2023. The Q-IPF model estimates a similar exchange rate passthrough at around 7 percent.

C. Shocks

As mentioned in Section III, even in the presence of shallow FX markets, FXI should be used only if shocks are large, posing significant risks to the central bank's objectives, and if FXI can be effective in supporting these objectives. This requires that the shock, such as one resulting in a widening of uncovered interest parity (UIP) premia and a sharp change in the exchange rate, lies towards the tails of the distribution, thereby triggering frictions in a manner that is likely to cause significant risks to central bank objectives. The next section will identify two specific shock scenarios and illustrate when the economy benefits from the use of FXI.

V. Assessing Effectiveness of FXI Under Adverse Scenarios

A scenario analysis is used to illustrate policy responses guided by the integrated policy framework. We consider two scenarios and two policy options. For each specific scenario, the magnitudes of underlying shocks are described in Appendix II. We consider two policy options to mitigate the impact of the shocks.

1) Interest rate policy only (IR only) allows adjustment in the policy rate and
2) Interest rate policy and the FXI (IR+FXI) allow the use of foreign exchange intervention as a complementary tool.

A. Scenario 1: Global fragmentation and domestic shock without significant risk-off shocks

The scenario assumes that global inflation pressure intensifies and prompts the central banks in major advanced economies to raise the policy rate faster than anticipated in the baseline. India's economy is also hit by inflationary shocks and the RBI needs to resume its tightening cycle by raising the policy rate despite a softening of the economy. India faces some exchange rate depreciation, but inflation expectations remain well anchored and there is a small UIP premium shock.

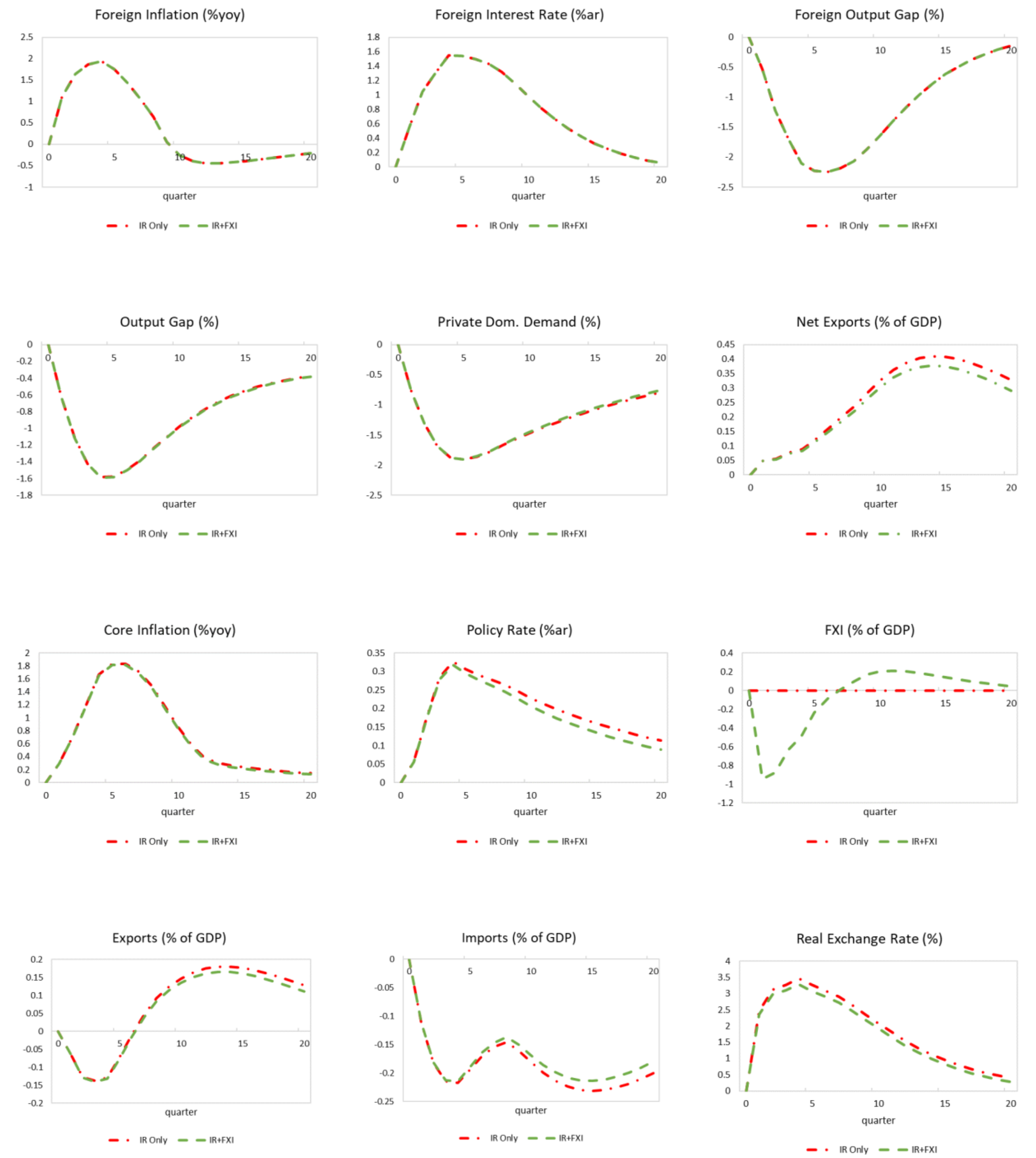
The policymakers face a tradeoff between safeguarding price stability and stabilizing output (Figure 7). Model simulations show that external shocks (stronger price and wage- pressures- in India's most important foreign trading partners, see Annex II for the shock profiles) lead to a significant increase in core inflation in foreign economies during 2023 and 2025 (peak at 2 percentage points higher than the baseline).[4] In response to a surge in inflation, foreign central banks need to raise interest rates by 1.6 percentage points (at peak) during the same period. Interest rate hikes abroad lead to some Rupee depreciation in real effective terms. The depreciation, together with adverse spillovers on domestic price- and wage- pressures in India pushed up India's core inflation by almost 2 percentage points at its peak. The output gap, which is effectively closed under the baseline, now turns negative, largely driven by a drop in domestic demand, notwithstanding some gain in net exports. Policymakers face a tradeoff between output and inflation stabilization.

Under the IPF guideline, FXI is not warranted nor effective in this adverse shock as the FX market remains deep without adverse currency risk-off shocks. Under the IR only option, the RBI needs to raise the policy rate by just below 0.5 percentage points at its peak as inflation expectations remain well anchored. Inflation is

[4] Assuming a deep FX market as the UIP premium remains stable.

gradually converging to 4 percent while a negative output gap will gradually improve. Since the FX market is deep, the use of FXI, in conjunction with the interest rate policy, (IR+FXI) does not provide additional benefits of easing exchange rate depreciation, closing the output gap, or mitigating inflationary pressures.

Figure 7. India: Scenario 1 - Global Trade Fragmentation



Note: 0 represents the initial quarter when shocks have not yet materialized.

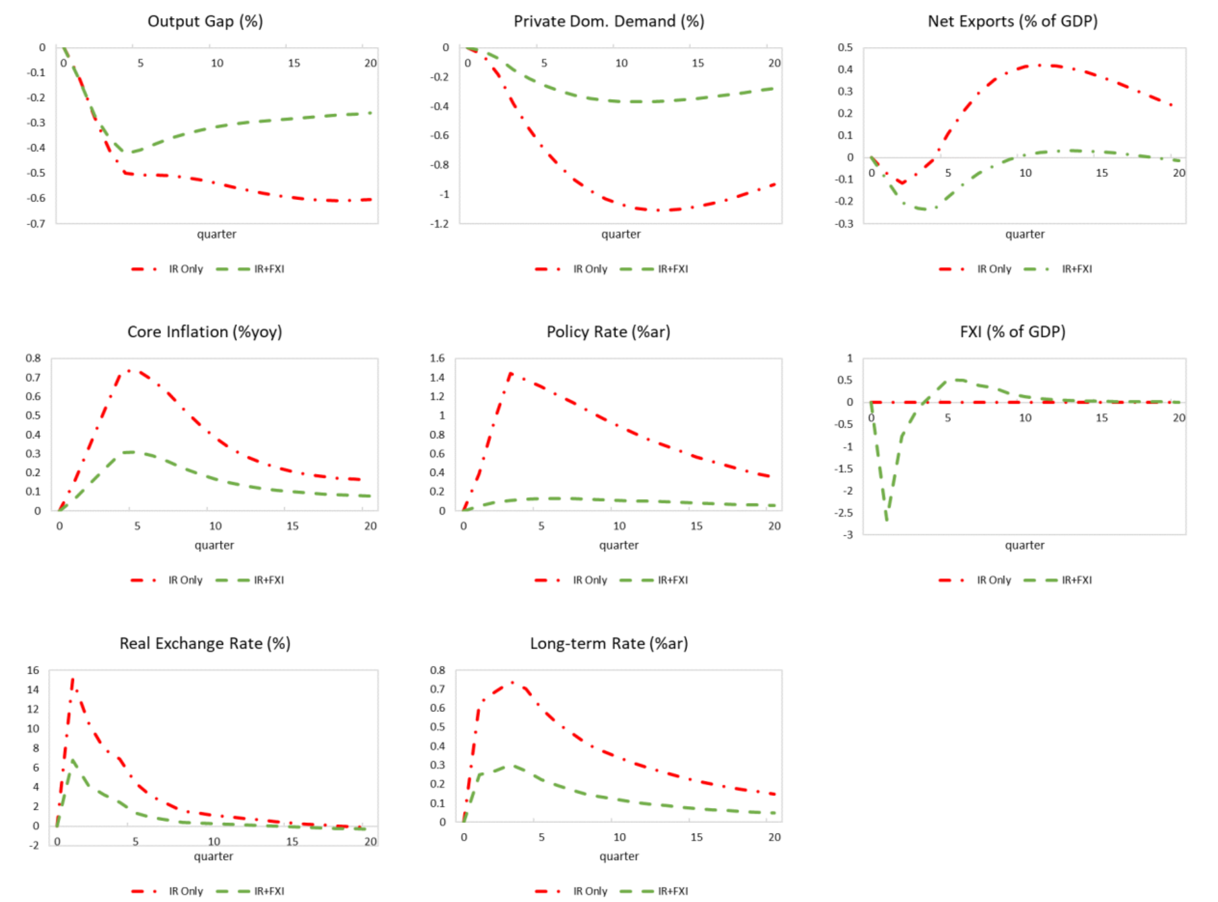
B. Scenario 2: Global financial market disruption with significant risk-off shocks

This scenario assumes aggressive interest rate hikes which result in global financial market turmoil, leading to a sharp slowdown in the global economy. India's economy is also hit by large UIP risk premium shocks which cause the exchange rate to depreciate significantly. In addition, domestic credit market conditions tighten, and output declines due to both negative spillovers from the foreign economy and the tightening of monetary and financial conditions.

Under Scenario 2, global financial market turmoil leads to a risk-off episode with capital outflows and higher domestic risk premiums. Such large shocks, if happening when the FX market is notably shallower, can cause significant exchange rate depreciation. Model simulation suggests that the combination of capital outflow and risk premium shocks (see Annex II for specific shock profiles) leads to a sharp depreciation of the real rupee exchange rate (15 percent at its peak). Despite gaining competitiveness, India's exports would decline as foreign demand declines although net exports would, on average, remain positive as imports also fall. Nonetheless, the downturn in domestic demand would outweigh the improvement in net trade with India's output gap negatively impacted and worsening over time. India's core inflation would increase slightly, driven by the depreciation.

When destabilizing capital outflows arise in shallow FX markets, FXI can ease the inflation output tradeoff for policymakers (Figure 8). The scenario assumes that, as large capital outflow shocks occur, India's FX market turns shallower. In such a scenario, the use of FXI could provide better output inflation outcomes. In particular, an FXI of about 2.5 percent of GDP will help moderate inflationary pressures by reducing the UIP risk premia and limiting the extent to which the rupee depreciates. Core inflation will rise, but by less compared to its rise under the IR only policy, and will converge to 4 percent towards the end of the projection period. Furthermore, the use of FXI takes some pressure off the policy rate hike, which reduces the drag on domestic activity. Specifically, the output gap under the IR+FXI policy option, despite being negative from adverse shocks, will gradually improve over the medium term when both interest rate and FXI are used, while the output gap under the IR only policy option deteriorates further over time. When both policy tools are used, the smaller policy rate hike also implies a smaller increase in the long-term rate and may be less disruptive to domestic fixed income and funding markets.

Figure 8. India: Adverse Scenario 2, Risk-Off Shock from Global Financial Turbulence



As a final exercise, we use a standard loss function—consistent with the policy mandate of the Reserve Bank of India—to evaluate different policy choices. The loss function is calculated as follows.

$$Loss_t = \sum_{i=0}^{5} \beta^i \left[(\pi_{t+i} - \pi^*)^2 + \omega_x (x_{t+i})^2 + \omega_i (i_{t+i} - i_{t+i-1})^2 \right.$$
$$\omega_x = 1; \omega_i = 1; \beta = 0.999; \pi^* = 3; t = 2023$$

Hence, the total loss is given by summing the squared deviation of inflation from its target, the output gap, and the change in the interest rate with equal weights for each year. The inclusion of the policy rate is a way to approximate the existence of an effective lower bound on policy rates. Even so, since the policy rate is not directly related to welfare, we also report results when it is excluded (i.e. the weight for the change in the policy rate ω_i is set to nil).

The results are shown in Table 3a. The left columns report the losses under the baseline projection for inflation, output, and interest rate in the next six years. The rest of the table reports the losses when Scenario 2 materializes. As the next to last row shows, the use of FXI significantly reduces total loss, by nearly 58 percent compared to using interest rate policy only. Most of the improvement comes from lower inflation and a reduction in interest rate variability. Even so, when the policy rate is excluded from the criterion (Table 3b), we still find a sizeable reduction in loss of more than 50 percent. The improvement from using FXI could even be higher if the economy starts with high inflation in the baseline. This is due to the quadratic nature of the loss function, which reflects an increasing cost to contain inflation as inflation gets higher and the risk of de-anchoring gets larger (for example, if the Phillips curve is non-linear).

Table 3a. Loss Function Evaluation with Interest Rate Smoothing

	WEO Baseline				IR Only				IR+FXI			
Period	Inflation	Output	Interest Rate Smoothing	Loss	Inflation	Output	Interest Rate Smoothing	Loss	Inflation	Output	Interest Rate Smoothing	Loss
2023	0.87	0.003	0.00	**0.87**	1.13	0.00	0.11	**1.19**	0.97	0.00	0.00	**0.98**
2024	0.23	0.000	0.00	**0.23**	1.34	0.25	1.00	**2.09**	0.59	0.17	0.01	**0.76**
2025	0.01	0.000	0.00	**0.01**	0.35	0.29	0.11	**0.69**	0.09	0.12	0.00	**0.21**
2026	0.01	0.000	0.00	**0.01**	0.13	0.32	0.09	**0.49**	0.05	0.08	0.00	**0.13**
2027	0.00	0.000	0.00	**0.00**	0.04	0.36	0.05	**0.42**	0.01	0.07	0.00	**0.08**
2028	0.00	0.002	0.00	**0.00**	0.03	0.31	0.02	**0.35**	0.01	0.05	0.00	**0.05**
Total Loss	**1.13**				**5.23**				**2.21**			

Note: Total losses are calculated based on equal weights on inflation (deviation from target), the output gap, and half weight on the interest rate change.

Table 3b. Loss Function Evaluation without Interest Rate Smoothing

	WEO Baseline				IR Only				IR+FXI			
Period	Inflation	Output	Interest Rate Smoothing	Loss	Inflation	Output	Interest Rate Smoothing	Loss	Inflation	Output	Interest Rate Smoothing	Loss
2023	0.87	0.003	0.00	**0.87**	1.13	0.00	0.11	**1.13**	0.97	0.00	0.00	**0.97**
2024	0.23	0.000	0.00	**0.23**	1.34	0.25	1.00	**1.59**	0.59	0.17	0.01	**0.75**
2025	0.01	0.000	0.00	**0.01**	0.35	0.29	0.11	**0.64**	0.09	0.12	0.00	**0.21**
2026	0.01	0.000	0.00	**0.01**	0.13	0.32	0.09	**0.45**	0.05	0.08	0.00	**0.13**
2027	0.00	0.000	0.00	**0.00**	0.04	0.36	0.05	**0.39**	0.01	0.07	0.00	**0.08**
2028	0.00	0.002	0.00	**0.00**	0.03	0.31	0.02	**0.34**	0.01	0.05	0.00	**0.05**
Total Loss	**1.13**				**4.54**				**2.20**			

Note: Total losses are calculated based on equal weights on inflation (deviation from target), and the output gap.

VI. Summary

India's FX market has undergone significant developments in the last decade in terms of the volume of FX turnover, derivatives, and NDF. The RBI and relevant authorities have pushed forward several steps to further develop local currency markets and better integrate the onshore and offshore markets, including lengthening domestic trading hours, simplifying procedures, improving market infrastructure, and encouraging the development of new instruments.

According to the published monthly FXI data, the RBI has been intervening regularly, in spot, future, and forward markets to cushion the impact of external shocks, smooth market volatility, preclude the emergence of disorderly market conditions (DMCs), and replenish its FX reserves. Total gross spot transactions (purchases and sales) have increased since 2019 both as a share of turnover and in level terms to the highest in more than a decade, particularly compared to the previous three years.

The paper applies the Integrated Policy Framework to illustrate when FXI could be beneficial to alleviate the output-inflation policy tradeoffs. According to the IPF guideline, FXI could be effective when a country is faced with a sufficiently large shock and experiences one out of three frictions: large unhedged FX mismatches, shallow FX market depth, and risks of de-anchoring inflation expectation. For India, those frictions seem to have a limited presence as the country has relatively low external debt and small FX liabilities, while inflation expectations are well anchored. Nonetheless, the quantitative IPF showed that even though India's FX market has been mostly deep, it could become shallow in certain periods, including during the GFC and COVID-19.

The two scenarios are specifically designed to illustrate that the effectiveness of FXI is also dependent on the types of shocks. The first scenario is designed such that the economy is faced with both domestic and foreign shocks but there is no risk-off shock. The FX market remains deep and inflation expectation remains well anchored. In this case, the use of FXI is ineffective in mitigating the output-inflation tradeoff. In contrast, the second scenario shows that FXI can help soften an adverse impact on domestic demand and output by limiting excessive rupee depreciation and absorbing the pressure from monetary policy tightening to contain inflation when there is a severe risk-off shock.

While FXI should be part of the policy toolkit in dealing with external shocks, it should only be used under specific circumstances. For India, the simulations showed that the effectiveness of FXI in easing inflation-output trade-offs is likely to be limited in normal times when the FX markets are liquid.

In future work, it would be interesting to analyze policy tradeoffs when inflation expectations are less-well anchored, following for instance IMF (2022). It would also be of interest to use the model to consider alternative policy scenarios, including the effects of forward guidance actions by the Federal Reserve.

Annex I. Model Calibration to India

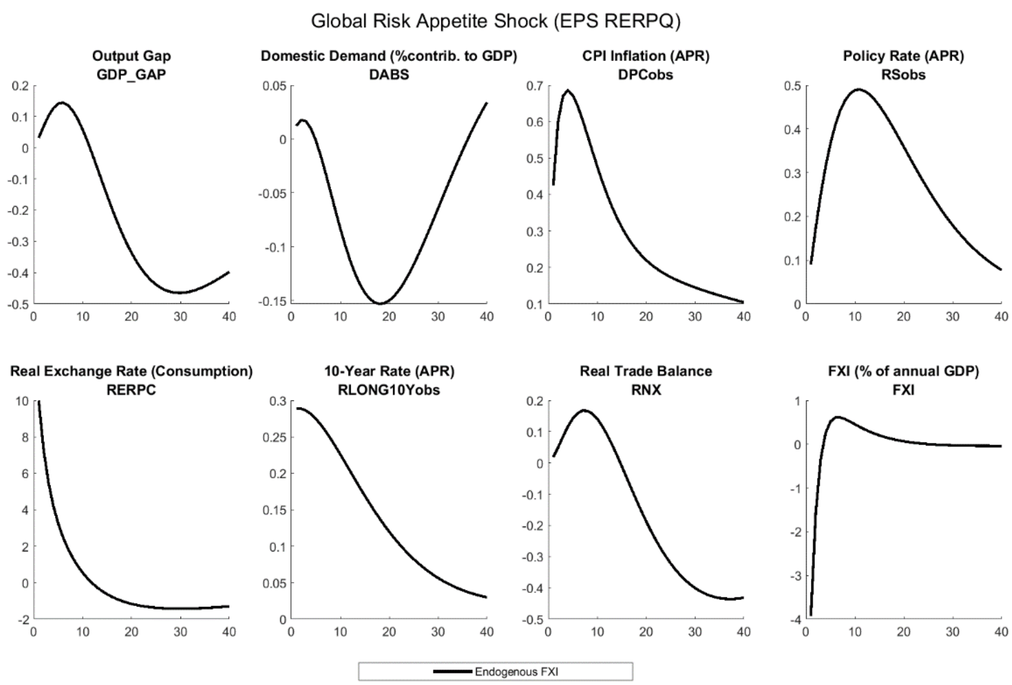
Table A.1 contains the calibrated steady states of the model variables, based on their respective sample averages.

Table A.1. Calibrated Steady States

Observables	Unit	Value
Real output	Quarterly rate	0.35
Core inflation	Annualized rate	5.20
Real exports	Quarterly rate	0.35
Real imports	Quarterly rate	0.35
Real government expenditure	Quarterly rate	0.35
Nominal wage growth	Annualized rate	6.62
Policy rate	Annualized rate	6.66
Long-term interest rate	Annualized rate	8.16

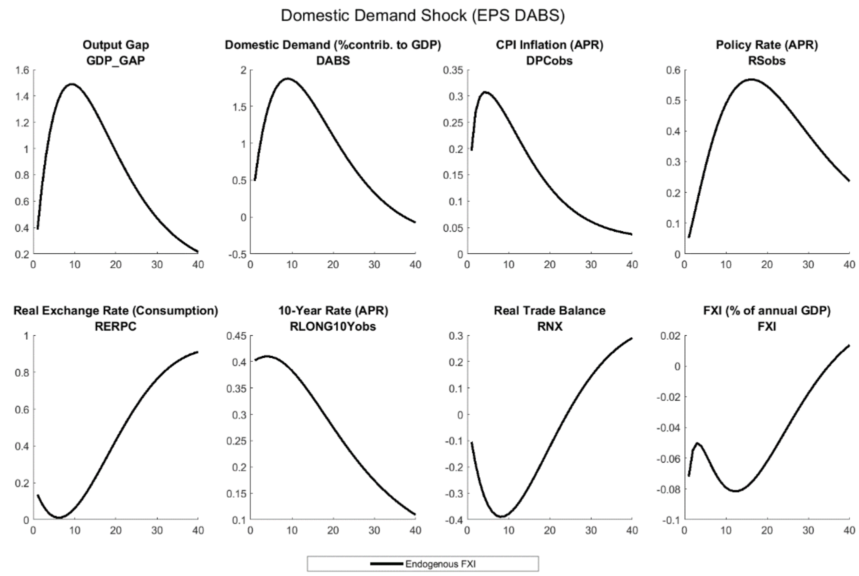
In the following, we present impulse response functions (IRFs) to key shocks.

Transmission of Foreign Investors Portfolio Outflow Shocks



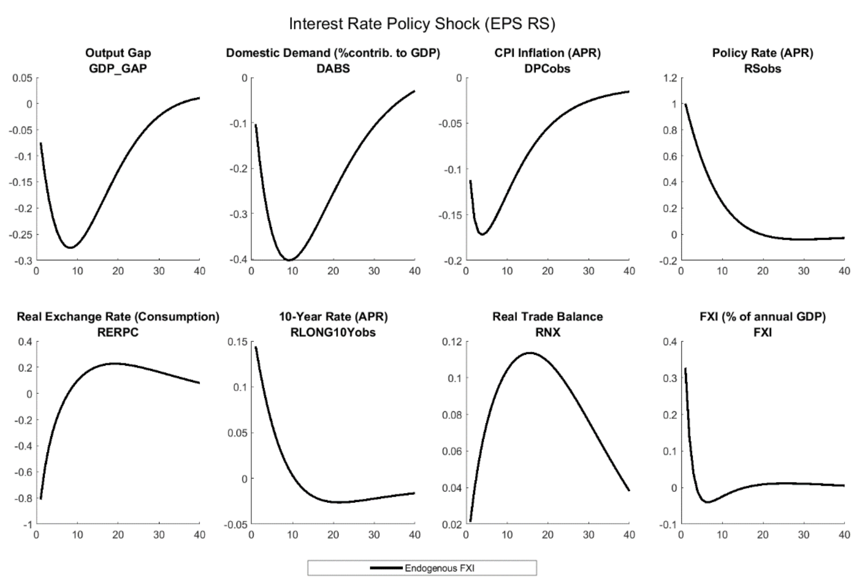
This shock is akin to a UIP risk premium shock in our model, and is here sized so it causes the real exchange rate to depreciate by 10 percent on impact. The depreciation gives rise to a policy trade-off, with domestic demand falling and inflation rising at the same time. This necessitates a persistent interest rate hike to bring inflation back to target as well as a sizable FXI (selling foreign FX reserves) to support the exchange rate. The higher policy rate path translates into higher long-term nominal interest rates through the expectations theory of the term structure.

Transmission of Domestic Demand Shocks



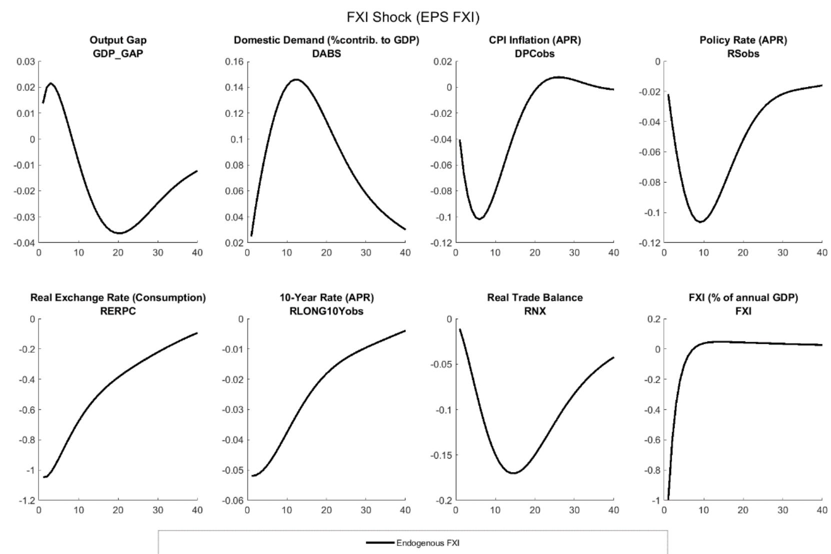
A positive shock causes domestic demand to increase by around 2 percent of GDP and leads to higher inflation. In response, monetary policy raises the policy rate, which also increases the long-term interest rate. Stronger domestic demand worsens the NFA position as the trade balance deteriorates and puts depreciation pressure on the real exchange rate. This leads to a small FXI as dictated by the estimated intervention rule. The finding that the consumption-based real exchange rate depreciates although the domestic policy rate is increased relative to the foreign policy rate is driven by the estimated shallow FX market. A shallow FX market means that the UIP premium rises when the trade balance and net foreign asset position worsen persistently, and this causes the exchange rate to depreciate despite that the real interest differential relative to the foreign economy increases.

Transmission of Interest Rate Policy Shocks



The figure reports the effects of a shock to the interest rate reaction function that is sized to trigger the nominal short-term interest rate to rise 100 basis points in the first period. Thereafter, the systematic part of the policy rule dictates the outcomes. The interest rate hike generates a decline in the output gap (about a quarter percentage point) and somewhat less impact on core CPI inflation. As the exchange rate appreciates, the central bank conducts FXI to accumulate reserves.

Transmission of FXI



The figure shows a negative shock to the estimated FXI rule where additional FXI is deployed through the sale of FX reserves.The currency depreciates notably, reflecting a shallow currency market, which reduces core inflation and necessitates a monetary policy rate cut. Domestic demand is higher, reflecting the stimulatory effect of a looser monetary policy stance, while trade balance deteriorates, and the output gap becomes negative.

Annex II. Scenario Shock Profile

The scenarios are constructed using unanticipated shocks whose values are described below. Each period in the model represents a quarter.

Scenario 1: Global Fragmentation and Domestic Shocks without Significant Risk-off Shocks
(Percent deviations from the baselines)

Shock/Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Domestic								
UIP Risk-premium shock	-0.3	-0.2	-0.1	0	0	0	0	0
Domestic price cost-push shock	0.4	0.4	0.4	0.4	0.33	0.27	0.2	0.13
Wage markup (labor supply) shock	0.4	0.4	0.4	0.4	0.33	0.27	0.2	0.13
Foreign								
Foreign price cost-push shock	0.3	0.3	0.3	0.3	0.25	0.2	0.15	0.1
Foreign wage markup (labor supply shock)	0.3	0.3	0.3	0.3	0.25	0.2	0.15	0.1
Foreign interest rate policy shock	0.125	0.125	0.0625	0.0625	0	0	0	0

Scenario 2: Global Financial Market Disruption with Significant Risk-off Shocks
(Percent deviations from the baseline)

Shock/Period	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Domestic								
UIP Risk-premium shock	-1.95	-1.2	-0.9	-0.6	-0.3	-0.15	-0.075	0
Domestic risk premium shock	0.1	0.1	0.1	0	0	0	0	0
Foreign								
Foreign private domestic demand shock	-0.1	-0.1	-0.1	-0.1	0	0	0	0
Foreign interest rate policy shock	0.1875	0.1875	0.09375	0.09375	0	0	0	0

Annex III. The Linearized Model

This appendix outlines the linearized two-country empirical formulation of the QIPF model, which consists of India and a foreign block (proxied by the United States). The model features an endogenous supply side, so no filtering of data is needed prior to estimation and has the following five building blocks.

1. **The aggregate demand block** stipulates that domestic production is used for private consumption $\hat{c}_t$ (endogenous), government spending $\hat{g}_t$ (exogenous), and exports $\widehat{m}_t^*$ and imports $\widehat{m}_t$ (endogenous). Quantities that grow with the stochastic unit root trend in technology are denoted with 'hats' and have been scaled with the stochastic technology shock to become stationary. They are hence expressed as deviations from the permanent technological level.[5] Since the model currently abstracts from endogenous capital accumulation, the first equation states that aggregate demand is determined by total private consumption $\hat{c}_t$, government spending $\hat{g}_t$, and the real trade balance (measured by the difference between total real exports $\widehat{m}_t^*$ and imports $\widehat{m}_t$). Exports depend on foreign demand $\hat{y}_t^*$ and relative prices, and imports are disaggregated into consumption and intermediate goods $\widehat{m}_{m,t}^*$ and influenced by domestic consumption and relative prices. Hence, exports consist of both intermediate imported goods and domestically produced goods $\widehat{m}_{d,t}^*$. One important feature is that the exogenous domestic risk-premium spread ψ_t enters the forward-looking consumption equation in addition to the inflation-adjusted policy interest rate $i_t - \pi_{c,t+1|t}$. In addition, the consumption Euler equation features an exogenous consumption demand shock $\upsilon_{c,t}$. All shocks are assumed to follow simple first-order autocorrelation (AR(1)) processes unless otherwise noted.

- $\hat{y}_t = c_y \hat{c}_t + g_y \hat{g}_t + m_y (\widehat{m}_t^* - \widehat{m}_t)$
- $\hat{c}_t = \frac{\delta_c}{1+\delta_c \tilde{\varkappa}_c} \hat{c}_{t+1|t} + \frac{\tilde{\varkappa}_c}{1+\delta_c \tilde{\varkappa}_c} \hat{c}_{t-1} - \frac{\sigma(1-\tilde{\varkappa}_c)}{1+\delta_c \tilde{\varkappa}_c} \left(i_t + \psi_t - \pi_{c,t+1|t}\right)$
- $+ \frac{1}{1+\delta_c \tilde{\varkappa}_c} \left(\upsilon_{c,t} - \delta_c \upsilon_{c,t+1|t}\right) + \frac{1}{1+\delta_c \tilde{\varkappa}_c} \left(\delta_c \hat{\mu}_{z,t+1|t} - \tilde{\varkappa}_c \hat{\mu}_{z,t}\right)$
- $\hat{g}_t = \rho_g \hat{g}_{t-1} + \varepsilon_{g,t}$
- $\widehat{m}_t = (1-\omega_x) \widehat{m}_{c,t} + \omega_x \widehat{m}_{m,t}^*$
- $\widehat{m}_{c,t} = \hat{c}_t - (1-\omega_c) \eta_c \left(p_{m,t} - p_t\right) + \vartheta_{m,t}$
- $\widehat{m}_{m,t}^* = \hat{y}_t^* - \hat{\tilde{z}}_t - (1-\omega_x) \eta_x \left(p_{m,t} - p_t\right) - \eta_f \left(p_{x,t} - p_t^*\right) + \vartheta_{m^*,t}$
- $\widehat{m}_{d,t}^* = \hat{y}_t^* - \hat{\tilde{z}}_t + \eta_x \omega_x \left(p_{m,t} - p_t\right) - \eta_f (p_{x,t} - p_t^*)$
- $\widehat{m}_t^* = (1-\omega_x) \widehat{m}_{d,t}^* + \omega_x \widehat{m}_{m,t}^*$

2. **The aggregate supply block** specifies how prices and wages are determined. Domestic price inflation π_t follows a Phillips curve with slope κ_p. Export $\pi_{x,t}$ and import $\pi_{m,t}$ pricing allow for a gradual and inherently persistent pass-through of exchange rate movements Δs_t. Consumer Price Index (CPI) inflation is the weighted average of domestic price inflation and import price inflation $\pi_{m,t}$. Wage setting follows Erceg, Henderson and Levin (2000) and depends on the expected wage growth and the labor wedge, i.e., the difference between the marginal rate of substitution and the consumption-based real wage $\left(mrs_t - \zeta_{c,t}\right)$. In addition, we allow for the possibility that wage growth is influenced by unexpected movements in the exchange rate $\Delta s_t - \Delta s_{t|t-1}$ via $\pi_{L,t}$ if ν>0. If empirically validated, this channel has the capacity to generate a more sustained inflationary impact of

[5] That is, in log levels $\hat{c}_t = c_t - \hat{z}_t$ where z_t is the accumulated sum of past growth rates of the permanent technology shock (deviations from the steady state), i,e. $\hat{z}_t = \sum_{j=0,\ldots,t} \hat{\mu}_{z,j}$.

an unexpected exchange rate depreciation and implies a more aggressive interest rate response to bring back inflation to the central bank's desired level. All the three cost-push shocks $\varepsilon_{\pi,t}$, $\varepsilon_{\pi_m,t}$ and $\varepsilon_{w,t}$ are white noise, while the growth rate of the permanent technology shock ($\hat{\mu}_{z,t}$) and the stationary technology shock ($\tilde{\epsilon}_t$) follows stationary AR(1) processes.

1. $\pi_t - \iota_p \pi_{t-1} = \beta\delta_c(\pi_{t+1|t} - \iota_p\pi_{t-1}) + \kappa_p mc_t + \varepsilon_{\pi,t}$
2. $\pi_{m,t} - \iota_m \pi_{m,t-1} = \beta\delta_c(\pi_{m,t+1|t} - \iota_m\pi_{m,t-1}) + \kappa_m mc_{m,t} + \varepsilon_{\pi_m,t}$
3. $\pi_{x,t} - \iota_x \pi_{x,t-1} = \beta\delta_c(\pi_{x,t+1|t} - \iota_x\pi_{x,t-1}) + \kappa_x mc_{x,t}$
4. $\pi_{c,t} = (1-\omega_c)\pi_t + \omega_c\pi_{m,t}$
5. $\pi_{w,t} - \tilde{\pi}_{w,t-1} = \beta\delta_c(\pi_{w,t+1|t} - \tilde{\pi}_{w,t}) + \kappa_w(mrs_t - \zeta_{c,t}) + \varepsilon_{w,t}$
6. $\tilde{\pi}_{w,t} = \iota_w\pi_{w,t} + (1-\iota_w)\pi_{L,t}$
7. $\pi_{L,t} = (1-\nu)\pi_{L,t-1} + \nu(\Delta s_t - \Delta s_{t|t-1})$
8. $y_t = (1+\phi_p)(\tilde{\epsilon}_t - \alpha\hat{\mu}_{z,t} + (1-\alpha)n_t)$
9. $\zeta_t = \omega_c(p_{m,t} - p_{d,t}) + \zeta_{c,t}$
10. $\zeta_t = \zeta_{t-1} + \pi_{w,t} - \pi_t - \hat{\mu}_{z,t}$

3. **The financial block** includes banks that engage in lending and financiers who trade currencies. It focuses on two types of financial frictions: the so-called Gabaix and Maggiori (2015) wedge or the "agency friction" due to financiers' limited risk-bearing capacity discussed previously.[6] Together with discounting, this gives rise to a modified UIP condition for the product real exchange rate $q_{p,t} = s_t + p_t^* - p_t$ and provides a possible rationale for using FXI (i.e., change in central banks reserves $b_{M,t}$) to lean against exogenous capital outflow shocks $b_{P,t}$. When the "agency friction" Γ is high, which we interpret as FX markets being shallow (see discussions earlier), credible FX interventions may be effective. The third equation is the log linearized equation for net foreign assets b_t, which shows the accumulation of NFA due to net exports nx_t, revaluation, interest rate spreads and carry costs. Finally, the last equation defines a 10-year nominal rate, which we use to identify the domestic risk-premium shock ψ_t, which in the linearized model is assumed to be exogenous and not feed through to the net foreign asset accumulation equation.

- $q_{p,t} = \delta_c q_{p,t+1|t} + (i_t^* - \pi_{t+1|t}^*) - \frac{1+r}{1+r^*}(i_t - \pi_{t+1|t}) + \frac{1+r}{1+r^*}\Gamma[b_{F,t} + b_F(i_t - \pi_{t+1|t})]$
- $b_{F,t} = -b_t - \frac{1}{\Gamma}\tilde{b}_{P,t} + b_{M,t}$
- $b_t = \frac{\bar{I}}{\Pi_y}b_{t-1} + \frac{b}{\Pi_y}[(1-\omega)Ii_{t-1} + \omega I^*\Delta_S(i_{t-1}^* + \Delta s_t) - \bar{I}(\pi_t + \hat{\mu}_{z,t})] - \frac{1-\omega}{\Pi_y}b_M[Ii_{t-1} - I^*\Delta_S(i_{t-1}^* + \Delta s_t)] - \frac{(1-\omega)(I-I^*\Delta_S)}{\Pi_y}(b_{M,t-1} - b_M(\pi_t + \hat{\mu}_{z,t})) + tb_t.$
- $tb_t = m_y(\hat{m}_t^* - \hat{m}_t + \gamma_t^{x,*})$
- $i_{L,t} = \frac{1}{40}\sum_{k=0}^{40}(i_{t+k} + \psi_{t+k})$

4. **The central bank policy block** assumes an interest rate policy reaction function, which is a standard simple forward-looking rule responding to inflation forecasts and featuring interest rate smoothing. Higher ρ means a higher degree of smoothing, while higher γ_π implies stronger policy reaction to expected inflation (and

[6] Hence, while our basic linearized model assumes that the balance sheet friction (the "sudden stop" wedge) due to banks' occasionally binding collateral constraints is nil, we are developing a regime-switching approach where this wedge is included.

hence more aggressive monetary policy). While the rule includes the possibility of an explicit exchange rate stabilization motive, we set γ_s to zero (because its estimated value was very small).

11. $i_t = \rho i_{t-1} + (1-\rho)\left[(1+\gamma_\pi)\bar{\pi}_{c,t+4|t} + \gamma_y \hat{y}_t\right] + \gamma_{\Delta y}\Delta y_t + \gamma_s \Delta s_t + \varepsilon_t^i$

In addition, the central bank can also use FXIs, measured by changes in FX reserves ($fx_t = b_{M,t}$ - $b_{M,t-1}$). Specifically, we study two specifications for FXI: (1) a model with an exogenous FXI rule based on an AR(1) process featuring an error correction term:

12. $fx_t = \rho_{fx,1} fx_{t-1} - \rho_{fx,2} b_{M,t-1} + \varepsilon_t^{fx}$. (FXI Rule 1)

This rule is suitable for countries that do not systematically intervene in FX markets, so changes in central bank reserves can be well approximated with a statistical process with mean reversion towards a "reserve anchor" b_M when $\rho_{fx,2} > 0$. To examine the possibility that FX interventions are used systematically to lean against undesired exchange rate movements, we also consider a second variant in which FX interventions systematically respond to changes in the nominal exchange rate. The formulation of this rule is primarily driven by empirical considerations:

13. $fx_t = \rho_{fx,1} fx_{t-1} - \rho_{fx,2} b_{M,t-1} - \left(1-\rho_{fx,1}\right)\frac{\gamma_{\Delta s}}{1-\gamma_{\Delta s}}\,\Delta s_t + \varepsilon_t^{fx}$. (FXI Rule 2)

Notice that the formulation of the rule allows for a very passive modest response to exchange rate movements when $\gamma_{\Delta s}$ is close to nil, but that the effective coefficient on Δs_t becomes notably larger when $\gamma_{\Delta s}$ approaches unity. While the specification of the rule is primarily driven by empirical considerations, we note that in the empirically realistic case in which exogenous portfolio flow shocks $\tilde{b}_{P,t}$ drive a significant portion of exchange rate movements, welfare is enhanced by leaning against exchange rate movements when the FX market is shallow.

5. **Lastly, the foreign block** is a closed economy formulation of the model above with equations for output, hours worked per capita, private consumption, price and wage inflation, and the policy rate. It includes seven shocks: a permanent technology shock $\hat{\mu}_{z,t}^*$, stationary technology shock $\tilde{\epsilon}_t^*$, government spending shock $\hat{g}_t^*$, $\upsilon_{c,t}^*$ consumption demand shock, $\varepsilon_{\pi,t}^*$ and $\varepsilon_{w,t}^*$ are price and wage cost-push shocks, $\varepsilon_{i,t}^*$ is a monetary policy shock. $\hat{\mu}_{z,t}^*$, $\tilde{\epsilon}_t^*$, $\hat{g}_t^*$, and $\upsilon_{c,t}^*$ are assumed to follow stochastic AR(1) processes, whereas the cost-push and monetary policy shocks are assumed to be white noise. Shocks in this large foreign economy can impact the small open economy, but shocks from the small open economy are assumed to not have any effect on the foreign block.

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