

Systematic Foreign Exchange Intervention and Macroeconomic Stability: A Bayesian DSGE Approach*

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This study quantitatively assesses the role of foreign exchange interventions (FXIs) by introducing a systematic FXI policy that follows a feedback rule responding to nominal FX rates into a small open-economy DSGE model. A quantitative analysis using Vietnamese data reveals that while the systematic FXI policy amplifies the effects of productivity shocks due to the lack of FX flexibility, it contributes to macroeconomic stability overall by insulating an economy from external shocks. The real FX rate, which is modeled as a non-stationary variable on the balanced-growth path, is mainly accounted for by productivity shocks, in contrast with the exchange rate disconnect but consistent with the Balassa–Samuelson relationship.

JEL Codes: F31, F41, E58.

1. Introduction

The role of foreign exchange interventions (FXIs) in achieving macroeconomic stability is a recurrent and controversial policy issue. In a canonical open-economy model, on the one hand, an inflexible foreign exchange (FX) regime relying on FXIs (e.g., a currency peg) often leads to economic destabilization because it cannot benefit

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from currency devaluation in the face of adverse shocks. In practice, on the other hand, many emerging market economies (EMEs) still extensively use FXIs to stabilize the FX rate as a nominal anchor. In particular, many EMEs adopt a “systematic managed floating” system, wherein a central bank *systematically* uses FXIs as policy tools to lean against the wind in the FX market (Frankel 2019). This systematic policy behavior of FXIs makes it challenging to examine their efficacy because a significant fraction of the effects of systematic policy is a consequence of changing the endogenous behavior or expectation formation of economic agents (i.e., rational expectations and forward-looking behavior). Hence, to investigate the role of a systematic FXI policy in achieving macroeconomic stability, it is essential to conduct quantitative analyses based on a structural model, in addition to reduced-form estimations as conducted by the previous empirical literature.

This paper contributes to the literature by introducing a systematic FXI policy into a small open-economy dynamic stochastic general equilibrium (DSGE) model and quantitatively investigating its contribution to macroeconomic stability using a Bayesian method. Specifically, the central bank is assumed to conduct FXIs that follow a systematic feedback rule, as suggested by the practices under the systematic managed floating system, in addition to conducting monetary policy that follows a feedback rule of the nominal interest rate. To quantitatively assess the efficacy of systematic FXIs, the model assumes that the FX rate can deviate from uncovered interest rate parity (UIP) due to the exogenous and time-varying risk premium for external debt and that FXIs can possibly affect the risk premium. The exogenous and time-varying deviations from UIP (“UIP shock”) are commonly assumed in many open-economy DSGE models (e.g., Schmitt-Grohe and Uribe 2017; Itskhoki and Mukhin 2021a, 2021b). While this approach to modeling the effects of FXIs relies on a somewhat ad hoc assumption to make FXIs potentially effective, a Bayesian estimation in the empirical exercise may find this channel quantitatively negligible; therefore, whether FXIs are *quantitatively* effective is an empirical question in the quantitative analysis.

While a Bayesian DSGE approach is one of the standard approaches for policy analysis in many fields of macroeconomic studies recently, a technical but difficult challenge in applying this approach to the analysis for EMEs is the fact that the real FX rate

seems to follow a non-stationary process in many EMEs. As the Bayesian DSGE approach must assume all variables to be stationary, a common methodology in the literature is to remove trends from data before an empirical analysis, using a filtering method such as the Hodrick-Prescott (HP) filter. However, many empirical studies on the determinants of the FX rate point to a cointegration relationship between the real FX rate and the relative productivity growth of tradable goods (i.e., the Balassa–Samuelson relationship); therefore, removing any non-stationary trends before an analysis is subject to the risk of missing important determinants of the FX rate.¹ Since an understanding of the underlying drivers of the FX rate is a prerequisite for investigating the effects of FXIs, the real FX rate in this study is modeled as a non-stationary variable characterized by the Balassa–Samuelson relationship, rather than a stationary variable—as in a standard model—and detrended on the balanced-growth path.

In the quantitative analysis, I focus on the role of FXIs in Vietnam, which is a typical country of a systematic managed floating regime, and examine the extent to which FXIs have contributed to macroeconomic stability in the country. To examine the role of FXIs in achieving macroeconomic stability, I adopt a two-step approach: First, I use Vietnamese data to estimate parameters using a Bayesian method and decompose the variance of output growth, inflation rate, and FX rates into several structural shocks. Second, by changing the parameters for the systematic FXI policy rule while keeping other estimated structural parameters unchanged, I examine how the variance decomposition results would change in the counterfactual case without FXIs. The quantitative analysis reveals that, first, in the baseline case where FXIs reasonably insulate the economy from the UIP shock, the real FX rate is mostly accounted for by productivity shocks. This result is in contrast to the exchange rate disconnect (e.g., Itskhoki and Mukhin 2021a) but consistent with the Balassa–Samuelson relationship. Second, it also shows that in the counterfactual case without FXIs, (i) the real and nominal FX rate would be much more volatile and mainly driven by

¹For empirical studies on the Balassa–Samuelson relationship, see Canzoneri, Cumby, and Diba (1999), Lee, Milesi-Ferretti, and Ricci (2008), Chong, Jordà, and Taylor (2012), and Berka, Devereux, and Engel (2018).

the UIP shock, which is consistent with the exchange rate disconnect under a floating FX rate regime, and (ii) inflation and output growth would also be more volatile. Result (i) implies that some differences in FX rate dynamics between advanced economies and EMEs may be partly associated with an FXI policy regime. Regarding result (ii), the impulse response analysis shows that a systematic FXI policy amplifies the macroeconomic fluctuations caused by the productivity shock while dampening those caused by the UIP and monetary policy shock. Therefore, FXIs can either stabilize or destabilize the economy, depending on the type of shocks driving the business cycle. Result (ii) implies that a systematic FXI policy contributes to macroeconomic stability, at least in Vietnam, by mitigating the adverse effects of the UIP shock as well as the country's own monetary policy disturbances.

This study relates to studies on FXIs and their role in achieving macroeconomic stability.² Among the numerous reduced-form empirical studies on the efficacy of FXIs, Domac and Mendoza (2004), Blanchard, Adler, and de Carvalho Filho (2015), and Fratzscher et al. (2019) are particularly relevant to this study because they emphasize the role of FXIs in reducing FX rate volatility. The efficacy of FXIs is investigated using an open-economy DSGE model with some frictions to make FXIs potentially effective by, among others, Garcia, Restrepo, and Roger (2009), Devereux and Yetman (2014), Benes et al. (2015), Buffie, Ariando, and Zanna (2018), Adler, Lama, and Medina (2019), Erceg et al. (2020), Fanelli and Straub (2020), Jeanne and Sandri (2020), Lama and Medina (2020), and Faltermeier, Lama, and Medina (2022), but those previous studies do not conduct empirical exercises and merely perform some quantitative simulations based on calibration. In terms of the model structure for the quantitative analysis, this study follows an open-economy DSGE model with time-varying deviations from UIP (e.g., Schmitt-Grohe and Uribe 2017; Chen, Fujiwara, and Hirose 2021; Itskhoki and Mukhin 2021a, 2021b; Katagiri and Takahashi 2021), which emphasizes the importance of exogenous shocks to the UIP condition in explaining real and nominal FX

²See Bank for International Settlements (2005), Disyatat and Galati (2007), and Hofman et al. (2020) for an extensive survey of FXIs in EMEs, including their motivations and efficacy.

rate dynamics. Regarding the empirical methodology, this study follows Lubik and Schorfheide (2007) in adopting a Bayesian DSGE approach to identify the policy reaction functions in a small open-economy DSGE model. Finally, the present study also relates to the quantitative analysis of the Balassa–Samuelson relationship using a structural model, which was pioneered by Asea and Mendoza (1994) and Devereux (1999). Recently, Meza and Urrutia (2011) and Berka, Devereux, and Engel (2018) show that the real FX rate dynamics in Mexico and the euro area are consistent with the Balassa–Samuelson relationship, respectively.

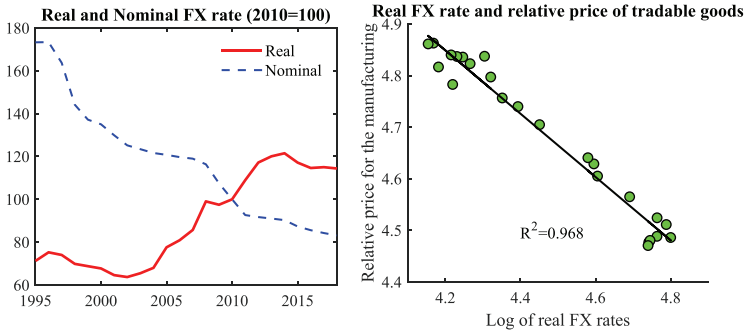
The remainder of the paper proceeds as follows. Section 2 presents an overview of the developments in FX rates and FXIs in Vietnam. Section 3 describes the model for analyzing the effects of FXIs, while Section 4 estimates the model parameters based on Vietnamese data and provides a quantitative analysis. Concluding remarks are presented in Section 5.

2. Foreign Exchange Rate and Intervention in Vietnam

This section presents an overview of the FX rate and FXI policy in Vietnam. First, it describes the developments in the real and nominal FX rates in the last several decades, and shows that those developments have been consistent with the Balassa–Samuelson relationship. It then describes the FXI policy in Vietnam and shows that FXIs are well approximated by a feedback rule that responds to the nominal FX rate; the rule is derived from a simple optimization problem for the central bank in the appendix. Finally, it shows several key business cycle moments with respect to the FX rate and compares them with those for advanced economies.

2.1 Developments in Foreign Exchange Rate

Over the last several decades, Vietnam has experienced secular appreciation and depreciation trends in the real and nominal FX rates, respectively. The first panel in Figure 1 shows the real and nominal FX rates vis-à-vis the U.S. dollar, from 1995. The figure indicates that the real FX rate is on a secular trend of appreciation, and that it has appreciated by more than 60 percent in the last two

Figure 1. Foreign Exchange Rate in Vietnam

Source: Haver Analytics.

Note: In the left panel, the real FX rate is the nominal FX rate vis-à-vis the U.S. dollar deflated by the CPI in Vietnam and the United States. In the right panel, the relative price for the manufacturing sector is defined as the GDP deflator for the manufacturing sector divided by the GDP deflator for the whole economy.

decades. On the other hand, the nominal FX rate has moved in the opposite direction and has continuously depreciated by more than 50 percent in total for the last two decades. Thus, by definition, the difference between the trends in the real and nominal FX rates is accounted for by high and volatile inflation, which has averaged approximately 8 percent for the last two decades.

The developments in the real FX rate in Vietnam have mostly been tracked by the manufacturing sector's relative price. Theoretically, if the law of one price for tradable goods is satisfied, the real FX rate can be approximated by the tradable-goods price relative to the price index of a consumption basket.³ Following the literature, the relative price for the manufacturing sector (= the GDP deflator for the manufacturing sector divided by the GDP deflator

³The law of one price for tradable goods is defined as $P_{T,t} = F_t P_{T,t}^*$, where $P_{T,t}$ and $P_{T,t}^*$ are the tradable-goods prices in the home and foreign countries, respectively, while F_t is the nominal FX rate. By dividing both sides of the equation by the aggregate price levels in the home and foreign countries, P_t and P_t^* , respectively, we obtain $P_{T,t}/P_t = (F_t P_t^*/P_t) P_{T,t}^*/P_t^*$, suggesting that the real FX rate, $F_t P_t^*/P_t$, is proportional to the relative price of tradable goods, $P_{T,t}/P_t$, if the relative price in the foreign country is stable.

for the whole economy) is used as a proxy for the relative price of tradable goods in Vietnam. The second panel in Figure 1 shows the scatter plots between the relative price for the manufacturing sector and the real FX rate in the last two decades. While the law of one price for tradable goods fits the data poorly in some countries, the figure indicates that the real FX rate vis-à-vis the U.S. dollar can be surprisingly well tracked by the relative price for the manufacturing sector in Vietnam, as predicted by the theory (R-squared is more than 0.96); this probably reflects the fact that the manufacturing sector in Vietnam is an export-oriented sector, with many foreign direct investment (FDI) firms.

Such an almost one-to-one relationship between the relative price for tradable goods and the real FX rate implies that the secular trend of appreciation in the real FX rate can perhaps be explained by the Balassa–Samuelson relationship. The Balassa–Samuelson relationship, which is one of the conventional theories that explain developments in the real FX rate, predicts a cointegration relationship between the real FX rate and the relative productivity of the tradable goods sector, given that the relative price of tradable goods should be inversely proportional to the sector's productivity relative to the whole economy. Since the share of output is cointegrated with relative productivity on the balanced-growth path in a standard growth model under some conditions, the theoretical prediction of the Balassa–Samuelson relationship can be reformulated by a cointegration relationship between the output share of tradable goods and the real FX rate. To examine this hypothesis in Vietnam, first, the output share of the manufacturing sector is chosen as a proxy for the output share of tradable goods. Then, the Engle–Granger cointegration test is applied to these two series in Vietnam to test the null hypothesis that they are not cointegrated. Even with the relatively small sample size ($n = 24$) for annual data, the null hypothesis is rejected at the 10 percent level (p-value is 0.081), suggesting that the real FX rate in Vietnam can be accounted for by the relative productivity of tradable goods, consistent with the Balassa–Samuelson relationship. In the next section, I use this cointegration relationship to characterize the balanced-growth path in our small open-economy DSGE model and more formally examine the underlying drivers of the real FX rate by a Bayesian method.

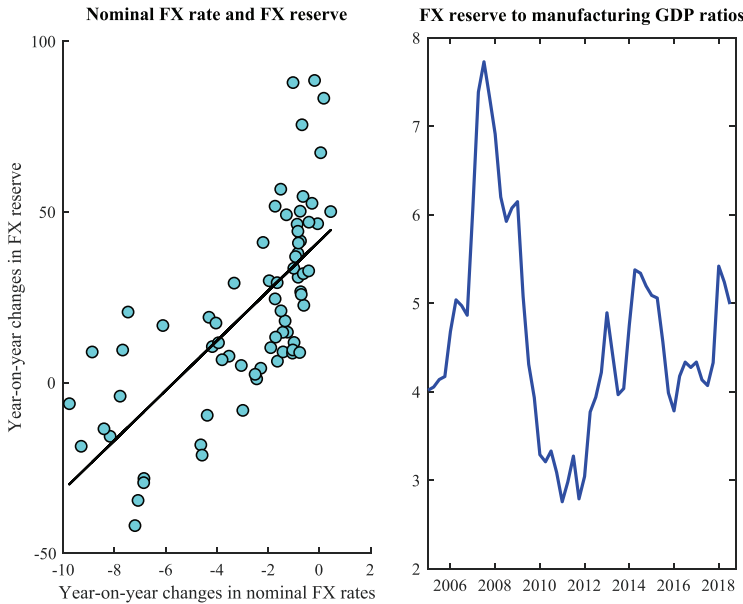
2.2 Policy Rule for Foreign Exchange Intervention

FXIs have been actively used in many EMEs to stabilize FX rate fluctuations. Specifically, Frankel (2019) has recently pointed out that most EMEs adopt neither a free-floating regime nor a hard-currency peg; instead, they follow a “systematic managed floating” system, which is an intermediate regime wherein a central bank systematically responds to market pressure by FXIs to avoid abrupt fluctuations in the FX market (i.e., lean against the wind) while allowing some of the market pressure to be reflected in the FX rate. Under the systematic managed floating regime, a central bank intervenes in the FX market to lean against the wind by carefully balancing the benefit from reducing the volatility of FX rates against the risk of running out of FX reserves. Since holding excessive FX reserves is also costly for them, a typical strategy of central banks is to accumulate FX reserves during normal times, up to a certain target level, and sell the FX reserves in the FX market to support their own currencies in the event of depreciation pressure.

Considering the Vietnamese FX regime and developments in the country’s FX reserves, Vietnam is categorized as a typical country that adopts the systematic managed floating regime. First, in Vietnam, the central bank sets the target FX rate vis-à-vis the U.S. dollar, and attempts to smooth the volatility of the FX rate by systematically intervening in the FX market to contain it within a ± 3 percent trading band of the target rate. Furthermore, the central bank does not adopt a fixed target rate, but gradually adjusts it daily to allow some market pressure to be reflected in the FX rate, which is also consistent with the systematic managed floating system. Second, the developments in the FX reserves also imply that Vietnam follows the systematic managed floating regime. The first panel in Figure 2 shows the scatter plots between changes in the nominal FX rate and Vietnam’s FX reserves on the U.S. dollar basis. The figure shows a clear and positive relationship between them, implying that the central bank in Vietnam sells their FX reserves in response to depreciation in the nominal FX rate to lean against the wind in the FX market.⁴ The right panel in Figure 2 shows the FX reserves

⁴As FX reserves are measured by the U.S. dollar rather than the domestic currency in the figure, any changes due to valuation do not matter here.

Figure 2. Foreign Exchange Interventions in Vietnam



Source: Haver Analytics, IMF.

Note: The left panel uses the data from 2001:Q1 to 2018:Q3, while the right panel uses the data from 2005:Q1 to 2018:Q3.

relative to the manufacturing GDP in Vietnam. The figure indicates that the ratio does not have a trend but has fluctuated around a certain level, implying that the central bank stabilizes the FX reserves around a specific level by accumulating them in normal times for sale in the face of depreciation pressure.

Given these motivations for the systematic managed floating regime, this study assumes that the central bank follows a feedback rule that responds to the FX rate and the lagged reserve-to-GDP ratios, as in Frankel (2019):

$$\Delta Res_t = \beta_0 + \beta_1 \Delta FX_t + \beta_2 \frac{Res_{t-j}}{GDP_{t-j}} + \varepsilon_t, \tag{1}$$

where ΔRes_t is the percentage change in the amount of FX reserves while ΔFX_t is the percentage change in the FX rate. Here, ε_t is the discretionary deviation from the policy rule (i.e., an FX policy

shock), which is estimated as an error term in estimating the FX-policy rule. In this FXI policy rule, it is expected that $\beta_1 > 0$ and $\beta_2 < 0$, implying that the central bank accumulates FX reserves when (i) the nominal FX rate appreciates and (ii) their reserve-to-GDP ratio is low, and vice versa. That is, under the systematic managed floating regime, the central bank is expected to conduct FXIs to lean against the wind in the FX market while taking care of the level of FX reserves. This FXI policy rule is a reduced-form policy rule for the central bank; however, in the appendix, it is shown that the rule can be derived from the optimization problem of the central bank to minimize the loss function based on (i) the volatility of the FX rate, (ii) the deviations from the optimal level of the FX reserves, and (iii) the volatility of the FX reserves.

To examine the empirical fit of the FXI policy rule, the parameter values, β_1 and β_2 , are estimated using Vietnamese quarterly data from 2004:Q4 to 2018:Q3. In the estimation, ΔFX_{t-1} is used as an instrumental variable for ΔFX_t to avoid a potential endogeneity problem that stems from the effect of the FXI policy shock on the FX rate, following the literature on the estimation of a monetary policy rule.⁵ Additionally, the lag for the reserve-to-GDP ratio is set at $j = 2$ to fit the Vietnamese data. The estimation result shows that both β_1 and β_2 are statistically significant in Vietnam, and that the quarter-on-quarter growth in FX reserves will (i) decline by 8.6 percent in response to an FX depreciation of 1 percentage point, and (ii) increase by 0.1 percent in response to a percentage-point decline in reserve-to-GDP ratios, both of which imply that Vietnam follows the systematic managed floating regime.⁶ While the FXI policy rule is more formally estimated in Section 4 using a Bayesian method,

⁵Given that the selling of FX reserves by the central bank positively affects FX rates, any discretionary FXI policy shocks, ε_t , in (1) are negatively correlated with ΔFX_t , and lead to a negative bias in the OLS estimator of β_1 . In the estimation of a monetary policy rule, Clarida, Galí, and Gertler (2000) estimate the feedback rule of the nominal interest rate that responds to inflation using historical inflation rates as an instrumental variable to avoid the endogeneity problem that stems from the effects of the monetary policy shock on inflation.

⁶Frankel (2019) estimates a similar FXI policy rule for Turkey and obtains a statistically significant result for $\beta_1 > 0$ and $\beta_2 < 0$, and concludes that Turkey follows the systematic managed floating regime.

the estimation result here is used as a prior means for the Bayesian estimation to help identify the parameters of the FXI policy rule.

Given that the central bank in Vietnam systematically conducts FXIs by following a feedback rule (1), the next question is, to what extent does the systematic FXI policy contribute to macroeconomic stability? In the empirical literature, Fratzscher et al. (2019) show that many central banks attempt to smooth the volatility of FX rates through FXIs, and that they succeed in doing so in many cases. Furthermore, Domac and Mendoza (2004) and Blanchard, Adler, and de Carvalho Filho (2015) show that countries associated with frequent FXIs have experienced lower volatility or smaller responses of FX rates in the event of capital flow shocks. These empirical studies, which use reduced-form estimation, provide strong evidence for the efficacy of FXIs. However, these studies alone may not suffice to explain the role of a systematic FXI policy because a significant proportion of the effects of any systematic policy is a consequence of changing the endogenous behavior or expectation formation of economic agents (i.e., rational expectations and forward-looking behavior). Therefore, quantitative studies based on a structural model are necessary to investigate further the effects of systematic FXI policy and its contribution to macroeconomic stability. Such effects of a systematic FXI policy are analogous to a systematic monetary policy that follows a feedback rule. For instance, Clarida, Galí, and Gertler (2000) argue that the monetary policy rule of the nominal interest rate that systematically responds to inflation more strongly is key to understanding the decline in inflation in the Volcker and Greenspan era, by comparing simulation exercises under different monetary policy regimes in a DSGE model. In a similar vein, in Section 4, the efficacy of systematic FXIs is quantified by comparing simulation exercises with and without the systematic FXI policy in a small open-economy DSGE model.

2.3 Business Cycle Moments for FX Rate

Table 1 summarizes key business cycle moments for real and nominal FX rates in Vietnam from 2005:Q1 to 2018:Q3. In the table, ΔF_t , ΔQ_t , and ΔY_t denote growth in nominal FX rates, real FX rates, and real GDP, respectively. For comparison, the table also shows

Table 1. Business Cycle Moments for the FX Rate

| | Vietnam | Japan | Euro Area |
|---|---------|-------|-----------|
| $\rho(\Delta Q_t)$ | 0.52 | 0.27 | 0.38 |
| $\sigma(\Delta Q_t) / \sigma(\Delta F_t)$ | 1.65 | 1.01 | 1.07 |
| $\sigma(\Delta F_t) / \sigma(\Delta Y_t)$ | 1.51 | 3.82 | 4.55 |
| $\rho(\Delta F_t, \Delta Q_t)$ | 0.36 | 0.99 | 1.00 |

Note: The table summarizes key business cycle moments with respect to real and nominal FX rates vis-à-vis the U.S. dollar in Vietnam, Japan, and the euro area. In the table, ΔF_t , ΔQ_t , and ΔY_t denote growth in nominal FX rates, real FX rates, and real GDP, respectively.

the business cycle moments for the euro area's and Japan's FX rate vis-à-vis the U.S. dollar during the same periods.

The table shows that the business cycle moments for the euro area and Japan are basically in line with the literature of the “exchange rate disconnect” (i.e., Itskhoki and Mukhin 2021a). Namely, real and nominal FX rates (i) follow a near-random walk process, (ii) have the same level of volatility, (iii) are about three-fold more volatile than GDP, and (iv) are almost perfectly correlated with each other.

In contrast to these features observed in advanced economies under a floating FX rate system, the table highlights the following four key features in Vietnam under the systematic managed floating system. First, real FX rates are much more persistent than a random walk. The autocorrelation of the first difference of the real FX rate in Vietnam is around 0.5, meaning that the real FX rate is non-stationary and significantly more persistent than a random walk. Second, real FX rates are more volatile than nominal FX rates. The standard deviation of real FX rates is larger than that of nominal FX rates by about 60 percent. Third, changes in real and nominal FX rates are more volatile than GDP growth but not as much as in advanced economies. The standard deviation of nominal FX rate growth is larger than that of GDP growth only by around 50 percent. Fourth, the correlation between real and nominal FX rates is positive but weak. The correlation coefficient between them is only 0.36.

The last three features imply that under the systematic managed floating regime, systematic FXIs to lean against the wind in the FX market possibly help stabilize the nominal FX rate. Under a fixed FX rate regime, the nominal FX rate has zero volatility and no correlation with any variables because it remains constant by construction. Hence, the lower standard deviation of the real and nominal FX rate, as well as the weaker correlation between them, observed in Vietnam implies that FX rate dynamics under the systematic managed floating regime are characterized in between the two extremes, namely a floating FX rate regime and a fixed FX rate regime.

3. Small Open-Economy DSGE Model

This section describes a small open-economy DSGE model for a quantitative analysis of FXIs. While the model follows a standard small open-economy DSGE model (e.g., Schmitt-Grohe and Uribe 2017), there are two main features that distinguish it from conventional models. First, the real FX rate is modeled as a non-stationary variable, rather than a stationary variable, to be consistent with Vietnamese data. As shown in the previous section, the real FX rate is well tracked by the relative price of the manufacturing sector and cointegrated with its output share. Thus, the real FX rate is modeled as a non-stationary variable, consistent with the Balassa–Samuelson relationship, and detrended using the cointegration relationship on the balanced-growth path. Second, FXIs are modeled as a policy rule, as in the previous section, and are assumed to have possible effects on the FX rate. In the next section, the parameters associated with the policy effect are estimated using a Bayesian method on Vietnamese data.

Except for the two features above, the model mostly follows a standard small open-economy DSGE framework. The economy comprises households, consumption-goods firms, and intermediate-goods firms. There are two types of consumption goods, tradable and non-tradable, while the law of one price for tradable goods between the country and the outside world is assumed. In the spirit of small open-economy models, the real interest rate in the world is assumed to be exogenous, while the FX rate is determined by the uncovered interest rate parity (UIP), with risk premiums to induce short-term

deviations from it. In what follows, each type of agent's behavior is described in turn.

3.1 Households

A representative household allocates its income to the consumption basket, C_t , and savings. The consumption basket consists of tradable and non-tradable consumption goods,

$$C_t = \left[\iota^{\frac{1}{\eta}} C_{T,t}^{\frac{\eta-1}{\eta}} + (1-\iota)^{\frac{1}{\eta}} C_{N,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}}, \quad (2)$$

where $C_{T,t}$ and $C_{N,t}$ are the consumption of the tradable and non-tradable goods, respectively. ι and η are the parameters for the share of the tradable goods in the consumption basket and that for the elasticity between the tradable and non-tradable goods, respectively. The price level of the consumption basket (i.e., the consumer price index, CPI) is given by

$$P_t C_t = P_{T,t} C_{T,t} + P_{N,t} C_{N,t}, \quad (3)$$

where $P_{T,t}$ and $P_{N,t}$ are the prices of the tradable and non-tradable consumption goods, respectively. Then, the demand functions for the tradable and non-tradable goods are derived from the household's optimal allocation between the tradable and non-tradable goods,

$$C_{T,t} = \iota \left(\frac{P_{T,t}}{P_t} \right)^{-\eta} C_t \quad \text{and} \quad C_{N,t} = (1-\iota) \left(\frac{P_{N,t}}{P_t} \right)^{-\eta} C_t. \quad (4)$$

Given these demand functions for tradable and non-tradable goods, the monopolistic firms in each sector solve their optimization problems.

The household supplies a labor force to obtain the wage income, $W_t L_t$, where W_t denotes the nominal wage and L_t denotes the hours worked. In addition, since all firms in the economy are owned by the household, it obtains the dividend, D_t , from the firms as another source of income. The household then allocates the income to the consumption basket, C_t , and savings. The household can borrow and save in the form of nominal one-period domestic bonds, B_t , and

one-period external debt, b_t^* . The household's budget constraint in period t is formulated as

$$P_t C_t + \frac{B_t}{R_t} + P_t \frac{b_t^*}{Q_t(r_t^* + \zeta_t)} = B_{t-1} + P_t \frac{b_{t-1}^*}{Q_t} + \sum_{j=T,N} W_{j,t} L_{j,t} + D_t + T_t, \tag{5}$$

where Q_t is the real FX rate, R_t is the nominal domestic interest rate, r_t^* is the real foreign interest rate, ζ_t is a time-varying risk premium for external debt, and T_t is a lump-sum transfer from the government. Following convention, an increase in Q_t means an appreciation of the domestic currency. In the spirit of a small open-economy model, the foreign real interest rate is assumed to be exogenous, and to follow the process,

$$\log r_t^* = (1 - \rho_{rr})\bar{r}^* + \rho_{rr} \log r_{t-1}^* + \varepsilon_{rr,t},$$

where $\varepsilon_{rr,t}$ is an iid shock with standard deviation, σ_{rr} , while \bar{r}^* is a steady-state value for r_t^* . The time-varying risk premium for external debt, ζ_t , captures all deviations from the interest parity due to various factors, including the effects of capital control.⁷ ζ_t will be specified in more detail later.

The household chooses their consumption, $C_{T,t}$ and $C_{N,t}$, labor supply, $L_{T,t}$ and $L_{N,t}$, and short-term domestic bonds and external debt, B_t and b_t^* , to maximize their lifetime utility,

$$E_0 \sum_{t=0}^{\infty} \beta^t U(C_t - hC_{t-1}, L_{T,t}, L_{N,t}),$$

subject to Constraints (2) and (5). $\beta \in (0, 1)$ is the constant discount factor, while h is the parameter for external habit formation. A functional form for the utility function, $U(\cdot)$, will be specified shortly.

⁷Jeanne and Korinek (2010) analyze the impact of a debt tax similar to the specification of ζ_t in (5) and interpret this additional cost for foreign borrowing as capital controls.

3.2 Consumption-Good Firms

The tradable and non-tradable consumption-good firms produce the final goods, $Y_{T,t}$ and $Y_{N,t}$, by aggregating the intermediate goods, $Y_{T,t}(i)$ and $Y_{N,t}(i)$, based on the following constant elasticity of substitution (CES) production function in a competitive market:

$$Y_{j,t} = \left(\int_0^1 Y_{j,t}(i)^{\frac{\nu-1}{\nu}} di \right)^{\frac{\nu}{\nu-1}}, \quad j = T, N,$$

where $\nu > 1$ is the elasticity of substitution. Let $P_{T,t}(i)$ and $P_{N,t}(i)$ be the prices of the tradable and non-tradable intermediate goods. The price index for the tradable and non-tradable intermediate goods, $P_{T,t}$ and $P_{N,t}$, is then defined as

$$P_{j,t} = \left(\int_0^1 P_{j,t}(i)^{\nu-1} di \right)^{-\frac{1}{\nu-1}}, \quad j = T, N,$$

while the demand for each intermediate good is derived from profit maximization by the consumption-good firms,

$$Y_{j,t}(i) = \left(\frac{P_{j,t}(i)}{P_{j,t}} \right)^{-\nu} Y_{j,t}, \quad j = T, N. \quad (6)$$

3.3 Intermediate-Good Firms

A continuum of intermediate-good firms indexed by i produces differentiated intermediate tradable and non-tradable goods using labor, $L_{T,t}(i)$ and $L_{N,t}(i)$, based on the following technology:

$$Y_{j,t}(i) = Z_t A_{j,t} L_{j,t}(i)^\alpha, \quad j = T, N, \quad (7)$$

where Z_t is a stationary component of aggregate productivity, which is common to all firms across the two sectors and follows the process,

$$\log Z_t = \rho_z \log Z_{t-1} + \varepsilon_{z,t},$$

where $\varepsilon_{z,t}$ is an iid shock with standard deviation, σ_z . Additionally, $A_{j,t}$ is a non-stationary and sector-specific component of productivity in period t . Let $a_{j,t} \equiv A_{j,t}/A_{j,t-1}$, and assume that $a_{j,t}$ follows the process,

$$\log a_{j,t} = (1 - \rho_{aj}) \log \bar{a}_j + \rho_{aj} \log a_{j,t-1} + \varepsilon_{aj,t}, \quad j = T, N,$$

where $\varepsilon_{aj,t}$ is an iid shock with standard deviation, σ_{aj} , while \bar{a}_j is a steady-state value for the sector-specific productivity growth. Previous empirical studies find that those non-stationary productivity shocks, in addition to stationary productivity shocks, play an important role in accounting for business cycles in EMEs (e.g., Aguiar and Gopinath 2007).

Under monopolistic competition, the intermediate-good firm, i , in each sector, j ($j = T, N$), maximizes its discounted profits by setting the price of its differentiated product subject to the household's demand (4) and the consumption-good firms' demand (6). Furthermore, following the New Keynesian literature, the intermediate-good firm faces a quadratic cost for deviating from the target inflation rate, $\bar{\pi}$, as well as the previous period's inflation rate, π_{t-1} . The optimization problem for the intermediate-good firm in period t is formulated as

$$\max \sum_{k=1}^{\infty} \frac{\Lambda_{t+k}}{\Lambda_t P_{t+k}} \left[P_{j,t+k}(i) Y_{j,t+k}(i) - W_{t+k} L_{j,t+k}(i) - \frac{\gamma_j}{2} \left(\frac{P_{j,t+k}(i)}{P_{j,t+k-1}(i)} - \pi_{t+k-1}^{\xi} \pi^{*1-\xi} \right)^2 P_{t+k} Y_{t+k} \right]$$

subject to (4), (6), and (7). Here, γ_j is the parameter for sector-specific price stickiness, while ξ is that for inflation indexation common across the two sectors. Λ_{t+k}/Λ_t is a stochastic discount factor for the household from periods t to $t+k$, where $\Lambda_t \equiv \partial U(\cdot)/\partial C_t$. As in a conventional New Keynesian model, the New Keynesian Phillips curve with inflation indexation for the tradable and non-tradable sectors is derived from the intermediate-good firm's optimization.

3.4 Central Bank

Unlike a conventional DSGE model, the central bank has two policy tools for stabilizing the economy: the short-term nominal interest rate, R_t , and the FXI using the FX reserves, Res_t . For both policy tools, this study does not examine the optimal policy; instead, it assumes a simple feedback rule to investigate these policies' effects empirically. The following section estimates the parameter values for

the policy rules using a Bayesian method and performs some counterfactual simulations under different parameter values to examine the efficacy of FXIs.

Regarding the interest rate policy, the central bank sets the short-term nominal interest rate following the Taylor-type policy rule with interest rate smoothing. In addition to the response to inflation and output growth, as in a conventional monetary policy rule, the nominal interest rate possibly responds to changes in the nominal FX rate,

$$R_t = (R_{t-1})^{\rho_R} \left[R^* \left(\frac{\pi_t}{\bar{\pi}} \right)^{\phi_\pi} \left(\frac{Y_t}{Y_{t-1}} \right)^{\phi_y} \left(\frac{Q_t/P_t}{Q_{t-1}/P_{t-1}} \right)^{\phi_q} \right]^{1-\rho_R} \times \exp(v_{m,t}). \quad (8)$$

The central bank can deviate from the rule by adding the “monetary policy shock,” $v_{m,t}$, which follows the process,

$$v_{m,t} = \rho_m v_{m,t-1} + \varepsilon_{m,t},$$

where $\varepsilon_{m,t}$ is an iid shock with standard deviation, σ_m . This monetary policy shock captures all discretionary deviations from the monetary policy rule.

Regarding the FXI policy, the central bank buys and sells their FX reserves, Res_t , following a simple feedback rule based on the nominal FX rate and the amount of the FX reserves, as described in Subsection 2.2:

$$\Delta Res_t = \Delta \bar{Res}_t \left(\frac{Q_t/P_t}{Q_{t-1}/P_{t-1}} \right)^{\theta_q} \left(\frac{Res_{t-1}/Y_{T,t-1}}{\bar{Res}_t/\bar{Y}_T} \right)^{\theta_{res}} \exp(v_{f,t}), \quad (9)$$

where the variables with bars are the steady-state values on the balanced-growth path. As discussed in Subsection 2.2, the central bank is expected to lean against the wind (i.e., $\theta_q > 0$) and accumulate the FX reserves when the amount is insufficient (i.e., $\theta_{res} < 0$). When these parameters are estimated by a Bayesian method, the estimated values in Subsection 2.2 are used for their prior means.

Finally, the central bank can deviate from the FXI rule by adding the “FXI policy shock,” $v_{f,t}$, which follows the process,

$$v_{f,t} = \rho_f v_{f,t-1} + \varepsilon_{f,t},$$

where $\varepsilon_{f,t}$ is an iid shock with standard deviation, σ_f . The FXI policy shock captures all discretionary and unsystematic deviations from the FXI rule.

The central bank’s balance sheet comprises FX reserves on its asset side and one-period nominal bonds on its liability side. Thus, the central bank’s balance sheet identity is specified as

$$P_t \frac{Res_t}{Q_t(r_t^* + \zeta_t)} = \frac{B_t}{R_t}.$$

Finally, the amount of lump-sum transfer from the government is specified as follows:

$$T_t = \frac{P_t}{Q_t} \left(Res_{t-1} - \frac{Res_t}{r_t^* + \zeta_t} \right) - \left(B_{t-1} - \frac{B_t}{R_t} \right). \quad (10)$$

This transfer rule suggests that the central bank transfers all the profits and losses associated with the management of their FX reserves and open-market operations.

3.5 Market Clearing

To close the model, the market clearing conditions for the tradable- and non-tradable-goods markets need to be satisfied. First, since the non-tradable goods should be consumed only in the domestic market, their market clearing condition is

$$Y_{N,t} = C_{N,t}.$$

Second, the market clearing condition for the tradable goods is derived by aggregating the household’s budget constraint with (i) the central bank’s balance sheet; (ii) the government’s transfer rule (10); and (iii) the law of one price for the tradable goods in the domestic and foreign markets. The law of one price for the tradable goods between the country and the outside world is specified as

$$\frac{P_{T,t}}{P_t} = \frac{1}{Q_t}, \quad (11)$$

which suggests that the relative price of the tradable goods is equal to the reciprocal of the real FX rate.⁸ As is well known, the law of one price for the tradable goods specified in (11) is empirically controversial for some countries. In Vietnam, however, as described by Figure 1 in Subsection 2.1, the manufacturing sector's deflator relative to the GDP deflator, which is a proxy for the relative price of the tradable goods—i.e., the left-hand side of Equation (11)—has almost perfectly tracked the real FX rate for the last two decades, which implies that the assumption in Equation (11) is reasonable in the empirical analysis, at least for the last several decades in Vietnam. Under Assumptions (i), (ii), and (iii), the market clearing condition for the tradable goods is formulated as

$$Y_{T,t} - C_{T,t} = \frac{Res_t + b_t^*}{r_t^* + \zeta_t} - (Res_{t-1} + b_{t-1}^*).$$

Note that the market clearing condition for the tradable goods is equivalent to the balance-of-payment identity in the model. That is, since the excess supply for the tradable goods in the domestic market, $Y_{T,t} - C_{T,t}$, is consumed in foreign countries, the left-hand side of this equation can be interpreted as the trade surplus. The right-hand side is the income balance and the resultant increase in net foreign assets, which comprise those held by the household, b_t^* , and the FX reserves held by the central bank, Res_t .

3.6 *UIP Condition and Effects of FXIs*

To derive the equilibrium conditions, first, the utility function is parameterized as follows:

$$U\left(\tilde{C}_t - h\tilde{C}_{t-1}, L_{T,t}, L_{N,t}\right) = \frac{\left(\tilde{C}_t - h\tilde{C}_{t-1} - \chi \sum_{j=T,N} \frac{L_{j,t}^{1+\omega}}{1+\omega}\right)^{1-\sigma}}{1-\sigma}, \quad (12)$$

⁸Here, as in the conventional small open-economy models in Chapter 8 of Schmitt-Grohe and Uribe (2017), it is implicitly assumed that the relative prices of the tradable and non-tradable goods in foreign countries are stable.

where $\tilde{C}_t \equiv C_t / (A_{T,t}^\iota A_{N,t}^{1-\iota})$. That is, following the literature (e.g., An and Schorfheide 2007), the consumption basket in the utility function is deflated by productivity in each sector to ensure that the economy evolves along the balanced-growth path. As is well known, without this assumption, the above form of the utility function (i.e., the Greenwood–Hercowitz–Huffman, or GHH, utility function) is not consistent with the balanced-growth path. The first-order conditions for the household’s optimization yield the equilibrium conditions, including the labor-supply function for each sector, $W_{j,t} / P_t = \chi L_{j,t}^\omega$, $j = T, N$, and the Euler equation for consumption, $U_C(t) = \beta R_t \mathbb{E}_t [U_C(t+1) / (\pi_{t+1} a_{T,t+1}^\iota a_{N,t+1}^{1-\iota})]$, where U_C is a marginal utility of consumption. In addition, by defining the stochastic discount factor, $\Lambda_{t+1} \equiv \beta U_C(t+1) / (U_C(t) a_{T,t+1}^\iota a_{N,t+1}^{1-\iota})$, the first-order condition for the external debt, b_t^* , yields the UIP condition,

$$\mathbb{E}_t \left[\Lambda_{t+1} \frac{R_t}{\pi_{t+1}} \right] = (r_t^* + \zeta_t) \mathbb{E}_t \left[\Lambda_{t+1} \frac{Q_t}{Q_{t+1}} \right], \tag{13}$$

indicating that the return from domestic bonds should be equal to that from external debt. This UIP condition implies that changes in the risk premium for external debt, ζ_t , potentially influence the real exchange rate by inducing time-varying deviations from UIP. As emphasized by Itskhoki and Mukhin (2021a), the exogenous deviations from UIP are interpreted as a consequence of financial frictions in the FX market, including the segmented financial market proposed by Gabaix and Maggiori (2015).

With the UIP condition (13) in mind, next, the risk premium for external debt, ζ_t , is assumed to consist of the following three components:

$$\zeta_t = \zeta \left[\exp(-b_t^* - \bar{b}^*) - 1 \right] + v_{q,t} + X_t. \tag{14}$$

The first component, $\zeta \left[\exp(-b_t^* - \bar{b}^*) - 1 \right]$, indicates that the risk premium is a decreasing function with respect to b_t^* . That is, the risk premium for external debt increases as the net foreign debt held by the household increases, thus pushing back the amount of the household’s foreign assets to their steady-state value. As is well known in the small open-economy model literature, without this risk premium, a steady state for foreign assets would not exist (Schmitt-Grohe and

Uribe 2003). Nevertheless, this first component is not quantitatively important for the FX rate dynamics because the parameter ζ is calibrated to an arbitrarily small number just for the existence of a steady state.

The second component of the risk premium in (14), $v_{q,t}$, is an exogenous fluctuation, which follows the process,

$$v_{q,t} = \rho_q v_{q,t-1} + \varepsilon_{q,t},$$

where $\varepsilon_{q,t}$ is an iid shock with standard deviation, σ_q . As in the previous studies using an open-economy DSGE model with time-varying deviations from UIP, this exogenous component helps the model account for the real and nominal FX rate dynamics in the quantitative analysis. Following Itskhoki and Mukhin (2021a), the stochastic shock, $\varepsilon_{q,t}$, is called the “UIP shock” hereafter.

The third and last component of the risk premium in (14), X_t , represents the effects of FXIs on the risk premium. X_t is assumed to follow the process,

$$X_t = \rho_X X_{t-1} + \psi FXI_t, \tag{15}$$

where FXI_t is the size of FXIs in period t . This formulation implies that FXIs are assumed to directly influence the risk premium on external debt and consequently have effects on the FX rate and the real economy through the UIP condition (13) in the model.⁹ The parameters ψ and ρ_X represent the magnitude of the FXI policy effects and their persistence, respectively. Based on the segmented financial market model by Itskhoki and Mukhin (2021a), where noise traders entail deviations from UIP by affecting financial intermediaries’ financial position, FXIs in the formulation (15) can be interpreted as a source of portfolio rebalance for financial intermediaries, thus entailing deviations from UIP. While this reduced-form approach makes FXIs potentially effective by assumption, a Bayesian estimation in the empirical exercise may find this channel quantitatively negligible (i.e., $\psi \approx 0$); therefore, whether FXIs are *quantitatively* effective is an empirical question in the quantitative

⁹Erceg et al. (2020) also assume that the FX rate deviates from UIP and that FXIs influence the deviations as this paper does, while their main focus is on non-linearity through the balance sheet channel.

analysis. Note that when $\psi = 0$ in (15), any transfers between b_t^* and Res_t associated with a standard form of FXIs—namely, the selling and buying of foreign currencies in the FX market by the central bank—have no effects on the FX rate as in a conventional DSGE model.

On the size of FXIs in period t , FXI_t , the literature emphasizes the importance of distinguishing FXIs from other changes in the FX reserves driven by, for instance, the FX reserve accumulation in normal time. Hence, given the FXI policy rule (9), the size of FXIs in this model is defined as

$$\begin{aligned}
 FXI_t &\equiv \log \left(\frac{\Delta Res_t}{\Delta Res_t} \right) - \theta_{res} \log \left(\frac{Res_{t-1}/Y_{T,t-1}}{Res_t/\bar{Y}_T} \right) \\
 &= \theta_q \log \left(\frac{Q_t/P_t}{Q_{t-1}/P_{t-1}} \right) + v_{f,t},
 \end{aligned}$$

implying that FXI_t equals the changes in the FX reserves excluding the mean-reverting FX reserve accumulation in normal time. Then, given the FXI policy rule (9), FXI_t consists of systematic and non-systematic FXIs, the first and second component of the second line of the equation.

3.7 *Balanced-Growth Path*

Since the model assumes the sector-specific non-stationary component of productivity, $A_{T,t}$ and $A_{N,t}$, the existence of a balanced-growth path is not trivial. Specifically, the following proposition specifies the conditions for having a balanced-growth path in the model:

PROPOSITION 1. *A balanced-growth path exists if and only if either of the following two conditions is satisfied: (i) The functional form for the consumption basket in (2) is Cobb-Douglas (i.e., $\eta = 1$), or (ii) the non-stationary components of productivity in the tradable and non-tradable sectors, $A_{T,t}$ and $A_{N,t}$, respectively, are cointegrated.*

Proof. Let the rate of cumulative non-stationary growth (i.e., the non-stationary growth rate from time 0 to time t) of C_t , $C_{j,t}$, and $P_{j,t}/P_t$ be $\exp(g_{c,t})$, $\exp(g_{c,j,t})$, and $\exp(g_{p,j,t})$, respectively,

where $j = T, N$. The demand function in (4) implies that $g_{c,j,t} = -\eta g_{p,j,t} + g_{c,t}$ for all j and t . Meanwhile, the budget constraint in (3) implies that $g_{c,t} = g_{p,j,t} + g_{c,j,t}$ for all j and t . Hence, if a balanced-growth path exists, we should have

$$(1 - \eta)g_{p,j,t} = 0 \quad \text{for all } j, t.$$

This implies that either (i) $\eta = 1$, or (ii) $g_{p,j,t} = 0$ for all j and t should be satisfied. In the case in (ii), we have $g_{c,t} = g_{c,T,t} = g_{c,N,t}$, indicating that $A_{T,t}$ and $A_{N,t}$ are cointegrated, because $g_{c,j,t}$ is equal to $\log(a_{j,t})$. \square

While this proposition merely suggests that either Condition (i) or Condition (ii) needs to be satisfied for a balanced-growth path to exist, the following corollary provides a useful clue to which condition is more likely to be satisfied for a particular country.

COROLLARY 1. *On the balanced-growth path, if Condition (i) in Proposition 1 is satisfied, the real FX rate is non-stationary and cointegrated with the relative productivity of the tradable sector, $A_{T,t}/A_t$, of order 1, as argued by the Balassa–Samuelson relationship. On the other hand, if Condition (ii) in Proposition 1 is satisfied, the real FX rate is stationary on the balanced-growth path.*

Proof. Let the non-stationary growth rate of the real FX rate be $g_{q,t}$. Then, we have $g_{q,t} = -g_{p,T,t}$, by the definition of the real FX rate. In the case in (i), given that $g_{c,t} = \iota g_{c,T,t} + (1 - \iota)g_{c,N,t}$, we have

$$g_{q,t} = g_{c,T,t} - g_{c,t} = (1 - \iota)(g_{c,T,t} - g_{c,N,t}),$$

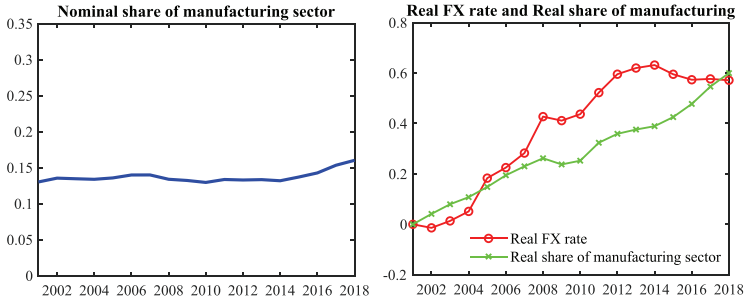
which implies that the real FX rate is cointegrated with the relative productivity, $A_{T,t}/A_t$, of order 1. On the other hand, in the case in (ii), given that $p_{T,t} = 0$, we have $g_q = 0$, which means that the non-stationary growth of the real FX rate is zero, and the real FX rate is stationary. \square

Intuitively, if the productivity across the sectors is cointegrated, as stated in Condition (ii), the relative productivity, $A_{T,t}/A_{N,t}$, is stationary, by definition, thus leading the real FX rate to be a stationary variable as well. On the other hand, if the productivity across

the sectors is not cointegrated, either of the sectors (tradable or non-tradable) produces the goods increasingly more efficiently than the other. Therefore, the output share and the relative price for the growing sector continue to increase and decrease, respectively, and a balanced-growth path exists only if those two forces are entirely offset each other under the Cobb-Douglas consumption basket. In this case, since the real FX rate is proportional to the relative price across the sectors under the law of one price for tradable goods, it is also cointegrated with the relative productivity growth for the tradable goods sector, which is exactly what is suggested by the Balassa–Samuelson relationship in the literature. As discussed in Subsection 2.1, a salient feature of the Vietnamese data is that the real FX rate exhibits a non-stationary upward trend that is cointegrated with the share of tradable goods in output, consistent with the Balassa–Samuelson relationship. Hence, in the empirical analysis hereafter, the CES function for the consumption basket (2) is assumed to be Cobb-Douglas (i.e., Condition (i) is satisfied and $\eta = 1$) to reconcile the stylized fact in Vietnam with the existence of a balanced-growth path.

While the Cobb-Douglas consumption basket looks somewhat restrictive at first glance, it is not a bad assumption, at least for the Vietnamese economy for the last several decades. A well-known property of the Cobb-Douglas consumption basket is a constant nominal share across sectors. As the left panel of Figure 3 shows, the nominal share of the manufacturing sector in output has remained almost constant since 2000, which implies that the Cobb-Douglas consumption basket is not a bad assumption for Vietnam. In addition, as the proof of Proposition 1 indicates, the Cobb-Douglas consumption basket implies $g_{q,t} = g_{c,T,t} - g_{c,t}$ in the long run. Since the right-hand side is the growth rate of tradable goods' share in real output, this property means that the long-run growth rate of real FX rate should be equal to that of tradable goods' share in real output. The right panel of Figure 3 shows that this property is satisfied in Vietnam, which also implies that the Cobb-Douglas consumption basket is not a bad assumption for Vietnam.¹⁰

¹⁰The right panel of Figure 3 is obtained by combining the constant nominal share in the left panel and the law of one price in the right panel of Figure 1. That

Figure 3. Nominal and Real Share of Manufacturing

Source: Haver Analytics.

Note: The left panel shows the nominal share of manufacturing sector in output since 2000 in Vietnam. The right panel shows the developments in log of the real FX rate (the red line with circles) and log of the share of manufacturing in real output (the green line with x-marks). In the right panel, both variables are normalized to zero in 2000.

While the balanced-growth path under Condition (i) (i.e., Cobb-Douglas consumption basket) is consistent with Vietnamese data for the last two decades, the relationship between the sectoral growth rate and the non-stationary real FX rate is an arguable issue in general. First, the non-stationarity of the real FX rate is arguable. In particular, it is statistically difficult to determine whether the real FX rate is stationary or non-stationary if time-series data are available only for several decades. While some empirical studies that use very long time-series data find the real FX rate to be non-stationary, quantitative studies that focus on advanced economies offer some evidence that the real FX rate is a very persistent but stationary variable.¹¹ Second, whether the sectoral-growth pattern should be consistent with the balanced-growth path is arguable in the first

is, when a nominal share across sectors is constant, a decrease in the manufacturing sector's relative price and an increase in its share in the real output should be offset with each other.

¹¹For empirical studies using long time-series data, see Engel and Kim (1999) and Engel (2000). For the analysis on advanced economies, Rabanal, Rubio-Ramirez, and Tuesta (2011) and Rabanal and Rubio-Ramirez (2015) argue that the real FX rate is very persistent but stationary.

place.¹² While this study assumes the existence of a balanced-growth path, the relationship between the longer-term sectoral-growth pattern and the real FX rate across countries is a challenging but interesting topic for future research.

4. Quantitative Analysis

This section quantitatively assesses the effects of FXIs using the small open-economy DSGE model described in the previous section. Specifically, the effects of FXIs in Vietnam are examined through a two-step approach: First, I estimate the structural parameters based on Vietnamese data and decompose the variances of the macroeconomic variables (e.g., the real and nominal FX rates, inflation, and output growth) into the structural shocks. Second, I quantify the efficacy of FXIs through the variance decomposition in a counterfactual exercise. In this exercise, the hypothetical economy without FXIs is constructed by changing the parameters of the FXI policy, while keeping the other structural parameters unchanged.

4.1 *Baseline Analysis*

4.1.1 *Estimation*

First, some parameters are calibrated to their conventional values in the literature.¹³ For the preference parameters, the discount factor, β , the constant relative risk aversion (CRRA) coefficient, σ , and the inverse of Frisch elasticity, ω , are calibrated to $0.99^{1/4}$, 2.0, and 1/2, respectively. The elasticity of the risk premium, ζ , is assigned an arbitrarily small number, 0.001, to secure the steady state as in Schmitt-Grohe and Uribe (2003). For the production parameters, the labor share, α , and the mark-up parameter, ν , are set to 0.64 and 6.0, respectively, both of which are conventional values. The target inflation rate, $\bar{\pi}$, is set to $1.04^{1/4}$, based on the targeted value

¹²Herrendorf, Rogerson, and Valentinyi (2014) argue that sectoral-growth patterns across countries are not consistent with balanced growth in the long run and suggest some theories to account for them. Meza and Urrutia (2011) examine the real FX rate under the “unbalanced” growth path to analyze the real FX rate in Mexico.

¹³See, for instance, Smets and Wouters (2007) and Galí (2015).

for inflation in Vietnam. Finally, the steady-state level of external debt, \bar{b}^* , is chosen such that the ratio of the external debt to the manufacturing GDP equals 247 percent, which has been the average level in Vietnam for the last decade.

Second, the rest of the structural parameters, including the volatility of shocks, are estimated using a Bayesian method on Vietnamese data. Specifically, I estimate 31 parameters (γ_H , γ_F , ξ , h , ψ , ι , \bar{Res} , \bar{a}_N , \bar{a}_T , \bar{r}^* , ρ_R , ϕ_π , ϕ_y , ϕ_q , θ_{res} , θ_q , $\rho_{a,N}$, $\rho_{a,T}$, ρ_z , ρ_m , ρ_q , ρ_f , ρ_{rr} , ρ_s , σ_{aN} , σ_{aT} , σ_z , σ_m , σ_q , σ_f , σ_{rr}) using the quarterly data from 2005:Q1 to 2018:Q3 for the following seven variables in Vietnam: (i) GDP growth, (ii) GDP growth for the manufacturing sector, (iii) the inflation rate, (iv) the short-term nominal interest rate (the discount rate), (v) the ratio of FX reserves to manufacturing GDP, (vi) the FX rate vis-à-vis the U.S. dollar, and (vii) the real interest rate in the United States (the federal funds rate deflated by the U.S. CPI).¹⁴ The prior distributions for the parameters of the FXI policy rule are based on the estimated values in Subsection 2.2, while those for the other parameters are based on their conventional values.

Table 2 summarizes the prior distributions and the estimation results. While most prior distributions are based on conventional values or set to be consistent with the Vietnamese data, several parameters with little information use distributions with relatively large standard deviation.¹⁵ Some comments are in order: First, the estimated values of the parameters for the cost of price changes in both sectors and indexation, γ_T , γ_N , and ξ —in particular, γ_T —are very small, implying that the Phillips curve in Vietnam is steep and that the inflation inertia is small. The steep Phillips curve probably reflects the fact that the inflation rate in Vietnam has been

¹⁴While the annual data are available from 1995 in Vietnam, as shown in Section 2, the quarterly data are available only from 2005.

¹⁵The prior mean of steady-state values for growth rate, FX reserves, and interest rates are set to the historical average. For the policy parameters, the FXI policy parameters are based on the estimation results in Section 2, while the response of interest rates to inflation follows the original Taylor rule. The prior means of price adjustment costs are set to 60, which implies that the price change probability is around two-thirds in the Calvo model. The parameter of consumption habit is based on the estimation results in Havranek, Rusnak, and Sokolova (2017). For other parameters, I use a distribution with relatively large standard deviation, such as Beta[0.5, 0.15], given that there is little prior information.

Table 2. Estimated Parameter Values

| Parameter | Posterior Mean | 90% CI | Prior Dist. | Prior Mean | Prior St. Dev. |
|------------------------|----------------|---------------|-------------|------------|----------------|
| γ_H | 13.34 | [6.68 19.68] | Gamma | 60 | 30 |
| γ_F | 0.36 | [0.11 0.59] | Gamma | 60 | 30 |
| ξ | 0.25 | [0.11 0.38] | Beta | 0.5 | 0.15 |
| h | 0.55 | [0.5 0.61] | Beta | 0.4 | 0.05 |
| ψ | 37.49 | [25.07 50.07] | Gamma | 5.0 | 5.0 |
| ι | 0.14 | [0.11 0.18] | Beta | 0.5 | 0.15 |
| $\overline{R\bar{E}s}$ | 0.03 | [0.02 0.03] | Gamma | 0.04 | 0.01 |
| \bar{a}_N | 1.016 | [1.014 1.019] | Gamma | 1.016 | 0.002 |
| \bar{a}_T | 1.021 | [1.018 1.025] | Gamma | 1.024 | 0.004 |
| \bar{r}^* | 0.998 | [0.997 1] | Gamma | 0.998 | 0.002 |
| ρ_R | 0.91 | [0.87 0.94] | Beta | 0.5 | 0.15 |
| ϕ_π | 1.93 | [1.12 2.72] | Gamma | 1.5 | 0.5 |
| ϕ_y | 0.70 | [0.2 1.18] | Gamma | 1.0 | 0.5 |
| ϕ_q | 0.58 | [0.19 0.94] | Gamma | 1.0 | 0.5 |
| θ_{res} | -0.11 | [-0.14 -0.07] | Norm | -0.1 | 0.03 |
| θ_q | 9.33 | [7.72 10.89] | Gamma | 8.6 | 1.00 |
| $\rho_{a,N}$ | 0.46 | [0.28 0.63] | Beta | 0.5 | 0.15 |
| $\rho_{a,T}$ | 0.30 | [0.14 0.47] | Beta | 0.5 | 0.15 |
| ρ_z | 0.85 | [0.76 0.95] | Beta | 0.5 | 0.15 |
| ρ_m | 0.67 | [0.55 0.8] | Beta | 0.5 | 0.15 |
| ρ_q | 0.66 | [0.52 0.79] | Beta | 0.5 | 0.15 |
| ρ_f | 0.36 | [0.19 0.51] | Beta | 0.5 | 0.15 |
| ρ_{rr} | 0.38 | [0.22 0.54] | Beta | 0.5 | 0.15 |
| ρ_X | 0.31 | [0.13 0.49] | Beta | 0.5 | 0.15 |
| σ_{aN} | 0.009 | [0.007 0.011] | InvG | 0.01 | Inf |
| σ_{aT} | 0.014 | [0.011 0.016] | InvG | 0.01 | Inf |
| σ_z | 0.006 | [0.004 0.008] | InvG | 0.01 | Inf |
| σ_m | 0.002 | [0.002 0.003] | InvG | 0.01 | Inf |
| σ_q | 0.021 | [0.014 0.029] | InvG | 0.01 | Inf |
| σ_f | 0.104 | [0.08 0.128] | InvG | 0.01 | Inf |
| σ_{rr} | 0.006 | [0.005 0.007] | InvG | 0.01 | Inf |

high and volatile, while the real GDP growth has been relatively stable. Second, the posterior mean of the effects of FXIs on the risk premium, ψ , is positive and statistically significant, although the prior distribution is set to strongly favor zero.¹⁶ The positive and

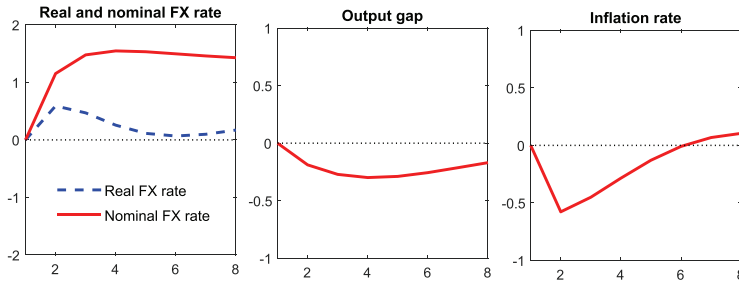
¹⁶While the prior mean for ψ is set to 5.0, note that this prior distribution strongly favors zero because the mode of the gamma distribution with the same values for the mean and standard deviation is zero, while the density function is decreasing.

statistically significant estimated value of ψ implies that FXIs in Vietnam have significantly affected the FX rate. Furthermore, the persistence parameter, ρ_X , is around 0.3, implying that the effects of FXIs are moderately persistent. Third, the estimated monetary policy rule suggests that the central bank raises the nominal interest rate in response to depreciation in the nominal FX rate ($\phi_q < 0$) in addition to inflation and output growth. This result suggests that the central bank in Vietnam leans against the wind in the FX market not only by FXIs but also by the nominal interest rate, as done by some small open-economy countries (Lubik and Schorfheide 2007). Fourth, the parameters for the FXI policy, θ_{res} and θ_q , are estimated in a way that is consistent with the practice under the systematic managed floating system, due partly to the use of the estimation results in Section 2 as their prior means. Fifth and finally, while not shown in the table, the estimated mean of the time-varying risk premium, ζ_t , is 0.0243, which implies that the annual risk premium for foreign borrowing in Vietnam is around 9.7 percent. While it seems too high at first glance, note that ζ_t in Equation (5) possibly includes the effects of capital control. Hence, this estimation result implies that Vietnam is characterized by relatively strict capital control, as is consistent with the Fernández et al. (2016) database on capital control measures.

4.1.2 Impulse Response to FXIs

To quantify the effects of FXIs, this subsection examines the impulse response to the FXI shock, ε_f , in the FXI policy rule (9). As a positive (negative) FXI shock means a decrease (an increase) in the supply of the U.S. dollar by the central bank, it is expected to make it difficult (easy) for private investors to borrow in the external debt market. To capture this transmission mechanism of FXIs inside the model, a positive (negative) FXI shock is assumed to raise (reduce) the risk premium for external debt, ζ_t , by influencing X_t in (14). Then, the change in the risk premium influences the FX rate through the UIP condition (13).

Figure 4 shows the impulse response of the nominal and real FX rate, the output gap, and the inflation rate to a negative FXI shock (i.e., selling of the U.S. dollar) of 1 percentage point of GDP. The figure indicates that FXIs have intuitive and sizable policy effects in

Figure 4. Impulse Response to the FXI

Note: The figure shows the impulse response to the FXI shock, ε_f , to quantify the effects of the FXI of 1 percentage point of GDP.

Vietnam. Regarding the effects on the real and nominal FX rate (the left panel in Figure 4), the figure indicates that (i) the real FX rate appreciates by an approximate 0.3 percentage point on impact and returns to the previous level within a few quarters, and (ii) the nominal FX rate appreciates by an approximate 1.2 percentage points on impact and keeps the appreciated level in the long run. The moderate and short-lived effects on the real FX rate and the significant and persistent effects on the nominal FX rate are consistent with the past empirical literature. Furthermore, as a result of the FX rate appreciation, FXIs have sizable effects on output and inflation as well (the middle and right panel in Figure 4). Specifically, the output gap declines by around 0.25 percentage point at the peak, while the inflation rate declines by 0.5 percentage point on impact and gradually returns to the previous level. Hence, selling the U.S. dollar through FXIs helps dampen the inflationary pressure by supporting the domestic currency value, while it induces moderate but adverse effects on real economic activity.

4.1.3 Variance Decomposition

Table 3 presents the results of the variance decomposition for the real and nominal FX rates, the inflation rate, output growth, and the FX reserves. Using Kalman smoothing, the fluctuations of these five variables are decomposed into the contributions of four groups of structural shocks: (i) the productivity shock (the non-stationary

Table 3. Variance Decomposition

| | Productivity | External | FXI | Monetary |
|-----------------|---------------------|-----------------|------------|-----------------|
| Real FX Rate | 69.7 | 2.6 | 8.8 | 18.9 |
| Nominal FX Rate | 2.2 | 23.4 | 72.1 | 2.3 |
| Inflation Rate | 62.3 | 3.8 | 13.5 | 20.4 |
| Output Growth | 78.7 | 2.8 | 10.9 | 7.7 |
| FX Reserve | 12.4 | 47.1 | 8.3 | 32.2 |

Note: The table shows the results of the variance decomposition for the real and nominal FX rate, inflation rate, output growth, and FX reserves. The fluctuations of these five variables are decomposed into the contributions of four groups of structural shocks: (i) the productivity shocks (the non-stationary productivity shock for the tradable and non-tradable sectors, ε_{aT} and ε_{aN} , and the stationary productivity shock, ε_z), (ii) the external shocks (the UIP shock, ε_q , and the U.S. monetary policy, ε_{rr}), (iii) the FXI shock (ε_f), and (iv) the monetary policy shock (ε_m).

productivity shock for the tradable and non-tradable sectors, ε_{aT} and ε_{aN} , and the stationary productivity shock, ε_z), (ii) the external shock (the UIP shock, ε_q , and the U.S. monetary policy shock, ε_{rr}), (iii) the FXI shock (ε_f), and (iv) the monetary policy shock (ε_m).

The table shows the following three notable features. First, around 70 percent of the fluctuations in the real FX rate can be explained by the productivity shocks. This result implies that the real FX rate is determined in a way that is consistent with the Balassa–Samuelson relationship in the model. Accordingly, the policy shocks that include the FXI and monetary policy shock account for only less than 30 percent of the real FX rate fluctuations, while the external shock that includes the deviations from the UIP condition (i.e., the UIP shock) and the U.S. monetary policy shock is almost negligible in explaining the real FX rate in Vietnam. Second, in contrast, the productivity shock can explain only a negligible amount of fluctuations in the nominal FX rate. Instead, the FXI policy shock is a dominant driver for it. This result is intuitive, given that the nominal FX rate in Vietnam has been relatively stable and moving in the completely opposite direction to the real FX rate due to the active FXIs under the systematic managed floating system, as described in Section 2. Third, the inflation rate and output growth

are driven mainly by the productivity shock, and the external shock plays an almost negligible role in explaining their fluctuations, as is similar to the real FX rate. Fourth and finally, the FXI shock accounts for only less than 10 percent of FX reserve fluctuations. Thus, more than 90 percent of changes in the FX reserves in Vietnam are accounted for by systematic responses to the nominal FX rate, pointing to the importance of the analysis of the systematic FXIs that respond to the nominal FX rate fluctuations. Regarding the root drivers of the systematic responses of the FX reserves, the external shock and the monetary shock have larger shares than the productivity shock, implying that the systematic FXIs absorb and mitigate the propagation of those shocks. In the following subsection, we will explore the effects of the systematic FXI policy by a counterfactual analysis.

4.2 Counterfactual Analysis for the Efficacy of FXIs

The estimation result in the previous subsection indicates that Vietnam's central bank has actively used FXIs as a tool for leaning against the wind in the FX market, and that the FXI policy shock has significant effects on the real and nominal FX rate. Given these significant effects of FXIs, an essential question for policymakers is, to what extent does the FXI policy contribute to macroeconomic stability in Vietnam? To answer this question, a counterfactual policy exercise is conducted in this subsection for the case without FXIs. Specifically, a hypothetical economy without FXIs is constructed by assuming that (i) the FX reserves do not respond to the nominal FX rate (i.e., $\theta_q = 0$) and (ii) the FXI shock is always zero (i.e., the variance of $\varepsilon_{f,t}$ is set to zero). Assumption (i) aims to stop systematic FXIs from leaning against the nominal FX rate fluctuations, while Assumption (ii) aims to stop non-systematic and discretionary FXIs through the FXI policy shock. Since the central bank is assumed to stop conducting both the systematic and the non-systematic FXIs in this scenario, this counterfactual policy framework can be interpreted as a floating FX regime without any FXIs. Since all the structural parameters, except these two, remain unchanged in the counterfactual simulation, we can examine the extent to which FXIs contribute to macroeconomic stability

by comparing the counterfactual simulation results to the baseline results.

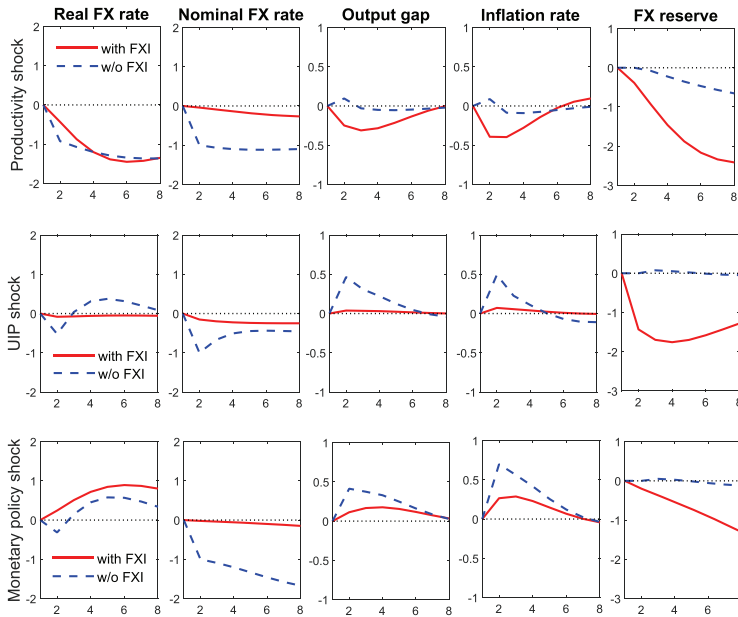
In what follows, first, the impulse responses to the productivity, UIP, and monetary policy shocks under the counterfactual FX policy regime are computed and compared with the baseline results to understand how the systematic FXI policy dampens or amplifies those responses. Then, by examining the variance decomposition in the counterfactual exercise, we investigate how much and why FXIs contribute to macroeconomic stability in Vietnam. Finally, we briefly consider the case of a flexible inflation-targeting regime to examine whether an interest rate policy can replace FXIs by more aggressively responding to the FX rate.

4.2.1 Impulse Responses under the Counterfactual FX Policy

Figure 5 presents the impulse response functions under the baseline and the counterfactual FX policies. The figure shows the responses of the real and nominal FX rates, output gap, inflation rate, and FX reserves to the productivity shock for the tradable goods (ε_{aT}), the UIP shock (ε_q), and the monetary policy shock (ε_m). In the figure, the red, bold lines represent the responses in the baseline case (i.e., with FXIs), while the dashed, blue lines represent the ones under the counterfactual FX policy (i.e., without FXIs). The signs and sizes of these shocks are adjusted and standardized, such that the nominal FX rate without FXIs depreciates by 1 percentage point on impact. Since the impulse response function is an endogenous reaction to exogenous shocks, the differences between the red, bold lines and blue, dashed lines are interpreted as the effects of the systematic FXIs formulated in Equation (9).

There are several notable features in the figure: First, while the systematic FXIs have minor effects on the real FX rate (the first column), they effectively mitigate the depreciation pressure on the nominal FX rate (the second column). More specifically, when the central bank conducts systematic FXIs that respond to the nominal FX rate based on the FXI policy rule (9), the size of the response of the nominal FX rate vis-à-vis the U.S. dollar to the productivity, UIP, and monetary policy shocks becomes less than 10 percent of those for the case without the systematic FXI policy. These mitigating effects of systematic FXIs emanate from the endogenous response

Figure 5. Impulse Responses with and without FXIs



Note: The figure presents the impulse response functions under the baseline and the counterfactual FX policies. In the figure, the red, bold lines represent the responses in the baseline case (i.e., with FXIs), while the dashed, blue lines represent those under the counterfactual FX policy (i.e., without any FXIs). The responses in the figure include those of the real and nominal FX rates, output gap, inflation rate, and FX reserves to the negative productivity shock for tradable goods (ε_{aT}), the depreciation UIP shock (ε_q), and the easing monetary policy shock (ε_m). The size of the shocks is standardized, such that the absolute size of the response of the nominal FX rate is equal to 1 percentage point on impact.

of the FX reserves. That is, with the systematic FXIs, the central bank sells and decumulates the FX reserves in response to the depreciation pressure in the FX market, as shown in the last column in Figure 5, suggesting that the systematic FXI policy uses the FX reserves as an effective shock absorber to stabilize the nominal FX rate as a nominal anchor.¹⁷

¹⁷In response to the productivity shock, the figure shows that the FX reserves decline even in the case without FXIs. In the event of an unexpected negative shock of tradable goods productivity, the neutral level of the FX reserves on the

Second, considering the response of the output gap or inflation rate to the productivity shock (the first row), the volatility is larger for the case with than for the case without FXIs. This result implies that the systematic FXI policy amplifies their responses, thus possibly destabilizing the economy. With a negative productivity shock in the tradable goods sector, the real and nominal FX rates depreciate due to the changes in the relative price between the tradable and non-tradable goods (i.e., the Balassa–Samuelson effect). With FXIs, however, such depreciation pressure in the FX market would be mitigated and become smaller. The smaller depreciation of the nominal FX rate reduces inflationary pressure in the domestic economy, thus decreasing the inflation rate and output gap further, and amplifying their responses. This transmission mechanism to amplify the responses to the negative productivity shock is the same as in previous studies on the currency peg, such as Galí and Monacelli (2005) and Chapter 9 in Schmitt-Grohe and Uribe (2017). In these studies, given a negative shock to tradable goods endowment or the terms of trade, a country adopting a currency peg faces a more severe economic downturn because it cannot benefit from the mitigating effects through currency devaluation. That is, as several empirical studies, including Forbes and Klein (2015), advocate, FX flexibility, rather than FXIs, can work as a shock absorber to dampen economic fluctuations when the productivity shock drives them.

Third, considering the responses of the output gap and inflation rate to the UIP and monetary policy shocks (the second and third row), the sizes of the responses are smaller in the case with FXIs. Therefore, in contrast to the case of the productivity shock, the systematic FXI policy dampens these responses rather than amplifies them. While the UIP shock induces the FX rate depreciation and thus positively affects both the output and the inflation rate by making the tradable goods more competitive, the systematic FXIs mitigate the depreciation pressure and dampen the responses of the output and the inflation rate. Similarly, while the easing monetary policy shock raises the inflation rate and the output gap, as in a canonical DSGE model, the systematic FXIs dampen these policy effects by counteracting the depreciation pressure in the FX market.

balanced-growth path becomes lower than before the shock, thus leading the FX reserves to decline and converge to the new steady-state level gradually.

Hence, in contrast to the case of the productivity shock, this result implies that the systematic FXIs can possibly contribute to macroeconomic stability by suppressing the nominal FX rate fluctuations caused by the UIP or the monetary policy shocks.

The above quantitative results imply that FXIs contribute to macroeconomic stability if the external shocks and the monetary policy shock are the more dominant drivers in the economy than the productivity shocks, and vice versa. This policy implication is consistent with a traditional Mundell-Fleming prescription of optimal exchange rate regimes: If real (nominal) shocks are dominant, then a flexible (inflexible) exchange regime is optimal. While this prescription is generally obtained in the model with imperfect goods markets as emphasized in Lahiri, Singh, and Végh (2008), the above quantitative results suggest that their prescription is also valid in a small-open economy DSGE model with a systematic FXI policy.

4.2.2 Variance Decomposition under the Counterfactual FX Policy

Given that the systematic FXIs can either dampen or amplify impulse responses, depending on the type of the exogenous shocks, whether the systematic FXI policy contributes to macroeconomic stability is an empirical question. To answer this empirical question, Table 4 shows the standard deviation (SD) of the real and nominal FX rates, output growth, inflation rate, and FX reserves in the model. In the table, the SD in the baseline (i.e., the case with FXIs, the first column) is normalized to 1. Considering the case without FXIs (the second column), the table indicates that FXIs substantially dampen the fluctuations of the nominal FX rate in Vietnam. Specifically, without FXIs, the SD of the nominal FX rate would be more than triple, which is consistent with the impulse response analysis in the previous subsection. Second and more importantly, the table indicates that the SD for the output growth and inflation rate would increase by 131 percent and 52 percent, respectively, in the counterfactual simulation without FXIs. Thus, while FXIs can either stabilize or destabilize the economy, as shown by the impulse response analysis, Table 4 implies that FXIs contribute to macroeconomic stability in Vietnam.

Table 4. Standard Deviation of Macroeconomic Variables

| | With FXI (Baseline) | Without FXI | Flexible IT |
|-----------------|--------------------------------|------------------------|------------------------|
| Real FX Rate | 1.00 | 1.87 | 1.54 |
| Nominal FX Rate | 1.00 | 3.65 | 2.76 |
| Output Growth | 1.00 | 2.31 | 1.81 |
| Inflation Rate | 1.00 | 1.52 | 1.02 |
| FX Reserve | 1.00 | 0.24 | 0.21 |

Note: The table shows the standard deviation (SD) of the real and nominal FX rates, output growth, inflation rate, and FX reserves in the model. The table shows the counterfactual SD relative to the baseline (the case with FXIs) by normalizing its SD to 1.

In the model, the FXIs contribute to macroeconomic stability solely through the systematic FXIs that respond to the nominal FX rate. The non-systematic FXIs, on the other hand, are modeled as an iid exogenous policy shock to the FXI policy rule in Equation (9); thus, they do not contribute to macroeconomic stability by construction. As discussed in Section 2, how the systematic FXIs stabilize the economy is analogous to how systematic monetary policy contributes to macroeconomic stability. That is, similarly to how a systematic monetary policy that strongly responds to the inflation rate contributes to stabilizing inflation by calming down inflation expectations (Clarida, Galí, and Gertler 2000), the systematic FXI policy contributes to macroeconomic stability by influencing the household's conditional expectations about future developments in the nominal FX rate. Such a policy implication about the systematic FXI policy is basically consistent with the previous literature on the efficacy of rule-based FXIs under a scarcity of FX reserves (Basu et al. 2018).

To further investigate how FXIs contribute to macroeconomic stability, Table 5 shows the results of the variance decomposition for the counterfactual case without FXIs. The structural shocks are grouped as in Table 3; however, the contribution of the FXI policy shock is equal to zero by construction because the FXI policy shock (i.e., non-systematic FXIs) is set to zero in the counterfactual simulation. The table indicates that in comparison with the baseline case in Table 3, the share of the external and the monetary policy

Table 5. Variance Decomposition without FXIs

| | Productivity | External | FXI | Monetary |
|-----------------|---------------------|-----------------|------------|-----------------|
| Real FX Rate | 22.0 | 67.2 | 0.0 | 10.8 |
| Nominal FX Rate | 9.4 | 74.2 | 0.0 | 16.3 |
| Inflation Rate | 10.3 | 52.3 | 0.0 | 37.5 |
| Output Growth | 13.8 | 73.7 | 0.0 | 12.6 |
| FX Reserve | 61.7 | 30.5 | 0.0 | 7.8 |

Note: The table shows the results of the variance decomposition for the real and nominal FX rate, inflation rate, output growth, and FX reserves without FXIs. The fluctuations of these five variables are decomposed into the contributions of four groups of structural shocks: (i) the productivity shocks (the non-stationary productivity shock for the tradable and non-tradable sectors, ε_{aT} and ε_{aN} , and the stationary productivity shock, ε_z), (ii) the external shocks (the UIP shock, ε_g , and the U.S. monetary policy, ε_{rr}), (iii) the FXI shock (ε_f), and (iv) the monetary policy shock (ε_m). The contribution of the FXI policy shock is, however, equal to zero, by construction, because the FXI policy shock is set to zero in the counterfactual simulation.

shocks rises, while the share of the productivity shocks declines. This result is consistent with the impulse response analysis, wherein FXIs amplify the response to the productivity shock while they dampen the responses to the UIP and monetary policy shocks. Particularly, the rise in the share of the external shock is remarkable. For the case with FXIs in Table 3, the share of the external shock is only around 20 percent for the nominal FX rate and less than 5 percent for the real FX rate, inflation rate, and output growth, respectively; however, in the case without FXIs, the shares rise to 50 to 70 percent for those variables. Thus, FXIs in Vietnam contribute to macroeconomic stability by dampening the effects of the external shocks, as well as the effects of their own monetary policy shock.

While the counterfactual simulation without FXIs suggests that a systematic FXI plays an important role in stabilizing output and inflation, the next question relevant to policymakers is whether an interest rate policy appropriately responding to the FX rate can replace FXIs. This question is important for many EMEs because some countries, including Vietnam, discuss a shift from the monetary policy regime relying on FXIs to the one with flexible FX rates and inflation targeting (IT). To answer this question, we examine

the SD of the macroeconomic variables for the “flexible IT regime,” where the central bank (i) does not conduct any systematic and non-systematic FXIs (i.e., $\theta_q = 0$ and the variance of $\varepsilon_{f,t}$ is zero), (ii) does not add any monetary policy shocks (i.e., the variance of $\varepsilon_{m,t}$ is zero), and (iii) adjusts the interest rate more aggressively in response to the FX rate (i.e., the value of ϕ_q is tripled). Those assumptions replicate the flexible IT regime in the sense that the central bank’s interest rate policy is flexible enough to respond to the FX rate but strictly follows the monetary policy rule (i.e., no ad hoc monetary policy shocks). The third column of Table 4 indicates that the flexible IT regime can reduce the SD of the inflation rate to the same level as in the baseline with FXIs, but it can do little to reduce the SD of the real and nominal FX rate and the output growth from the counterfactual case without FXIs. Hence, this exercise suggests that the central bank can stabilize the inflation rate even without FXIs, by following a monetary policy rule aggressively responding to the FX rate, but the interest rate policy cannot substitute for FXIs in terms of the whole macroeconomic stability including real economic activity.

Given the result that the monetary policy shock, in addition to the external shock, would substantially destabilize the economy without systematic FXIs, the next question relevant to policymakers is, what if the monetary policy shock does not exist? Since the monetary policy shock is a discretionary deviation from the monetary policy rule based on the 4 percent inflation target, this question is equivalent to asking, what if Vietnam’s central bank adopts a more stringent inflation-targeting regime? This question is important for many EMEs because some, including Vietnam, discuss a shift from the monetary policy regime relying on FXIs to the one with flexible FX rates and more stringent IT. To answer this question, we examine the SD of the macroeconomic variables in the case without the monetary policy shock (i.e., the variance of $\varepsilon_{m,t}$ is set to zero), in addition to the FXIs. The third column of Table 4 indicates that the SD of the inflation rate is higher than in the baseline but substantially smaller than in the case without FXIs, and that the SD of the real and nominal FX rate and the output growth is almost at the same level as in the case with the monetary policy shock. Therefore, the central bank can stabilize the inflation rate to some extent, even without FXIs, by following a stricter IT regime as a nominal anchor

for monetary policy, but a stricter IT regime is hard to substitute for FXIs in terms of macroeconomic stability as a whole.

In summary, the counterfactual simulation exercises have the following two policy implications. First, while FXIs can either stabilize or destabilize the economy, they contribute to macroeconomic stability in Vietnam by mitigating the effects of the external and monetary shock. Second, an interest rate policy aggressively responding to the FX rate can possibly stabilize the inflation rate without FXIs, but it is generally hard to achieve macroeconomic stability as a replacement for FXIs. Note, however, that these policy implications come with the caveat that the role of FXIs highly depends on which shocks are dominant for business cycles. For instance, for a country where the nominal FX rate is mainly driven by domestic productivity shocks rather than external shocks, including the non-fundamental deviations from UIP, more FX flexibility rather than FXIs is desirable for macroeconomic stability. Thus, FXIs should have a relatively important role in small EMEs with underdeveloped FX markets because such countries tend to be more susceptible to external shocks and deviations from UIP. In other words, with more developed and deeper FX markets, a flexible interest rate policy appropriately responding to the FX rate can perhaps replace FXIs as a policy tool to achieve macroeconomic stability, which is in line with policy recommendations in International Monetary Fund (2020).

4.2.3 Business Cycle Moment

This subsection discusses the business cycle moments in the baseline and the counterfactual simulation by comparing with data (Table 6). As discussed in Section 2, key features for the Vietnamese economy in comparison with advanced economies such as the euro area and Japan include (i) real FX rates are much more persistent than a random walk, (ii) real FX rates are more volatile than nominal FX rates, (iii) changes in real and nominal FX rate are more volatile than GDP growth but not as much as in advanced economies, and (iv) correlation between real and nominal FX rates is positive but weak. First, Table 6 indicates that the baseline case with FXIs fairly well replicates those key features of business cycle moments observed in data. While this good model fit is not that surprising because the

Table 6. Business Cycle Moments: Data vs. Model

| | Data | Model | |
|---|------|----------|-------------|
| | | With FXI | Without FXI |
| $\rho(\Delta Q_t)$ | 0.52 | 0.68 | 0.03 |
| $\sigma(\Delta Q_t) / \sigma(\Delta F_t)$ | 1.65 | 1.62 | 0.83 |
| $\sigma(\Delta F_t) / \sigma(\Delta Y_t)$ | 1.51 | 1.28 | 2.01 |
| $\rho(\Delta F_t, \Delta Q_t)$ | 0.36 | 0.36 | 0.76 |

Note: The table summarizes key business cycle moments with respect to real and nominal FX rates vis-à-vis the U.S. dollar in the Vietnamese data and the model. In the table, ΔF_t , ΔQ_t , and ΔY_t denote growth in nominal FX rates, real FX rates, and real GDP, respectively.

model parameters are estimated using Vietnamese data, it implies that the simple small open-economy model in this paper captures a key mechanism of FX rate dynamics in Vietnam.

Second, Table 6 shows that the business cycle moments are remarkably different in the counterfactual case without FXIs. Compared with the baseline case with FXIs, the business cycle moments in the counterfactual case without FXIs are characterized by the properties that (i) real FX rates are much less persistent and close to a random walk, (ii) real FX rates are as volatile as nominal FX rates, (iii) changes in real and nominal FX rate are twofold more volatile than GDP growth, and (iv) correlation between real and nominal FX rates is positive and close to one. In other words, the business cycle moments in the counterfactual case without FXIs become much closer to those in advanced economies under a floating FX regime in Table 1. Hence, while the business cycle properties in advanced economies and EMEs are different in many ways (e.g., Aguiar and Gopinath 2007), this result suggests that the differences with respect to FX rate dynamics may be partly associated with those in their FXI policy.

4.2.4 Robustness Check: Is the Result Specific to Vietnam?

One of the main takeaways from the quantitative analysis is that a systematic FXI policy amplifies the macroeconomic fluctuations

caused by the productivity shock while dampening those caused by the UIP and monetary policy shock. While this implication is consistent with a traditional Mundell-Fleming prescription of optimal exchange rate regimes, a key question for policymakers is whether it is not specific to Vietnam but applicable to other countries. To answer this question, this subsection focuses on the following two Vietnam-specific features in the quantitative exercise—namely, (i) the tight Balassa–Samuelson (BS) relationship and (ii) the small price adjustment cost in a tradable goods sector—and then examines how the above takeaway changes when these two features are relaxed.

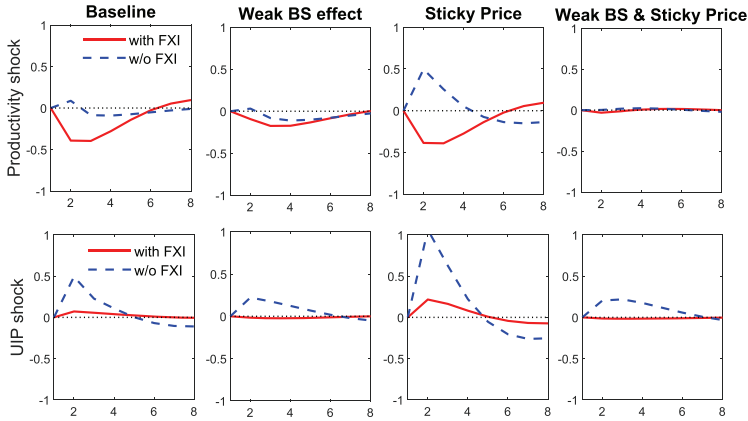
First, the tight BS relationship is relaxed. As Section 2 shows, real FX rates have been almost perfectly tracked by the relative price of manufacturing goods in Vietnam, which implies that the Vietnamese economy is characterized by a tight BS relationship. Since such a law of one price for tradable goods is empirically controversial for some countries, it is worthwhile to examine how the result differs for the economy with a less obvious BS effect. To describe a weak BS relationship in the model, the tradable goods sector is assumed to have some market power in a global market, and the equilibrium of the export market is modeled as

$$Y_{T,t} - C_{T,t} = \left(\frac{P_{T,t}/P_t}{1/Q_t} \right)^{-\nu_x} \bar{C}_W, \quad (16)$$

where the left-hand side is net export while the right-hand side is a demand for tradable goods in an export market. Note that the law of one price for tradable goods in the baseline specification (11) is a special case that the demand elasticity goes to infinite, $\nu_x \rightarrow \infty$. The demand in the global market, \bar{C}_W , is calibrated so that the law of one price is satisfied at the steady state. Hereafter, in the model with a weak BS effect, ν_x is set to 100.

Figure 6 shows the response of inflation to the productivity and UIP shock. In the model with a weak BS effect (the second column), the responses to the productivity and UIP shock become smaller than the baseline (the first column). This is because in the model with a weak BS effect, the tradable goods firms do not need to set their prices to be entirely consistent with the real FX rate but flexibly do so by accepting some fluctuations of export demand,

Figure 6. Response of Inflation to Productivity and UIP Shock



Note: The figure presents the response of inflation to the negative productivity shock for tradable goods (ε_{aT}) in three different environments. In the “weak BS effect” model, the law of one price for tradable goods does not hold because the tradable goods sector is assumed to have some market power in a global market, as described in (16). In the “sticky price” model, the price adjustment cost in the tradable sector, γ_T , is assumed to take the same value as that in the non-tradable goods sector, γ_N . Both of them are assumed in the “weak BS and sticky price” model.

thus making the responses to the shocks smaller. Hence, while the main takeaway does not qualitatively change, a systematic FXI is more effective (both negatively and positively) for the country with a tight BS effect because those countries are more susceptible to FX fluctuations.

The second robustness check examines the case where the price adjustment cost in the tradable goods sector is higher. Specifically, while the estimation value of the price adjustment cost in the tradable goods sector, γ_T , is close to zero in Vietnam, the “sticky price” model in Figure 6 assumes that it is as large as that in the non-tradable goods sector, γ_N . The third column in the figure shows that the response of inflation becomes larger in the “sticky price” model, while the fourth column shows that the higher price adjustment cost in the tradable goods sector does not significantly change the responses when the BS effect is weak. In other words, the price

adjustment cost in the tradable goods sector significantly changes the quantitative result only in the model with a tight BS relationship. With a tight BS relationship, tradable goods firms are forced to set prices entirely consistent with the real FX rate; therefore, the higher price adjustment cost requires more significant changes in the output gap, thus leading to larger economic fluctuations, including those in the non-tradable goods sector. In reality, however, the tight BS relationship and the higher price adjustment cost in a tradable goods sector may hardly coexist because firms possibly differentiate their products to avoid costly adjustments due to high price adjustment costs. While such endogenous dynamics between price adjustment costs and product differentiation is an interesting topic, it is beyond the scope of this paper.

5. Concluding Remarks and Policy Implications

This study quantitatively assesses the role of foreign exchange interventions by introducing a systematic FXI policy that follows a feedback rule responding to the nominal FX rate in a small open-economy DSGE model. Consistent with a traditional Mundell-Fleming prescription of optimal exchange rate regimes, a systematic FXI policy amplifies the macroeconomic fluctuations caused by the productivity shock while dampening those caused by the UIP and monetary policy shock. A quantitative analysis of Vietnamese data using a Bayesian method reveals that FXIs significantly contribute to macroeconomic stability and that with reasonable FXIs that insulate an economy from the external shock, the real FX rate is mainly accounted for by productivity shocks, pointing to the importance of the Balassa-Samuelson relationship in Vietnam.

Those quantitative results have some policy implications regarding macroeconomic stability in a post-pandemic world as of October 2022. First, in the face of the FX rate depreciation due to the rapid monetary tightening by the Federal Reserve (the Fed), the EMEs' authorities could consider temporally using FXIs as one of the tools for economic stability. In particular, if they believe that part of the Fed's monetary tightening is temporary or the FX depreciation is somewhat caused by non-fundamental and speculative factors associated with the Fed's monetary policy captured by the UIP shock, the quantitative results suggest that FXIs are an appropriate policy

tool for economic stability. Second, when signs of domestic inflation due, for example, to higher commodity prices are observed, EMEs' authorities should not hesitate to increase the interest rate following the monetary policy rule. Any delays in monetary tightening would result in high inflation, thus leading to further FX rate depreciation. While the FX rate depreciation caused by the monetary policy shock would eventually force the EMEs' authority to conduct FXIs, as observed in Vietnam, FXIs can only partially mitigate such adverse effects. All in all, EMEs' authorities should appropriately use FXIs in combination with other policy tools for economic stability by carefully identifying the causes of FX rate depreciation.

Appendix. FXI Policy and Central Bank's Optimization

In the estimation, the following feedback rule responding to the nominal FX rate and the historical reserve-to-GDP ratio is used for the FXI policy:

$$\Delta Res_t = \beta_0 + \beta_1 \Delta FX_t + \beta_2 \frac{Res_{t-1}}{GDP_{t-1}} + \varepsilon_t. \quad (\text{A.1})$$

This appendix aims to derive this feedback policy rule from a central bank's optimization problem.

First, given that the central bank attempts to (i) smooth out the volatility of the nominal FX rate, (ii) keep the FX reserves close to the optimal level, and (iii) avoid large changes in the FX reserves, the loss function for the central bank is formulated as follows:

$$\frac{1}{2} (\Delta FX_t)^2 + \frac{\lambda_1}{2} (Res_t - \bar{Res})^2 + \frac{\lambda_2}{2} (\Delta Res_t)^2.$$

In the loss function, the first term represents the loss incurred by the volatility of FX rates, $(\Delta FX_t)^2$, while the second term represents the loss incurred by the deviations of FX reserves, Res_t , from their optimal level, \bar{Res} . The last term implies that the central bank would gradually change the amount of their FX reserves. $\lambda_1 \geq 0$ and $\lambda_2 \geq 0$ are the parameters for the weight of each term in the loss function.

Second, changes in FX rates are assumed to follow a simple process:

$$\Delta FX_t = x_t - \chi \Delta Res_t, \quad (\text{A.2})$$

where x_t is an exogenous component for FX rate growth, and the second part implies that the central bank can support their own currency's value by selling their FX reserves in the FX market (i.e., $\chi \geq 0$). In other words, if FXIs are not effective at all, then $\chi = 0$ and the FX rate is exogenously determined only by x_t .

Finally, the optimization problem for the central bank is formulated as a minimization problem of the loss function (5) subject to (A.2). The first-order condition with respect to ΔRes_t yields the following policy rule for FXIs:

$$\Delta Res_t = \frac{\chi}{\lambda_1 + \lambda_2} \Delta FX_t - \frac{\lambda_1}{\lambda_1 + \lambda_2} (Res_{t-1} - \bar{Res}_t), \quad (\text{A.3})$$

which is exactly the same as the feedback rule used in the main text. Some comments are in order. First, the policy rule suggests that the central bank's FX reserves positively respond to FX rates. Particularly, the central bank sells their FX reserves ($\Delta Res_t < 0$) in the event of depreciation pressure ($\Delta FX_t < 0$) to lean against the wind. Second, the second term suggests that when the FX reserves are less than optimal, the central bank attempts to raise the reserves to converge them to their optimal level, and vice versa. The convergence speed depends on the relative sizes of the weights in the loss function, λ_1 and λ_2 . Third, if the central bank follows this policy rule for FXIs, it is challenging to identify and estimate the effects of FXI from data. That is, even if Equation (A.2) specifies the *negative* correlation between FXIs and the FX rates (i.e., selling the FX reserves positively affects FX rates), the observed relationship between them in empirical data should be *positive*, as described in Equation (A.3), due to the endogenous policy response by the central bank. Thus, while we usually observe a clear and positive relationship between them in many EMEs, it should not be interpreted to mean that selling FX reserves causes depreciation of the nominal FX rate. Rather, it should be interpreted to mean that the central bank systematically sells their FX reserves in response to the depreciation of the nominal FX rates. Paradoxically, Equation (A.3) implies that the

more negative the relationship between FXIs and the FX rates in Equation (A.2) is, the more positive the relationship between them is observed in data. The economic intuition is that when the central bank knows that FXIs are more effective in supporting their own currency in the face of depreciation pressure, it reacts to the depreciation pressure more aggressively, thus leading to the more positive correlation between FXIs and FX rates.

References

- Adler, G., R. Lama, and J. P. Medina. 2019. "Unconventional Policies and Exchange Rate Dynamics." *Journal of International Money and Finance* 95 (July): 402–23.
- Aguar, M., and G. Gopinath. 2007. "Emerging Market Business Cycles: The Cycle Is the Trend." *Journal of Political Economy* 115 (1): 69–102.
- An, S., and F. Schorfheide. 2007. "Bayesian Analysis of DSGE Models." *Econometric Reviews* 26 (2–4): 211–19.
- Asea, P. K., and E. G. Mendoza. 1994. "The Balassa-Samuelson Model: A General-Equilibrium Appraisal." *Review of International Economics* 2 (3): 244–67.
- Bank for International Settlements. 2005. "Foreign Exchange Market Intervention in Emerging Markets: Motives, Techniques and Implications." BIS Papers No. 24.
- Basu, S. S., A. R. Ghosh, J. D. Ostry, and P. E. Winant. 2018. "Managing Capital Outflows with Limited Reserves." *IMF Economic Review* 66 (2): 333–74.
- Benes, J., A. Berg, R. Portillo, and D. Vavra. 2015. "Modeling Sterilized Interventions and Balance Sheet Effects of Monetary Policy in a New-Keynesian Framework." *Open Economies Review* 26 (1): 81–108.
- Berka, M., M. B. Devereux, and C. Engel. 2018. "Real Exchange Rates and Sectoral Productivity in the Eurozone." *American Economic Review* 108 (6): 1543–81.
- Blanchard, O. J., G. Adler, and I. E. de Carvalho Filho. 2015. "Can Foreign Exchange Intervention Stem Exchange Rate Pressures from Global Capital Flow Shocks?" IMF Working Paper No. 15/159.

- Buffie, E. F., M. Airaudo, and F. Zanna. 2018. "Inflation Targeting and Exchange Rate Management in Less Developed Countries." *Journal of International Money and Finance* 81 (March): 159–84.
- Canzoneri, M. B., R. E. Cumby, and B. Diba. 1999. "Relative Labor Productivity and the Real Exchange Rate in the Long Run: Evidence for a Panel of OECD Countries." *Journal of International Economics* 47 (12): 245–66.
- Chen, Y.-C., I. Fujiwara, and Y. Hirose. 2021. "Exchange Rate Disconnect and the General Equilibrium Puzzle." CEPR Discussion Paper No. 16555.
- Chong, Y., O. Jordà, and A. M. Taylor. 2012. "The Harrod–Balassa–Samuelson Hypothesis: Real Exchange Rates and Their Long-Run Equilibrium." *International Economic Review* 53 (2): 609–34.
- Clarida, R., J. Galí, and M. Gertler. 2000. "Monetary Policy Rules and Macroeconomic Stability: Evidence and Some Theory." *Quarterly Journal of Economics* 115 (1): 147–80.
- Devereux, M. B. 1999. "Real Exchange Rate Trends and Growth: A Model of East Asia." *Review of International Economics* 7 (3): 509–21.
- Devereux, M. B., and J. Yetman. 2014. "Globalisation, Pass-through and the Optimal Policy Response to Exchange Rates." *Journal of International Money and Finance* 49 (Part A): 104–12.
- Disyatat, P., and G. Galati. 2007. "The Effectiveness of Foreign Exchange Intervention in Emerging Market Countries: Evidence from the Czech Koruna." *Journal of International Money and Finance* 26 (3): 383–402.
- Domac, I., and A. Mendoza. 2004. "Is There Room for Foreign Exchange Interventions under an Inflation Targeting Framework? Evidence from Mexico and Turkey." Policy Research Working Paper No. 3288, World Bank.
- Engel, C. 2000. "Long-run PPP May Not Hold after All." *Journal of International Economics* 51 (2): 243–73.
- Engel, C., and C.-J. Kim. 1999. "The Long-Run U.S./U.K. Real Exchange Rate." *Journal of Money, Credit and Banking* 31 (3, Part 1): 335–56.
- Erceg, C. J., J. Lindé, T. Adrian, P. Zabczyk, and J. Zhou. 2020. "A Quantitative Model for the Integrated Policy Framework." IMF Working Paper No. 2020/122.

- Faltermeier, J., R. Lama, and J. P. Medina. 2022. "Foreign Exchange Intervention for Commodity Booms and Busts." *European Economic Review* 143 (April): Article 104018.
- Fanelli, S., and L. Straub. 2020. "A Theory of Foreign Exchange Interventions." Working Paper.
- Fernández, A., M. W. Klein, A. Rebucci, M. Schindler, and M. Uribe. 2016. "Capital Control Measures: A New Dataset." *IMF Economic Review* 64 (3): 548–74.
- Forbes, K. J., and M. W. Klein. 2015. "Pick Your Poison: The Choices and Consequences of Policy Responses to Crises." *IMF Economic Review* 63 (1): 197–237.
- Frankel, J. 2019. "Systematic Managed Floating." *Open Economies Review* 30 (2): 255–95.
- Fratzscher, M., O. Gloede, L. Menkhoff, L. Sarno, and T. Stohr. 2019. "When Is Foreign Exchange Intervention Effective? Evidence from 33 Countries." *American Economic Journal: Macroeconomics* 11 (1) : 132–56.
- Gabaix, X., and M. Maggiori. 2015. "International Liquidity and Exchange Rate Dynamics." *Quarterly Journal of Economics* 130 (3): 1369–1420.
- Galí, J. 2015. *Monetary Policy, Inflation, and the Business Cycle: An Introduction to the New Keynesian Framework and Its Applications*, Second edition. Princeton University Press.
- Galí, J., and T. Monacelli. 2005. "Monetary Policy and Exchange Rate Volatility in a Small Open Economy." *Review of Economic Studies* 72 (3): 707–34.
- Garcia, C., J. Restrepo, and S. Roger. 2009. "Hybrid Inflation Targeting Regimes." IMF Working Paper No. 09/234.
- Havranek, T., M. Rusnak, and A. Sokolova. 2017. "Habit Formation in Consumption: A Meta-analysis." *European Economic Review* 95 (June): 142–67.
- Herrendorf, B., R. Rogerson, and A. Valentinyi. 2014. "Growth and Structural Transformation." In *Handbook of Economic Growth*, Vol. 2, ed. P. Aghion and S. Durlauf, 855–941 (chapter 6). Elsevier.
- Hofman, D., M. Chamon, P. Deb, T. Harjes, U. Rawat, and I. Yamamoto. 2020. "Intervention Under Inflation Targeting — When Could it Make Sense?" IMF Working Paper No. 20/9.

- International Monetary Fund. 2020. "Toward an Integrated Policy Framework."
- Itskhoki, O., and D. Mukhin. 2021a. "Exchange Rate Disconnect in General Equilibrium." *Journal of Political Economy* 129 (8): 2183–2232.
- . 2021b. "Mussa Puzzle Redux." NBER Working Paper No. 28950.
- Jeanne, O., and A. Korinek. 2010. "Excessive Volatility in Capital Flows: A Pigouvian Taxation Approach." *American Economic Review* 100 (2): 403–7.
- Jeanne, O., and D. Sandri. 2020. "Optimal Reserves in Financially Closed Economies." *Journal of International Money and Finance* 104 (June): Article 102178.
- Katagiri, M., and K. Takahashi. 2021. "Do Term Premiums Matter? Transmission via Exchange Rate Dynamics." BIS Working Paper No. 971.
- Lahiri, A., R. Singh, and C. A. Végh. 2008. "Optimal Exchange Rate Regimes: Turning Mundell-Fleming's Dictum on Its Head." In *Money, Crises, and Transition: Essays in Honor of Guillermo A. Calvo*, ed. C. M. Reinhart, C. A. Végh, and A. Velasco. The MIT Press.
- Lama, R., and J. P. Medina. 2020. "Mundell Meets Poole: Managing Capital Flows with Multiple Instruments in Emerging Economies." *Journal of International Money and Finance* 109 (December): Article 102193.
- Lee, M. J., M. G. M. Milesi-Ferretti, and M. L. A. Ricci. 2008. "Real Exchange Rates and Fundamentals: A Cross-Country Perspective." IMF Working Paper No. 2008/13.
- Lubik, T. A., and F. Schorfheide. 2007. "Do Central Banks Respond to Exchange Rate Movements? A Structural Investigation." *Journal of Monetary Economics* 54 (4): 1069–87.
- Meza, F., and C. Urrutia. 2011. "Financial Liberalization, Structural Change, and Real Exchange Rate Appreciations." *Journal of International Economics* 85 (2): 317–28.
- Rabanal, P., and J. F. Rubio-Ramirez. 2015. "Can International Macroeconomic Models Explain Low-frequency Movements of Real Exchange Rates?" *Journal of International Economics* 96 (1): 199–211.

- Rabanal, P., J. F. Rubio-Ramirez, and V. Tuesta. 2011. "Cointegrated TFP Processes and International Business Cycles." *Journal of Monetary Economics* 58 (2): 156–71.
- Schmitt-Grohe, S., and M. Uribe. 2003. "Closing Small Open Economy Models." *Journal of International Economics* 61 (1): 163–85.
- . 2017. *Open Economy Macroeconomics*. Princeton University Press.
- Smets, F., and R. Wouters. 2007. "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach." *American Economic Review* 97 (3): 586–606.