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The portfolio balance channel of capital flows and foreign exchange intervention in a small open economy ☆

Carlos Montoro [a], Marco Ortiz [b],*

[a] *Banco Central de Reserva del Perú, Jr. Santa Rosa 441, Lima, 15001 Lima, Peru*
[b] *Universidad del Pacífico, Jr. Sanchez Cerro 2020, Jesus María, 15076 Lima, Peru*

A R T I C L E   I N F O

A B S T R A C T

In this paper we extend a new Keynesian small open economy model with a segmented financial market featuring financial intermediaries as in Itskhoki and Mukhin (2021). The former ingredients generate deviations from the uncovered interest parity (UIP) condition. More precisely, the portfolio decisions of financial intermediaries add a time varying risk-premium element to the traditional UIP that depends on foreign exchange intervention (FXI) and FX orders by foreign investors. We present closed form solutions for optimal FXI. Additionally, we analyse the effectiveness of different FXI rules commonly discussed across policymakers. Our findings are as follows: (i) FXI rules can improve welfare in presence of the portfolio balance channel; (ii) under a general parametrization, fundamental shocks can trigger an inefficient path for the exchange rate; (iii) optimal policy calls for leaning against the wind to portfolio flow shocks and leaning with the wind to fundamental shocks; (iv) the effectiveness of FXI rules depends on the frequency and nature of the shocks and parameters characterizing the economy.

1. Introduction

Interventions by central banks in foreign exchange (FX) markets have been common in many countries, and they have become even more frequent in recent years. These interventions have been particularly large during periods of capital inflows, when central banks bought foreign currency to prevent an appreciation of the domestic currency. Also, they have been recurrent during periods of financial stress and capital outflows, when central banks used their reserves to prevent sharp depreciations of their currencies. The recent COVID-19 crises and the aggressive contractionary monetary policy cycle started by the Federal Reserve in 2022 have created significant capital flows, record levels for the U.S. dollar and sharp cur-

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rency depreciations across the world. Several central banks - both in emerging and developed economies - have responded by using foreign exchange interventions (FXI). These interventions were sterilised in most cases, enabling central banks to keep short-term interest rates in line with policy rates.

Given the scale of interventions in FX markets, it should be important for them to include this factor in their policy analysis frameworks. A variety of questions need to be addressed, such as: Which channels are at work? Are there benefits to intervention rules? What should be the optimal monetary policy design in the context of FXI? To analyse these questions we need an adequate framework of exchange rate determination.

There is substantial empirical evidence that traditional approaches of exchange rate determination (e.g., asset markets) fail to explain exchange rate movements in the short-run.[1] The literature shows that most exchange rate fluctuations at short- to medium-term horizons are related to order flows - the flow of transactions between market participants - as in the microstructure approach presented by Lyons (2006), and not to macroeconomic variables. However, in most of the models used for monetary policy analysis, the exchange rate is closely linked to macroeconomic fundamentals, as in the uncovered interest rate parity (UIP) condition. Such inconsistency between the model and exchange rate determination could lead in some cases to incorrect policy prescriptions such as the overestimation of the impact of macroeconomic fundamentals and the corresponding underestimation of the impact of *liquidity* trading and international financial shocks. The latter includes, *inter alia, changes to the ownership of domestic currency instruments by non-residents, current account transactions such as trade in goods and services, transfers in capital income, remittances, and tourism related flows which are not related to traditional macroeconomic fundamentals.*

The questions around intervening in financial markets when the price of an asset is misaligned from macroeconomic fundamentals are relevant in the current policy debate. Both the Global Financial Crisis (GFC) and the COVID pandemic triggered the use of a series of non-conventional instruments focused in the support of specific assets. More recently, the ECB launched its Transmission Protection Instrument (TPI), aimed to counter the *"deterioration in financing conditions not warranted by country-specific fundamentals"*.[2]

An example of how a small open economy central bank intervenes is shown in Figs. 1 and 2. They present the share of ownership of fixed income assets by non-residents for the case of Peru - a small open economy committed to FXI - from 2008 to 2018. Foreign ownership increases during periods of domestic currency appreciation while the Central Bank intervenes by purchasing dollars from the public. Moreover, the increase in foreign ownership has a negative correlation with the 10-year bond yields. These dynamics, namely the positive correlation between the exchange rate and interest rates, constitute a challenge for models in which the exchange rate is determined by the interest rate differential.

We present a model with segmented and incomplete financial markets as in Bacchetta and Wincoop (2006) and Itskhoki and Mukhin (2021). The presence of risk-averse financial intermediaries, who act as market-makers and absorb the changes in portfolio positions of the rest of agents, will generate deviations from the uncovered interest parity (UIP) condition. More precisely, financial intermediaries portfolio decisions endogenously add a time-varying exchange rate risk premium element to the traditional UIP that will react to FXI by the central bank. In this setup, central bank FXI affects exchange rate determination through two channels:[3] (i) the portfolio balance channel, and (ii) the expectations channel. In the first one, a sterilised intervention alters the value of the currency because it modifies the ratio between domestic and foreign assets held by the private sector; according to the second, the promise of future interventions impacts the current exchange rate.

We solve the model in discrete time and obtain an explicit optimal FXI rule. Additionally, we complement our analytical results with numerical simulations. The analytical approach focuses on the special case of and unitary elasticity of inter temporal substitution and unitary elasticity of substitution across goods produced in different countries. In this case, the net exports in the model remain at zero. This mutes a very important channel through which macroeconomic shocks will impact the equilibrium exchange rate in a non-efficient manner. When we allow for a more general parametrization and keep the assumption that financial account transactions are settled in hard currencies, shocks to macroeconomic fundamentals will also activate the portfolio balance channel, causing inefficient dynamics for the exchange rate. To keep the analysis simple, we follow Itskhoki and Mukhin (2021) by considering only productivity and portfolio flow shocks.[4]

Relying on numerical analysis also allows us to explore the use of implementable rules, this is, rules that do not rely in the perfect and simultaneous identification of unobservable shocks. We provide welfare results for FXI rules commonly attributed to central banks that use this instrument: a leaning-against-the-wind rule and a real-exchange-rate stabilization rule.

Findings. Our results show that FXI is a useful policy tool for central banks, particularly in small open economies with incomplete, segmented, and shallow financial markets. The presence of frictions creates welfare losses that can be mitigated with FXI. Additionally, we show how monetary and FXI policies can complement each other. Since the optimal policy requires the contemporaneous identification of shocks, we focus our attention on rules commonly discussed in the literature

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[1] See Meese and Rogoff (1983).

[2] See ECB (2022).

[3] We acknowledge the presence of a third important channel: *the volatility channel.* When the central bank affects the equilibrium volatility of the exchange rate, the impact of portfolio flow shocks in the economy is reduced. For a discussion see Montoro and Ortiz (2016).

[4] The literature classifies these variables into *fundamental* and *non-fundamental*. As Vitale (2006) clarifies, this classification makes reference to the traditional monetary models of the exchange rate, which consider fundamental variables as the ones pertaining nominal and real macroeconomic factors such as money supply, policy interest rates and output. Consequently, variables reflecting portfolio flow shocks, exchange rate risk and risk-aversion changes, - which also play an important role underpinning the equilibrium value of the exchange rate - are considered *non-fundamental*.

of FXI and their impact on welfare. Finally, we estimate a Bayesian Vector Autoregressive model (BVAR) for Peru, finding empirical support linking FXI to both financial and macroeconomic shocks.

Related Literature. Our paper follows the literature of FX determination in general equilibrium with imperfect financial markets. Our closest references are Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021) which show how the role of financial intermediaries creates a risk-bearing channel that can explain the disconnection and exchange rate determination puzzles. Moreover, these frictions create a role for FXI. Cavallino (2019) studies the optimal FXI policy in a continuous-time SOE New Keynesian model, finding how this tool complements monetary policy when the economy is hit by non-fundamental portfolio flow shocks. Gabaix and Maggiori (2015) and Cavallino (2019) work in an incomplete financial markets setup, in which financial intermediaries face a collateral constraint. The limit to their position in foreign currency is linked to a moment of the equilibrium distribution of the exchange rate in an ad hoc manner. In this case, FXI affects the economy by increasing or decreasing the value of financiers' collateral. In contrast, we emphasize the portfolio balance channel as in Itskhoki and Mukhin (2021), but focusing in a small open economy.[5]

There is a handful notable papers studying the role of FXI in a DSGE setup. Chang (2019) presents a model in which imperfect substitution across assets denominated in different currencies occurs only when banks face a binding borrowing constraint. In this region of the state-space, FXI by the central bank becomes effective. Fanelli and Straub (2021) introduce convex costs to carry traders, reducing the central bank's incentives to curtail exchange rate volatility. Amador et al. (2020) study the use of exchange rate policies when the economy is at the zero lower bound. Liu and Spiegel (2015) also study optimal FXI and capital controls in a DSGE model of small open economy subject to non-fundamental capital inflows and imperfect substitutability between home and foreign currency bonds. Benes et al. (2015) provides a framework for the joint analysis of hybrid inflation targeting (IT) regimes with FXI strategies (e.g., exchange rate corridors, pegged or crawling exchange rates, managed floats.), where the central bank can exercise control over the exchange rate as an instrument independent of monetary policy and the policy interest rate.[6]

Our paper also relates to the literature on the effectiveness of FXI. The empirical evidence in this front ranges widely and remains inconclusive. Reviews by Menkhoff (2012) and Ghosh et al. (2016) suggest that interventions in some cases have a systematic impact on the exchange rates, and are able to reduce exchange rate volatility. FXI appears to be more effective when it is consistent with monetary policy. This evidence indicates that the impact of FXI depends on the specific episode and instrument used. These results build on the seminal work on the effectiveness of FXI by Dominguez and Frankel (1990).

Finally, our paper focuses on the properties of optimal rules and the welfare losses derived from using simple and implementable rules. Seminal papers in this literature are Giannoni and Woodford (2003) and Giannoni (2004).

Outline. The paper is organized as follows. Section 2 presents an empirical exercise for the case of Peru, a small open economy which actively intervenes in FX markets. Section 3 presents the model. Section 4 discusses the optimal policy under the Linear Quadratic Approach. Section 5 presents an analysis of optimal simple FXI rules. Section 6 concludes. All proofs and details of the derivations are left for the online appendix.

2. The Impact of External Shocks and FXI

In this section, we document how a small open economy with an active FXI policy reacts to external shocks. As Patel and Cavallino (2019) report, central banks use this instrument with different goals in mind, reacting to both unwelcome financial developments and to capital flows related to fundamentals.

We present the case of Peru, a resource-rich small open economy with a central bank that actively intervenes in FX markets. We estimate a Vector Autoregressive system with exogenous variables using quarterly data from 2001Q1 to 2019Q4. We perform our empirical exercises using the Bayesian Estimation, Analysis and Regression (BEAR) toolbox.[7] The exogenous variables represent external shocks to the country. We use the Chicago Board Options Exchange's CBOE Volatility Index (VIX), a measure of United States stock market's volatility, as a proxy for financial shocks and the Terms of Trade (TOT) as a proxy for fundamental shocks. For domestic variables, we use the gross-domestic-product (GDP), the trade balance (TB), the real exchange rate (RER) and a measure of foreign exchange intervention (FXI) from the central bank of Peru.

The small open economy (Peru) is represented by:

$$Z_t'B_0 = \sum_{j=1}^{p} Z_{t-j}'B_i + \sum_{i=0}^{p} Z_{t-i}^{*'}\widetilde{B}_i^* + w_t'D + \varepsilon_t', \tag{1}$$

where Z_t represents the $n \times 1$ vector of endogenous variables; ε_t the $n \times 1$ vector of structural shocks ($\varepsilon_t \sim N(0, I_n)$) which are independent of the exogenous block shocks; B_i are $n \times n$ matrices of structural parameters for $i = 0, \ldots, p$; and, D is $r \times n$

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[5] This is an important distinction since financial account transactions made by small open economies are mostly settled in hard currencies. Gopinath et al. (2020) details how the vast majority of international trade transactions are invoiced in hard currencies. Regarding financial instruments Maggiori et al. (2020) documents the pervasive preference of investor holdings for securities in hard currencies. Aizenman et al. (2021) describes how the reduction of the original sin has brought up the risk on/risk off dynamics associated with capital flows highlighted in our model. Thus, the higher participation of foreign investors in domestic markets has exposed countries to larger capital outflows.

[6] Ghosh et al. (2016) discusses the use of hybrid IT schemes in emerging market economies (EME). Authors recommend the use of a two-instrument IT framework as a way to reinforce its commitment to a low inflation rate.

[7] This toolbox was developed by the European Central Bank and it is fully described by Dieppe et al. (2016).

matrix of structural parameters. Z_t^* represents the $n^* \times 1$ vector of endogenous variables at the global level and $\widetilde{B}^*$ is a $n^* \times n^*$ matrix of structural parameters. From the perspective of the small open economy, the global variables are taken as exogenous. For details of the empirical strategy, see section F of the online appendix.

Left hand panel in Fig. 3 shows that an exogenous shock to international financial markets, associated with capital outflows, produces a persistent real depreciation, a negative impact on the trade balance and FX sales by the central bank. In the appendix, we present an exercise in which we substitute the measurement of FXI with the level of Net Foreign Reserves (NIR), as a proxy of FXI, obtaining similar results. A negative development in international financial markets triggers FX sales and a drop in foreign reserves.

Right hand panel in Fig. 3 shows the response of the Peruvian economy to a positive terms of trade shock. In this case, we observe a real appreciation, a surge in the trade balance and FX purchases by the central bank. The empirical analysis suggests, for the case of Peru, that FXI reacts to capital flows originated by both financial and real shocks.[8]

3. The Model

We present a model for a small open economy with nominal rigidities in line with the contributions from Galí and Monacelli (2005) and Christiano et al. (2005), among others. To maintain the concept of general equilibrium, we use a two-country framework taking the size of one economy close to zero, such that the small (domestic) economy does not affect the large (foreign) economy.[9] The economy is composed by households, firms, financial intermediaries (FX dealers) and central bank who intervenes in FX markets.

3.1. Households

There is a continuum of households who derive utility from consumption and leisure. Because of the segmented financial markets assumption, households will only consider the domestic interest rate in their maximization problem. The representative household maximizes:

$$\mathbb{E}_0 \left[\sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\gamma_c}}{1-\gamma_c} - \frac{L_t^{1+\chi}}{1+\chi} \right] \tag{2}$$

Subject to:

$$B_{t+1} = R_{t-1} B_t + W_t L_t - P_t C_t + \Gamma_t^d + \Gamma_t^{cb} + T_t + \Pi_t \tag{3}$$

where γ_c is the relative risk aversion parameter, $1/\chi$ is the Frisch elasticity of labor supply, W_t is the nominal wage, P_t is the consumer price index and R_{t-1} is the domestic nominal interest rate. Γ_t^d are profits from financial intermediaries and Γ_t^{cb} are transfers from the central bank. As owners of monopolistic firms, they also receive profits (Π_t) and T_t represents the transfers/taxes from the government.

Each household owns the same share of firms and dealer agencies in the home economy. Transactions between foreign and domestic markets occur in foreign currency bonds (hard currency). Domestic households offset their foreign currency bond position originated in the financial account transactions against financial intermediaries.

The consumption basket is given by:

$$C_t \equiv \left[(\gamma)^{1/\varepsilon_H} \left(C_t^H \right)^{\frac{\varepsilon_H-1}{\varepsilon_H}} + (1-\gamma)^{1/\varepsilon_H} \left(C_t^F \right)^{\frac{\varepsilon_H-1}{\varepsilon_H}} \right]^{\frac{\varepsilon_H}{\varepsilon_H-1}}, \tag{4}$$

where supra-indexes H and F stand for home and foreign produced goods, respectively. The parameter γ regulates the home bias, while ε^H is a measure of the substitutability between home and foreign produced goods. The consumer price index, under these preference assumptions, is determined by the following condition:

$$P_t \equiv \left[\gamma \left(P_t^H \right)^{1-\varepsilon_H} + (1-\gamma) \left(P_t^F \right)^{1-\varepsilon_H} \right]^{\frac{1}{1-\varepsilon_H}} \tag{5}$$

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[8] This result is also in line with Faltermeier et al. (2022) who find that the optimal response to a commodity price boom consists in FX purchases and net foreign reserves accumulation.

[9] We acknowledge that the general equilibrium perspective introduces a series of linear relationships among the foreign economy variables. The disadvantage of following this modelling strategy is that shocks to foreign variables will not be observed independently, as only a combination of foreign variables will impact the domestic economy. This would not allow us to analyse the impact of shocks to foreign variables independently (and the impact would depend as well on the calibration of the foreign economy.)

where P_t^H and P_t^F denote the price level of the home-produced and imported goods, respectively.[10]

Consumption decisions and the supply of labour. The condition characterising the optimal allocation of domestic consumption is given by the following equation:

$$U_{C,t} = \beta \mathbb{E}_t \left\{ U_{C,t+1} R_t \frac{P_t}{P_{t+1}} \right\} \tag{6}$$

The first-order condition that determines the supply of labour is characterised by the following equation:

$$-\frac{U_{L,t}}{U_{C,t}} = \frac{W_t}{P_t}.$$

where $\frac{W_t}{P_t}$ denotes real wages. In a competitive labour market, the marginal rate of substitution equals the real wage.

3.2. Firms

A continuum of z of intermediate firms exists. These firms operate in a perfectly competitive market and use the following linear technology:

$$Y_t^{int}(z) = A_t L_t(z) \tag{8}$$

$L_t(z)$ is the amount of labour demand from households, A_t is the level of technology.

These firms take as given the real wage, W_t/P_t, paid to households and choose their labour demand by minimising costs given the technology. The corresponding first order condition of this problem is:

$$L_t(z) = \frac{MC_t(z)}{W_t/P_t} Y_t^{int}(z)$$

where $MC_t(z)$ represents the real marginal costs in terms of home prices. After replacing the labour demand in the production function, we can solve for the real marginal cost:

$$MC_t(z) = \left(1 - \tau^H\right) \frac{W_t}{A_t} \tag{9}$$

where τ^H is a subsidy to correct the steady state market power distortion. Given that all intermediate firms face the same constant returns to scale technology, the real marginal cost for each intermediate firm z is the same, that is $MC_t(z) = MC_t$. Also, given these firms operate in perfect competition, the price of each intermediate good is equal to the marginal cost. Therefore, the relative price $P_t(z)/P_t$ is equal to the real marginal cost in terms of consumption unit (MC_t).

Price-Setting. Final goods producers purchase intermediate goods and transform them into differentiated final consumption goods. These firms operate in a monopolistic competitive market, where each firm faces a downward-sloping demand function. Furthermore, we assume that in each period t final goods producers face an exogenous probability of changing prices given by $(1 - \theta)$. Following Calvo (1983), we assume that this probability is independent of the last time the firm set prices and the previous price level. Thus, the maximization problem of firm z is given by:

$$\max_{\widehat{P}^H} \sum_{k=0}^{\infty} \theta^k \mathbb{E}_t \left[\mathcal{Q}_{t,t+k} \left(Y_{t+k}^H(j) \left\{ \widehat{P}_t^H - (1 - \tau^H) P_t MC_{t+k} \right\} \right) \right] \tag{10}$$

where $\mathcal{Q}_{t,t+k} = \beta^k \frac{U_{C,t+k}}{U_{C,t}}$ is the stochastic discount factor and $Y_{t,t+k}^H(j)$ is the demand for good j in $t + k$ conditioned to a fixed price from period t, given by:

$$Y_{t+k}^H(j) = \left(\frac{\widehat{P}_t^H}{P_{t+k}^H} \right)^{-\varepsilon} Y_{t+k}^H \tag{11}$$

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[10] In the *special case* of $\varepsilon_H = 1$ we use the following definitions:

$$C_t \equiv \frac{\left(C_t^H\right)^\gamma \left(C_t^F\right)^{1-\gamma}}{\gamma^\gamma (1-\gamma)^{(1-\gamma)}}; \quad P_t = \left(P_t^H\right)^\gamma \left(P_t^F\right)^{1-\gamma};$$

where ε reflects the elasticity of substitution across varieties. Regarding the subsidy τ^H, the policy maker sets it constant to maximize the steady state welfare of the domestic economy.[11]

The solution to the firms' problem and the Calvo pricing assumption allows to obtain an expression for the optimal price:

$$\tilde{p}_t^H = \left[\frac{1 - \theta \left(\pi_t^H \right)^{\varepsilon - 1}}{1 - \theta} \right]^{\frac{1}{1 - \varepsilon}} \tag{13}$$

where $\tilde{p}_t^H \equiv \frac{\widehat{P_t^H}}{P_t^H}$ and π^H reflects the inflation rate of home goods.

3.3. Financial Intermediaries

There are (a measure) m of symmetric risk-averse intermediaries who operate in the secondary bond market. Each dealer receives FX purchase and sale orders from households, the central bank and foreign investors, respectively. As in Stoll (1978), intermediaries will use their own portfolio to provide the immediacy service to the rest of the population, acting as market-makers. The market will present imbalances, as in Gabaix and Maggiori (2015), and the net position of financial intermediaries will be affected by the orders of the rest of agents. In compensation for providing this service, intermediaries will charge a risk premium priced in the equilibrium exchange rate.

The exchange rate S is defined as the price of foreign currency in terms of domestic currency, such that a decrease (increase) corresponds to an appreciation (depreciation) of the domestic currency. At the end of the period, any profits - either positive or negative- are transferred to the households. Financial intermediaries maximize a CARA utility of the return over investments in units of the domestic consumption good:

$$\max_{d_{t+1}^*} \mathbb{E}_t \left\{ -\frac{1}{\omega} \exp \left(-\omega \frac{\widetilde{R}_{t+1}^*}{R_t} d_{t+1}^* \right) \right\} \tag{14}$$

The return on intermediaries' strategy is given by:

$$\widetilde{R}_{t+1}^* = R_t^* \frac{S_{t+1}}{S_t} - R_t \tag{15}$$

where $\mathbb{E}_t$ is the rational expectations operator, $\omega \geqslant 0$ is the coefficient of absolute risk aversion and $\widetilde{R}_{t+1}^*$ is the peso carry trade return on the portfolio. As in Itskhoki and Mukhin (2021), the open position absorbed by the financial intermediaries (d^*) will be an endogenous object as it will be derived from the domestic currency demand from households (via the financial account flows), foreign carry traders and the central bank FXI.

Financial intermediaries will quote a price for each equilibrium position they have to absorb. Since trade against all agents occurs simultaneously, the portfolio equation can be utilized to get the exchange rate at which financial intermediaries are willing to mirror the position of the rest of agents.

Lemma 3.1. The equilibrium condition in the financial market is given by:

$$s_t = \mathbb{E}(s_{t+1}) + i_t^* - i_t + \frac{1}{2}\sigma^2 - \frac{\omega}{m}\sigma^2 D_{t+1}^* \tag{16}$$

where $i_t^* - i_t \equiv log(R_t^*/R_t)$, $\sigma^2 \equiv var_t(\Delta s_{t+1})$, which is the volatility of the log nominal exchange rate, and D_{t+1}^* is the aggregate position of financial intermediaries.

We assume that domestic and foreign households have portfolios composed entirely of assets in their respective currencies, while foreign demand for local currency bonds is left to a group of noise-traders who have an exogenous demand. Their position is given by:

$$N_{t+1}^* = n\left(e^{\psi_t} - 1\right) \tag{17}$$

where $\psi_t = \rho_\psi \psi_{t-1} + \sigma_\psi \varepsilon_t^\psi$; $\varepsilon_t^\psi \sim i.i.d.(0,1)$ and n represents the mass of noise traders. We assume noise traders follow a zero-capital strategy; this means that a long position in foreign currency will have an equivalent short position in domestic currency.

These assumptions allow us to capture some of the stylized facts documented for small open economies:[12]

- A large share of the trade is invoiced in foreign currency.

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[11] In section E of the online appendix, we show this value is given by:

$$\tau^H = \frac{\varepsilon\gamma - \varepsilon + 1}{\varepsilon\gamma} \tag{12}$$

[12] See Amador et al. (2020),Gopinath et al. (2020), Aizenman et al. (2021) and Maggiori et al. (2020)

- A large share of financial account transactions is denominated in foreign currency.
- The share of instruments denominated in local currency creates a 'risk-on/ risk-off' channel.
- Capital flow shocks are not necessarily driven by macroeconomic fundamentals.

The parameter m merits and additional discussion, as it reflects the risk-baring capacity of FX intermediaries. The finance literature relates the portfolio balance channel to depth and liquidity of this inter-dealer market. Thus, the importance of the portfolio balance effect in the determination of the exchange rate and the effectiveness of FXI will depend on how developed financial markets are. Studies on the effectiveness of FXI seem to be consistent with this view.[13]

3.4. Central Bank

The central bank issues the domestic bonds and sets the interest rates paid by these assets. We assume the central bank is able to control the domestic interest rate as it can always perform fully sterilised interventions.[14] From here, we assume the central bank follows a zero-capital strategy:

$$B_{t+1}^{cb} + S_t B_{t+1}^{cb,*} = 0$$

where $B_t^{cb,*}$ represents the central bank's foreign reserves and B_t^{cb} are bonds issued by the central bank (deposit certificates) used for sterilisation of FXI. The Central Bank flow constraint is given by:

$$B_{t+1}^{cb} + S_t B_{t+1}^{cb,*} + \Gamma_t^{cb} = R_t B_t^{cb} + R_t^* S_t B_t^{cb,*}$$

where Γ_t^{cb} are the Central Bank's transfers to the population in the form of domestic bonds.[15] The central bank will take an open position in foreign currency assets offsetting the position of FX intermediaries.

The rest of the model describes a standard small open economy model. See section C in the online appendix for details.

Now we can characterize the portfolio balance channel of capital flows. When carry traders increase their demand for domestic currency bonds, they will do it by selling foreign currency bonds to either financial intermediaries or the central bank, since we assume that domestic households do not hold foreign currency bonds. If the central bank does not intervene, the foreign currency holdings of financial intermediaries increase, and from Eq. (16), this generates a currency appreciation at impact. Intermediaries will only hold this position if the risk premium increases to compensate them for their long position in foreign currency. Notice that the central bank can intervene, sharing the order burden with financial intermediaries, changing their portfolio and affecting the equilibrium exchange rate.

A key aspect of the model is that dealers do not consider the Central Bank's portfolio as part of their own. Therefore agents will not undo the shifts in the Central Bank's portfolio.[16] Dealers will demand a premium for shifts in the exposure generated by central bank FXI.

As discussed by Mendoza (1991) and Schmitt-Grohe and Uribe (2003), the equilibrium of the canonical small open economy model solved by local methods exhibit a random walk component. In particular, the marginal utility of wealth will follow a unit root process. For this reason, the literature considers several mechanisms to induce a unique steady-state. A feature of this model is that the portfolio balance channel creates and endogenous risk premium that stabilizes the net foreign assets around its steady-state level. We leave the proof for section D in the online appendix.

The availability of FXI as a policy tool opens the question of the optimal use of this instrument. In the next section we discuss the optimal FXI policy.

4. Optimal policy under the linear quadratic approach

In this section, we perform optimal policy exercises. As Benigno and Woodford (2012) discuss, the linear-quadratic approximation helps to gain insight into fully optimal policy. However, to obtain a closed-form solution, we use some simplifying assumptions. In particular, following Galí and Monacelli (2005) for the case of optimal monetary policy in a small open economy and Cavallino (2019) for the case of foreign exchange interventions, we use a logarithmic utility in consumption and a unit elasticity of substitution parameter between home and foreign goods. We call this special case the Cole-Obstfeld economy.

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[13] See Filardo et al. (2022).

[14] However, in practice sterilised interventions have limits. For example, the sale of foreign bonds by the central bank may be limited by the level of foreign reserves. On the other hand, the sterilised purchase of foreign currency is limited by the availability of instruments to sterilise those purchases (e.g., given by the demand for central bank bonds or by the stock of treasury bills in the hands of the central bank). Also, limits to the financial losses generated by FXI can represent a constraint for intervention itself.

[15] In this model there is no distinction between spot or derivative FXI. Thus, these interventions can be understood as the central bank buying and selling non-deliverable forwards settled in domestic currency. For a discussion on dollar liquidity effects of spot FXI see Armas and Ortiz (2020).

[16] This result is related to a violation of the Ricardian equivalence. It is possible to understand it as an extension from the government wealth to the composition of the government's portfolio. If agents consider the central bank's portfolio as part of theirs, FXI becomes ineffective.

4.1. Optimal FXI with flexible prices

In this section, we discuss the optimal FXI policy following the linear-quadratic approach when prices are flexible. Following De Paoli (2009), the optimal policy will attempt to replicate the complete international financial markets. Following the literature, we define the Backus-Smith wedge as:[17]

$$\Lambda_t = \frac{C_t}{Q_t C_t^*} \tag{18}$$

where $Q_t \equiv S_t P_t^* / P_t$ is the real exchange rate. In section E.2 of the online appendix we show that the households' welfare loss is a function of the Backus-Smith wedge. The optimal policy problem under de LQ approximation is summarized in the following proposition:

Proposition 4.1. The solution to the problem:

$$\max_{\{b_{t+1}^{cb}\}_{t=0}^{\infty}} \mathbb{W} = \mathbb{E}_0 \left\{ -\frac{(\Phi_1 + \Phi_2)}{2} \beta^t \sum_{t=0}^{\infty} \lambda_t^2 + \mathcal{O}\left(\|a\|^3\right) + t.i.p. \right\} \tag{19}$$

subject to:

$$b_{t+1} - \frac{1}{\beta} b_t = -(1-\gamma)\lambda_t \tag{20}$$

$$\lambda_{t+1} - \lambda_t = \frac{\omega \sigma_e^2}{m}\left(-\overline{Y} b_{t+1} - \overline{Y} b_{t+1}^{cb} - n\psi_t \right) \tag{21}$$

Consists in setting:

$$b_{t+1}^{cb} = -\overline{Y} b_{t+1} + n\psi_t, \quad \text{foreach } t \geqslant 0. \tag{22}$$

Proof: See section E.2. of the online appendix.

Here $\lambda_t \equiv \hat{\Lambda}_t$ represents the consumption wedge in deviations from its steady state value. Φ_1 and Φ_2 are combinations of parameters. $\mathcal{O}\left(\|a\|^3\right)$ groups the terms of order greater than 2 and $t.i.p.$ represents the terms independent of the policy.

In the Cole-Obstfeld economy under the LQ approximation, the productivity shocks do not trigger a misalignment in the exchange rate. Thus, the central bank can restore the optimal allocation by compensating the open position absorbed by financial intermediaries. The optimal allocation involves a constant level of labour and a consumption.[18]

4.2. Optimal Monetary and FX policies with Price Rigidities

In this section we study how the frictions introduced in the foreign exchange market interact with the objectives of a central bank under price rigidities. In section E.3 of the online appendix we show that the loss function under sticky prices is a function of the three gaps in the economy: the price dispersion gap (π^H), the output gap (x^H) and the Backus-Smith gap (λ). The following proposition characterizes the solution to the central bank problem.

Proposition 4.2. The solution to the problem:

$$\max_{\{b_{t+1}^{cb}, i_t\}_{t=0}^{\infty}} \mathbb{W} \equiv -\frac{1}{2} \mathbb{E}_0 \left\{ \sum_{t=0}^{\infty} \beta^t \left(\phi_\lambda \lambda_t^2 + \phi_\pi (\pi_t^H)^2 + \phi_y (x_t^H)^2 \right) \right\} \tag{23}$$

subject to:

$$b_{t+1} - \tfrac{1}{\beta} b_t = -(1-\gamma)\lambda_t$$

$$x_t^H = \left(\tfrac{1}{\gamma} - \tfrac{\gamma}{1+\gamma-\gamma^*}\right)\left(\tfrac{\omega\sigma_e^2}{m}\left(-n_{t+1} - b_{t+1}^{cb} - b_{t+1}\right)\right) + \mathbb{E}_t x_{t+1}^H - \tfrac{1}{\gamma}\left(i_t - \mathbb{E}_t \pi_{t+1} - r_t^n\right)$$

$$\pi_t^H = \beta \mathbb{E}_t\left(\pi_{t+1}^H\right) + \tfrac{(1-\theta)(1-\beta\theta)}{\theta}\left((1+\chi)y_t^H + (1-\gamma)\lambda_t\right)$$

is given by the the optimal FXI:

$$b_{t+1}^{cb} = \frac{m}{\omega\sigma_e^2}\phi_\pi\left(\mathbb{E}_t \pi_{t+1}^H\right) + n\psi_t - b_{t+1} \tag{24}$$

and the monetary policy:

$$i_t = \left(1 - \kappa\gamma\frac{\phi_\pi}{\alpha}\right)\mathbb{E}_t \pi_{t+1}^H + r_t^n \tag{25}$$

Proof: See section E.3 of the online apprendix.

Here ϕ_λ, ϕ_π and ϕ_y are combinations of parameters. The result shows an interesting interaction between monetary and FXI policies. When the FXI policy is optimal, the central bank can use its monetary instrument to focus in the domestic front, however, the shocks that deviate expected prices from its optimal level will affect the Backus Smith wedge. In this case, FXI policy must also correct the relative price distortion between domestic and foreign goods caused by price stickiness. In turn, when monetary policy can fully stabilize inflation expectations, optimal FXI reverts to the flexible prices case.

5. Optimal simple rules

Giannoni (2004) argue that the policy rules specified in terms of a mapping from disturbances to the instrument could exhibit a series of undesirable features. They propose the use of rules that react to the projected path of target variables and that are considered *targeting criteria* in the sense of Svensson and Woodford (2004). In this case, the rule would be *robust*, as the process of exogenous disturbances will not affect the central bank FXI criterion.

By fixing $\lambda_t = \bar\lambda \;\forall t$ and replacing it in Eq. (21), we can express the optimal intervention rule as the one that eliminates UIP deviations:

$$\mathbb{E}(\Delta s_{t+1}) = i_t - i_t^* \tag{26}$$

Notice that the optimal policy closes the Backus-Smith wedge. The optimal rule under the LQ approximation in (22) forces the central bank to identify the 'non-fundamental' shocks in order to react in an optimal manner. A rule such as would be categorized by Svensson and Woodford (2004) as a *explicit instrument rule*, since the instrument reacts only to predetermined and exogenous variables, which are independent of the policy decision. However, this specification lacks robustness, as different specifications for the portfolio flow shock process would lead to a different policy rule. Thus, presenting the *targeting criterion* in (26) will comply with the desirable properties discussed.[19]

In practice central banks normally react to readily observable variables or expectations of target variables. For this reason, we study the welfare implications of two families of rules that are commonly discussed in policy circles. First a rule that reacts to expected variations in the exchange rate, and second, a rule that reacts to the deviations in the real exchange rate from its steady state value. We contrast these rules with a rule derived from the LQ derivation in the previous section.[20] Following Galí and Monacelli (2005), we evaluate each policy by calculating the welfare loss, expressed in terms of the proportion of each period's consumption that a typical household in the home economy would need to give up in a deterministic world so that its welfare is equal to the expected conditional utility in the stochastic case. More precisely, we calculate ω_c that satisfies the following equation.

$$\mathbb{E}_t\left[\sum_{t=0}^{\infty}\beta^t \ln C_t - \frac{L_t^{1+\chi}}{1+\chi}\right] = \frac{1}{1-\beta}\left[\ln\left(1 - \frac{\omega_c}{10000}\right)C - \frac{L^{1+\chi}}{1+\chi}\right] \tag{27}$$

where variables without time subscripts denote their respective steady state values. We consider the measure for conditional and unconditional welfare.[21]

By contrasting these rules with the optimal linear-quadratic plans we can observe the welfare losses from following different rules and how welfare changes in more general setups.

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[19] In our setup, this is a measure of the 'fundamental' level of the exchange rate. This idea is close to the long-standing practice in central banks of calculating real exchange rate misalignments. For a discussion, see Clark and MacDonald (1999).

[20] Here we assume that central banks do not engage in FXI for mercantilist reasons. As Cavallino (2019), we rule out these FXI motives due to potential retaliation.

[21] For this measure we calculate the constant that makes the measure equivalent to the unconditional and conditional ergodic means of the calculated welfare variable, starting from the steady state. For a discussion see Born and Pfeifer (2020).

5.1. FXI rules

We present two simple rules that are commonly discussed among policy makers and contrast them to rules that react directly to shocks. The first one considers the expected changes in the exchange rate, constituting a pure 'leaning-against-the-wind' (OSR-LAW) strategy.

$$B_{t+1}^{cb,*} = -\phi_s(\mathbb{E}S_{t+1} - S_t) \tag{28}$$

According to this rule, when the economy faces depreciation (appreciation) pressures on the domestic currency, the central bank sells (purchases) foreign bonds to prevent the exchange rate from fluctuating.

Under the second rule, the central bank reacts to misalignments of the real exchange rate relative to its steady state value. We call this strategy the 'real-exchange-rate stabilization' rule (OSR-RER).

$$B_{t+1}^{cb,*} = -\phi_q\left(Q_t - \overline{Q}\right) \tag{29}$$

For reference, we present two additional rules, one reacts to portfolio shocks (OSR-PF), and one which reacts to productivity shocks (OSR-PROD).

To set the parameter values of these rules we use the optimal simple rules command in Dynare to perform a search for the parameter that maximizes welfare. We follow the steps in Born and Pfeifer (2020) to recover the welfare equivalent consumption parameter. In this manner, we consider the maximum welfare the central bank can achieve following a particular family of rules. Since many of our results are numerical, we perform a robustness exercise to understand how the effectiveness of these rules depends on the structure of the economy.

Calibration. Before presenting the results of the quantitative analysis, we discuss the calibration of the model. To be consistent with the special case for which the optimal policy is calculated analytically we set $\gamma_c = 1$. In the general case, we calibrate it to 1.5.

Instead of calibrating the rest of the parameters to a particular economy, we set the parameters at values that are standard in the new open economy literature, as shown in Table 1. The discount factor β is fixed at 0.995, which implies an annualized real interest rate of 2% in the steady state. The elasticity of the labour supply is set at 1.5, within the values found in empirical studies. The value of the substitution elasticity between domestic and foreign goods is a controversial parameter. We follow previous studies in the DSGE literature, which consider values between 2.5 and 5.1. The share of domestic tradable goods in the CPI is set to 0.85, which implies a participation of imported final goods of 0.15 in the domestic CPI, in line with other studies for small open economies. Regarding price stickiness, the assumption implies that firms keep their prices fixed for 4 quarters on average.

The coefficient of absolute risk aversion for dealers was set to 500 as in Bacchetta and Wincoop (2006). Finally, the standard deviation of the TFP shock is set to 0.03 while the standard deviation of the portfolio flow shocks is set to 0.01. In this manner, in the non-FXI equilibrium we obtain a variance decomposition for the output that keeps that proportion (75% explained by TFP shocks).

5.2. Optimal simple rules under flexible prices

5.2.1. Cole-Obstfeld case

Table 2 shows the results under the Cole-Obstfeld calibration. Our results are in line with the closed-form optimal policy found under flexible prices in Section 4.1. When the economy is hit by both fundamental (productivity) and non-fundamental (portfolio flow shocks), the optimal policy consists of identifying non-fundamental shocks and reacting to them. In this manner, the central bank fully stabilizes the Backus-Smith wedge and achieves the first-best allocation. The simple rules reacting to deviations of the real exchange rate or expected variations in the nominal exchange rate are effective relative to the non-FXI case. With these simple rules, the central bank improves welfare and reduces the volatility of all the cyclical variables considered. Since the source of the inefficiency comes from portfolio flow shocks, the strength of the reaction in these cases depends on the frequency of shocks. As Panel B in Table 2 shows, when there are no portfolio flow shocks, the optimal policy is not to intervene. Similarly, Panel C, which presents the case in which the economy is only hit by portfolio flow shocks, shows that all FXI rules are effective in stabilizing the economy. It is also important to note that the rule reacting to the fundamental shock (last column) always finds it optimal not to react at all. We consider this as a key result that holds across our exercises under the Cole-Obstfeld parametrization.

5.2.2. General parametrization case

Table 3 shows the results when a higher elasticity of intertemporal substitution and a higher Armington elasticity are considered. As we depart from the Cole-Obstfeld setup, the results change. In particular, trade stops to be "balanced" and households use the financial account to smooth their consumption over time.[22] Without FXI the productivity shock creates a fall in the H good price. The lower price increases foreign demand for good H and exports will rise. In our setup the higher

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[22] See Galí and Monacelli (2005) for a discussion of the trade balance properties of this setup under different parametrizations.

exports increase the amount of dollar-denominated assets in the economy, which strengthens the domestic currency. This reduces the price of goods *F*. Since productivity of goods *H* is still high, the overall effect is a lower price of goods *H* and *F* in terms of labour, generating a positive income effect, a higher wage, and a higher marginal cost. In turn, this creates a relatively lower output expansion.

This channel is also related to imperfect international risk sharing. As Cole (1988) and Cole and Obstfeld (1991) discuss, under specific parametrizations of the economy, the portfolio autarky leads to the Pareto efficient allocation. Thus, in the Cole-Obstfeld case, the autarky portfolio does not create any inefficiencies. Once we depart from this case, idiosyncratic shocks to productivity will lead to an inefficient relative price between home and foreign goods. Absent the instruments for agents to ex-ante diversify the risk associated with the relative price of their labour to the consumption basket, idiosyncratic shocks will yield inefficient relative prices. As Cole (1988) shows, the existence of Arrow securities would make home agents enter an implicit pooling agreement through which income effects generated by these shocks would be reduced. Thus, with imperfect risk sharing and home bias in consumption, the income effect generated by the shock inefficiently increases the relative price of home to foreign goods. Therefore, when a idiosyncratic positive productivity shock hits the economy, the real exchange rate follows a path that is more appreciated than the optimal. In our setup, the central bank can purchase foreign bonds to reduce the inefficiency generated by the portfolio balance effect.[23] [24]

5.3. Optimal simple rules with sticky prices

Now we introduce sticky prices to study how monetary and FXI policies interact. Results are presented in Table 4. As we can observe, the results are similar to the ones under flexible prices. This is consistent with the analytical result found in the previous section: since monetary policy fully stabilizes inflation expectations, the problem faced by the cenrtal bank becomes equivalent to the one under flexible prices.

Thus, in our setup, a central bank equipped with FXI and monetary policy is capable of stabilizing both fronts. We also perform exercises in which the central bank reacts to CPI inflation, confirming the results in Galí and Monacelli (2005) that Taylor rules reacting to PPI inflation achieve a higher welfare.[25]

Regarding the impact of price stickiness, Fig. 7 show that it has a limited impact on welfare. Since we have only included TFP and portfolio flow shocks in our setup, the optimal PPI Taylor rule parameter stabilizes inflation expectations, leaving the overall welfare almost unaltered. Consistent with our analytical results, optimal FXI with stable inflation expectations matches the flexible prices case.

5.4. Model dynamics

5.4.1. Reaction to a TFP shock

We reserve a few lines to explore the dynamics of the model. The left hand panel in Fig. 4, shows the reaction of the economy to a positive TFP shock under the Cole-Obstfeld parametrization. Both the portfolio flows (OSR-PF) and productivity (OSR-PROD) rules call for no reaction. As discussed by Cole and Obstfeld (1991) in this case trade remains "balanced" and the Backus-Smith wedge is not affected. Following the Backus-Smith condition, agents who prefer the home good increase their consumption and labour remains constant. After the shock subsides, the economy goes back to its steady state level.

Under the rules reacting to the exchange rate, "leaning against the wind" (OSR-LAW), and "real exchange rate stabilization" (OSR-RER), the central bank intervenes to smooth the path of the exchange rate. Now the intervention creates a lower depreciation on impact. Relative to the efficient case, the higher price of the domestic good to foreign good creates a lower external demand. Since agents are more productive, the home goods market clears with a fall in hours worked. Lower exports and higher imports generate a deficit in the trade balance. This breaks the Backus-Smith condition. As the shock subsides in the next period, these rules push the exchange rate along its efficient path. The lower balance of trade pressures the real exchange rate, making domestic goods relatively cheaper even after the positive productivity shock has subsided. Foreign demand increases and market clearing involves a higher level of labour and lower consumption. The deviations of the Backus-Smith condition generate welfare losses. In this case, as we observed in the LQ exercise, it would be optimal for the central bank to not intervene.

Under the general parametrization, shown in the right hand panel the idiosyncratic TFP shock triggers a substitution of home goods towards foreign goods by domestic agents. The higher exports prompt a larger position in foreign currency bonds by the domestic economy and a lower depreciation. Thus, consumption of foreign goods becomes relatively cheaper to the benchmark. Since agents anticipate the reversal of the shock, consumption becomes cheaper relative to the next periods, which is equivalent to a lower real interest rate. For this reason, consumption increases beyond its efficient level, putting pressure on wages through a lower labour supply. The optimal policy calls for a reaction which pushes for a higher depreciation to limit the income effect. Under the optimal policy, agents take full advantage of the productivity shock, leading to higher output and a positive balance of trade in the first period.

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[23] Jermann (2002) also discusses the optimal international risk sharing in production economies under idiosyncratic productivity shocks.

[24] This result can also explain why central banks accumulate reserves when terms of trade increase.

[25] See section G of the online appendix.

5.4.2. Reaction to a portfolio shock

Fig. 5 shows the IRF to a negative portfolio flow shock. In this case, the FXI rule reacting to portfolio flow shocks fully stabilizes the economy, muting the impact of the shock. When the central bank does not intervene, the domestic currency depreciates. The effect is similar to a negative terms of trade shock, as the lower value of the home goods generates a negative income effect. Without financial frictions domestic agents would be able to smooth consumption paying the foreign interest rate. In our setup, this mechanism is affected by the nature of international financial markets. When a negative portfolio flow shock hits, financial intermediaries increase the risk compensation demanded for a shorter position in foreign currency. Since borrowing from foreign households implies an even shorter position for the financial intermediaries, the effective cost of borrowing increases.[26] The higher domestic interest rate generates a fall in consumption and an increase in hours worked. Once the shock subsides, the opposite occurs as noise trader demand for domestic currency reverts to its steady state value and the real exchange rate falls. This creates a lower risk-adjusted interest rate, consumption rises and labour falls. Overall, these dynamics break the Backus-Smith condition and reduce welfare, since the home agent lowers its consumption precisely when their preferred good is cheaper. FXI targeting the exchange rate can smooth the dynamics, improving welfare. However, among the rules considered, the highest welfare level is achieved by identifying and offsetting portfolio flow shocks.[27]

5.5. Robustness to the frequency of shocks

To study the role of the frequency of shocks, we normalize the sum of variances of the TFP and portfolio shocks and change their relative weight. As the importance of portfolio shocks increases, the central bank obtains a higher relative welfare gain with the rules that respond to the exchange rate (OSR-LAW and OSR-RER). The reason is that when the dynamics of the exchange rate are dominated by portfolio flow shocks, the central bank does a better job reacting to that variable. When the dynamics of the economy is purely dominated by productivity shocks, the best response under the Cole-Obstfeld calibration is to not intervene, obtaining a zero value for the reaction parameter in the optimal rules, as shown in the left hand panel of Fig. 6. Under the general case in the right hand panel, the rule reacting to TFP shocks dominates when portfolio flow shocks are not present. As the relative frequency of portfolio flow shocks increases, the rule reacting to portfolio flow shocks grants a higher welfare. OSR-LAW and OSR-RER rules present significant welfare gains relative to the no FXI strategy. We leave the rest of the robustness analysis for section H of the online appendix.

6. Conclusions

In this paper, we present a model to analyse foreign exchange intervention when an economy presents a segmented international financial market featuring noise traders and financial intermediaries as in Itskhoki and Mukhin (2021). The presence of risk-averse financial intermediaries who make portfolio decisions adds an endogenous risk-premium to the traditional uncovered interest rate condition.

In this setup, the central bank can use FXI to affect the position of FX intermediaries and their requested compensation for FX trades. Our results illustrate that FXI is effective at stabilizing the economy in the face of portfolio flow shocks. In this case, the central bank can effectively insulate the economy from these shocks through a leaning-against-the-wind type of policy, selling FX denominated assets when the exchange rate rises, and buying them when it falls. Different from previous research we solve analytically for the optimal policy in discrete time through and LQ approximation. This allows us to present an optimal policy rule and characterize some of its properties.

An additional novel result is found through numerical simulations. Under the general calibration, fundamental shocks can cause the exchange rate to deviate from its efficient path. Specifically, when the elasticity of substitution between home and foreign goods stops to be unitary, terms of trade stop providing insurance against idiosyncratic output shocks as Cole and Obstfeld (1991) discuss. For this reason, macroeconomic fundamental shocks trigger an entry/exit of capital flows, affecting the path of the exchange rate through the portfolio balance channel. Here the optimal FXI policy leans-with-the-wind, allowing the economy to take advantage of the transitory higher productivity.

This pattern seems to agree with the way small open economies operate, reacting to capital flows triggered by both financial and macroeconomic shocks. Using Peruvian data, we build a Bayesian Vector Autoregressive model with block exogeneity and find support for the use of FXI in reaction to both types of shocks.

Considering the optimal policy may be difficult to implement, we also consider simple rules that are commonly discussed in the FXI literature: (1) a leaning-against-the-wind rule and (2) real exchange rate stabilization rule. When reacting to the exchange rate without taking into consideration the shock behind its movement, the rules' effectiveness will depend on the frequency of the shocks and the parameters characterizing the economy. We conclude that these policies would be more effective in small open economies (lower home bias) subject to large portfolio flow shocks (relative to TFP shocks) and with a lower degree of financial development (lower risk-bearing capacity).

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[26] Another interpretation is that the home country agents obtain debt in foreign currency and demand hedge from the domestic financial intermediaries.

[27] The result of currency depreciations related to increases in domestic interest rates is related to the forward premium puzzle. Itskhoki and Mukhin (2021) explain this puzzle using a similar mechanism in a two large country economy setup.

In terms of policy, the design of a FXI policy needs to consider more information than previously thought. Relying on broad recipes for exchange rate stabilization can be a useful tool, however, it can also lead to more instability - the exact opposite result to the one intended with this instrument.

Data availability

Data will be made available on request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Figures and Tables

Figs. 1–3.

Fig. 1. Foreign Ownership of Peruvian Government Bonds and Nominal Exchange Rate (2008–2018). Source: Central Reserve Bank of Peru (BCRP). Note: Figure plots the monthly average nominal exchange rate (PEN/USD) and the outstanding balance of *Bonos del Tesoro Peruano* (BTP) reported by non-resident investors over the total balance.
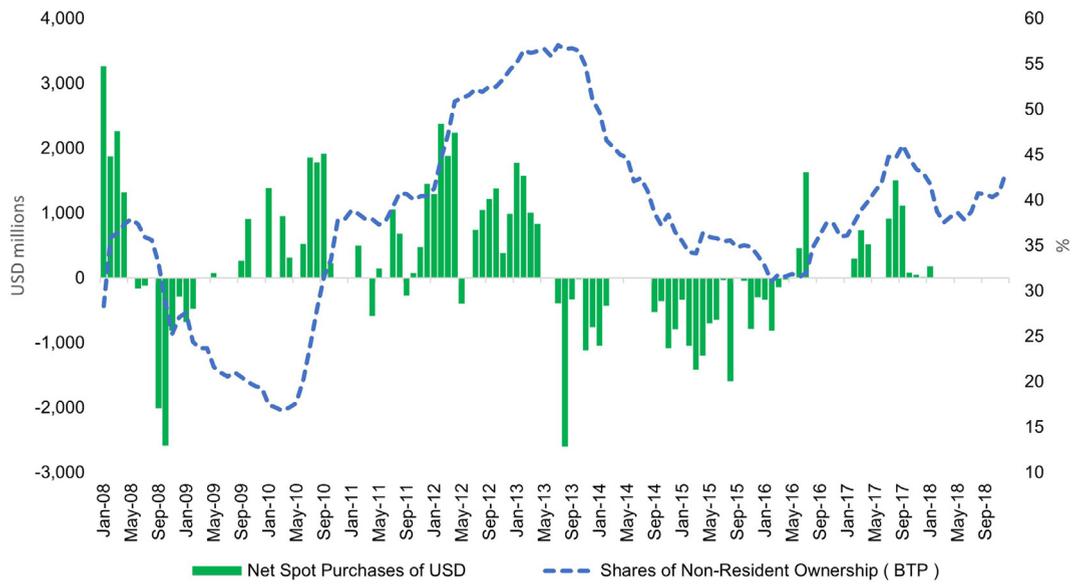
Fig. 2. Foreign Ownership of Peruvian Government Bonds and Spot Foreign Exchange Intervention (2008–2018). Source: Central Reserve Bank of Peru (BCRP). Note: Figure plots the monthly average of the nominal exchange rate (PEN/USD) and the monthly average of net spot purchases of U.S. dollars by the central bank in USD millions.

Fig. 3. Responses of Peruvian variables after a positive shock to the CBOE Volatility Index (left hand) and to the Terms of Trade (right hand); median value (solid line) and 68% bands (shaded areas).

A.1. Calibration

Table 1.

Table 1
Baseline calibration.

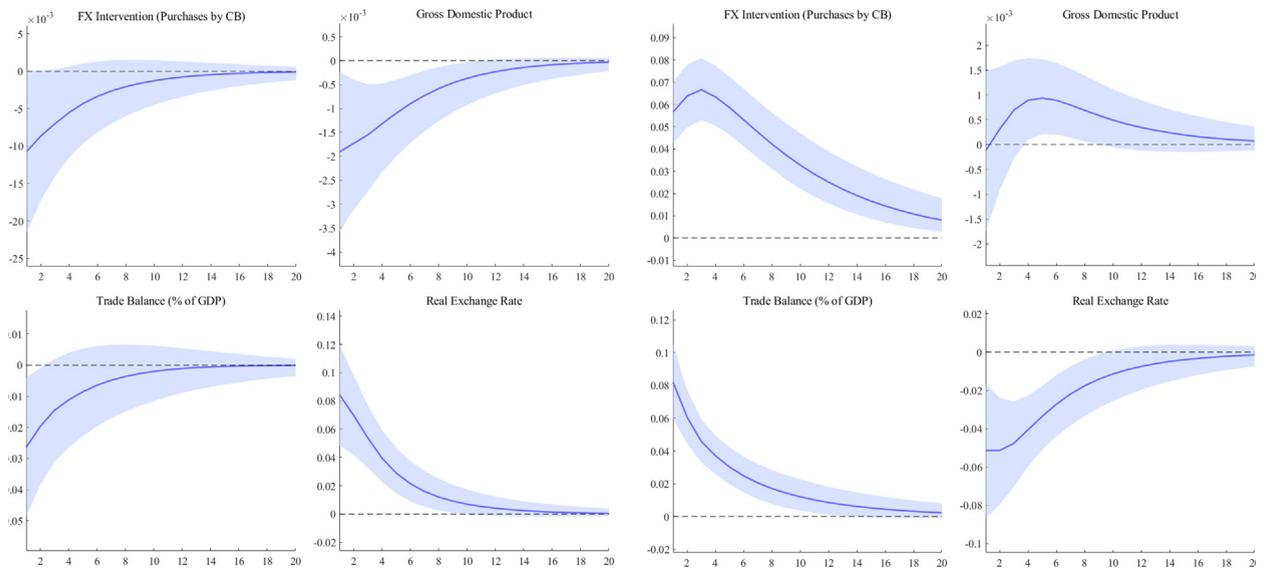| Parameter	Value	Description
β	0.995	Consumers/time − preferenceparameter
χ	1.5	Laboursupplyelasticityparameter
γ_c	1.5	IntertemporalElast.ofsubst.parameter
$\varepsilon_H, \varepsilon_F$	3	Elast.ofsubst.btw.homeandforeigngoods
γ, γ^*	0.85	Shareofdomesticgoodsinconsumption
θ_H	[0, 0.75]	Domesticgoodspricerigidity
m	1	SizeofFXdealermarket
n	1	SizeofNoisetraders
ω	500	Absoluteriskaversionparameter(dealers)
σ_A	0.03	S.D.ofTFPshock
σ_ψ	0.01	S.D.ofPortfolioflowshock

Note: In the Cole-Obstfeld case we set $\gamma_c = 1$ and $\varepsilon_H = \varepsilon_F = 1$.

A.2. Optimal simple rules with flexible prices

Tables 2,3.

Table 2
Cyclical properties and welfare losses under flexible prices Cole-Obstfeld case: $\gamma_c = 1$, $\varepsilon_H = \varepsilon_F = 1$, $\theta_H = 0$.

	No FXI	OSR PF	OSR RER	OSR LAW	OSR PROD
A. All shocks					
Output (S.D.)	3.06	3.00	2.83	2.88	3.06
Consumption (S.D.)	3.37	2.55	3.20	3.03	3.37
Labour (S.D.)	0.58	0.00	0.19	0.15	0.58
Backus-Smith wedge (S.D.)	9.74	0.00	3.11	2.53	9.74
Real exchange rate (S.D.)	7.95	2.55	1.07	1.49	7.95
Welfare loss (Unconditional)	22.47	3.82	5.73	5.09	22.47
Welfare loss (Conditional)	22.31	3.81	5.70	5.06	22.31
FXI rule coefficient	0.00	1.00	1.12	−0.82	0.00
B. Productivity shocks only					
	NoFXI	*OSRPF*	*OSRRER*	*OSRLAW*	*OSRPROD*
Output (S.D.)	3.00	3.00	3.00	3.00	3.00
Consumption (S.D.)	2.55	2.55	2.55	2.55	2.55
Labour (S.D.)	0.00	0.00	0.00	0.00	0.00
Backus-Smith wedge (S.D.)	0.00	0.00	0.00	0.00	0.00
Real exchange rate (S.D.)	2.55	2.55	2.55	2.55	2.55
Welfare loss (Unconditional)	3.82	3.82	3.82	3.82	3.82
Welfare loss (Conditional)	3.81	3.81	3.81	3.81	3.81
FXI rule coefficient	0.00	-	0.00	0.00	0.00
C. Portfolio flow shocks only					
	NoFXI	*OSRPF*	*OSRRER*	*OSRLAW*	*OSRPROD*
Output (S.D.)	0.58	0.00	0.00	0.00	0.58
Consumption (S.D.)	2.21	0.00	0.00	0.00	2.21
Labour (S.D.)	0.58	0.00	0.00	0.00	0.58
Backus-Smith wedge (S.D.)	9.74	0.00	0.00	0.00	9.74
Real exchange rate (S.D.)	7.53	0.00	0.00	0.00	7.53
Welfare loss (Unconditional)	18.65	0.00	0.00	0.00	18.65
Welfare loss (Conditional)	18.51	0.00	0.00	0.00	18.51
FXI rule coefficient	0.00	1.00	0.00	-14.3×10^5	-

Note: S.D. denotes standard deviation in percentage. Welfare loss is expressed in one per thousand of steady state consumption. Foreign exchange intervention rule coefficient represents the optimal value for the coefficient of the family of rules presented in each column obtained through the optimal simple rules command in Dynare.

Table 3
Cyclical properties and welfare losses under flexible prices General case: $\gamma_c = 1.5$, $\varepsilon_H = \varepsilon_F = 3$, $\theta_H = 0$.

	A. All shocks				
	No FXI	OSR PF	OSR RER	OSR LAW	OSR PROD
Output (S.D.)	2.63	2.52	2.40	2.43	2.94
Consumption (S.D.)	2.60	2.43	2.61	2.56	2.28
Labour (S.D.)	0.89	0.48	0.66	0.62	0.83
Backus-Smith wedge (S.D.)	3.19	1.97	2.54	2.39	2.87
Real exchange rate (S.D.)	1.64	0.46	0.57	0.52	2.03
Welfare loss (Unconditional)	9.32	6.09	7.47	7.08	8.23
Welfare loss (Conditional)	9.26	6.06	7.43	7.04	8.18
FXI rule coefficient	0.00	1.00	1.25	-1.18	0.19
	B. Productivity shocks only				
	NoFXI	OSRPF	OSRRER	OSRLAW	OSRPROD
Output (S.D.)	2.52	2.52	2.52	2.63	2.84
Consumption (S.D.)	2.43	2.43	2.43	2.31	2.08
Labour (S.D.)	0.48	0.48	0.48	0.42	0.36
Backus-Smith wedge (S.D.)	1.97	1.97	1.97	1.72	1.40
Real exchange rate (S.D.)	0.46	0.46	0.46	0.79	1.29
Welfare loss (Unconditional)	6.09	6.09	6.09	5.59	5.00
Welfare loss (Conditional)	6.06	6.06	6.06	5.56	4.97
FXI rule coefficient	0.00	–	0.00	0.20	0.19
	C. Portfolio flow shocks only				
	NoFXI	OSRPF	OSRRER	OSRLAW	OSRPROD
Output (S.D.)	0.75	0.00	0.00	0.00	0.75
Consumption (S.D.)	0.93	0.00	0.00	0.00	0.93
Labour (S.D.)	0.75	0.00	0.00	0.00	0.75
Backus-Smith wedge (S.D.)	2.51	0.00	0.01	0.00	2.51
Real exchange rate (S.D.)	1.57	0.00	0.01	0.00	1.57
Welfare loss (Unconditional)	3.23	0.00	0.03	0.00	3.23
Welfare loss (Conditional)	3.21	0.00	0.00	0.00	3.21
FXI rule coefficient	0.00	1.00	176.98	-14.3×10^5	–

Note: S.D. denotes standard deviation in percentage. Welfare loss is expressed in one per thousand of steady state consumption. Foreign exchange intervention rule coefficient represents the optimal value for the coefficient of the family of rules presented in each column obtained through the optimal simple rules command in Dynare.

A.3. Optimal simple rules under price rigidities

Table 4.

Table 4
Cyclical properties and welfare losses under sticky prices (FXI rules, PPI Taylor rule).

	PPI No FXI	PPI PF	PPI RER	PPI LAW	PPI PROD
Cole-Obstfeld case: $\gamma_c = 1$, $\varepsilon_H = \varepsilon_F = 1$, $\theta_H = 0.75$					
Output (S.D.)	3.06	3.00	2.83	2.82	3.06
Consumption (S.D.)	3.38	2.55	3.20	2.97	3.38
Labour (S.D.)	0.59	0.00	0.19	0.20	0.59
Backus-Smith wedge (S.D.)	9.78	0.01	3.11	2.49	9.78
Nom. ex. rate (S.D.)	13.57	3.61	1.22	1.65	13.57
CPI inflation rate (S.D.)	2.03	0.54	0.18	0.24	2.03
PPI inflation rate (S.D.)	0.00	0.00	0.00	0.01	0.00
Welfare loss (Unconditional)	22.62	3.82	5.73	5.07	22.62
Welfare loss (Conditional)	22.46	3.81	5.70	5.05	22.46
FXI rule coefficient	0.00	1.00	1.12	−0.83	0.00
General case: $\gamma_c = 1.5$, $\varepsilon_H = \varepsilon_F = 3$, $\theta_H = 0.75$					
	PPI No FXI	PPI PF	PPI RER	PPI LAW	PPI PROD
Output (S.D.)	2.63	2.51	2.37	2.40	2.94
Consumption (S.D.)	2.60	2.42	2.58	2.53	2.28
Labour (S.D.)	0.89	0.49	0.69	0.65	0.83
Backus-Smith wedge (S.D.)	3.19	1.96	2.52	2.36	2.87
Nom. ex. rate (S.D.)	2.80	0.66	0.82	0.75	3.49
CPI inflation rate (S.D.)	0.42	0.10	0.12	0.11	0.52
PPI inflation rate (S.D.)	0.00	0.00	0.01	0.01	0.00
Welfare loss (Unconditional)	9.32	6.09	7.47	7.08	8.24
Welfare loss (Conditional)	9.27	6.06	7.43	7.04	8.19
FXI rule coefficient	0.00	1.00	1.30	−1.20	0.19

Note: S.D. denotes standard deviation in percentage. Welfare loss is expressed in one per thousand of steady state consumption. Foreign exchange intervention rule coefficient represents the optimal value for the coefficient of the family of rules presented in each column obtained through the optimal simple rules command in Dynare.

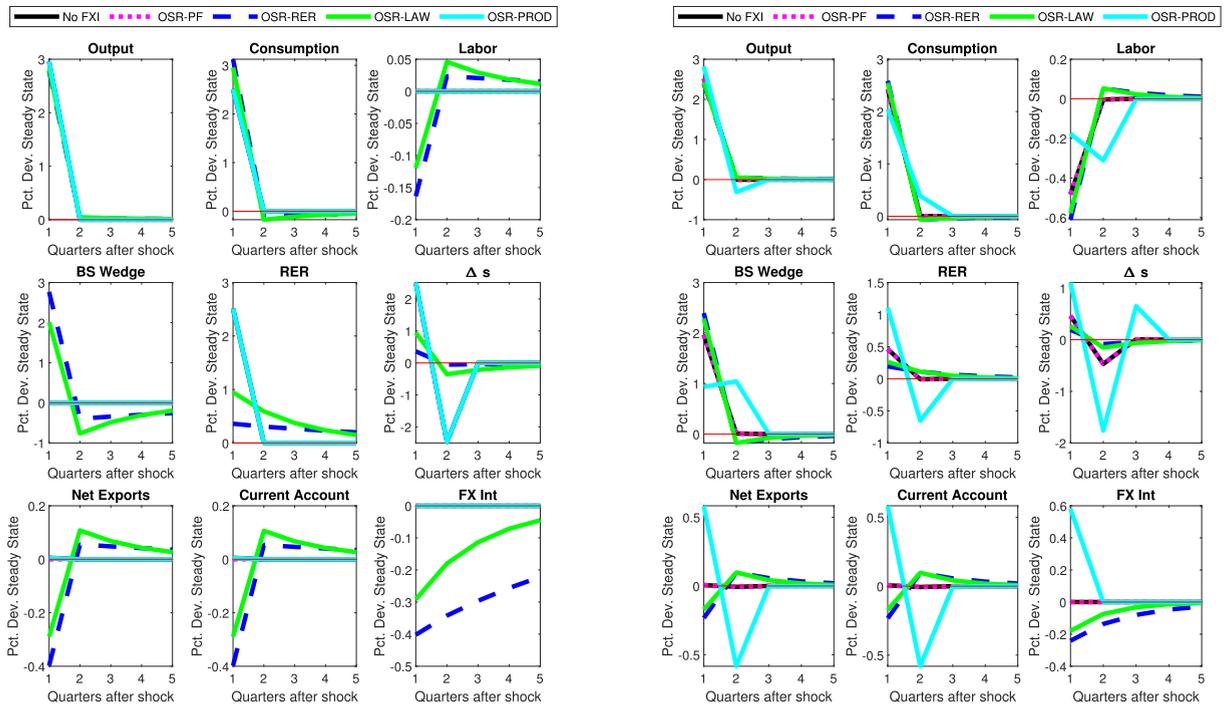## A.4. Impulse response functions - flexible prices

Figs. 4,5.

Fig. 4. Response to a 1% standard deviation shock to TFP (Cole-Obstfeld case (left panel) and general case (right panel). Notes: Impulse response to a positive productivity shock under different FXI policies. (1) No FXI: Benchmark under no FXI; (2) OSR-PF: Optimal simple rule reacting to portfolio flow shocks; (3) OSR-LAW: optimal simple rule reacting to deviations of real exchange rate from its steady-state; (4) OSR-LAW: optimal simple rule reacting to expected exchange rate variations; (5) OSR-PROD: optimal simple rule reacting to deviations of TFP from its steady-state..
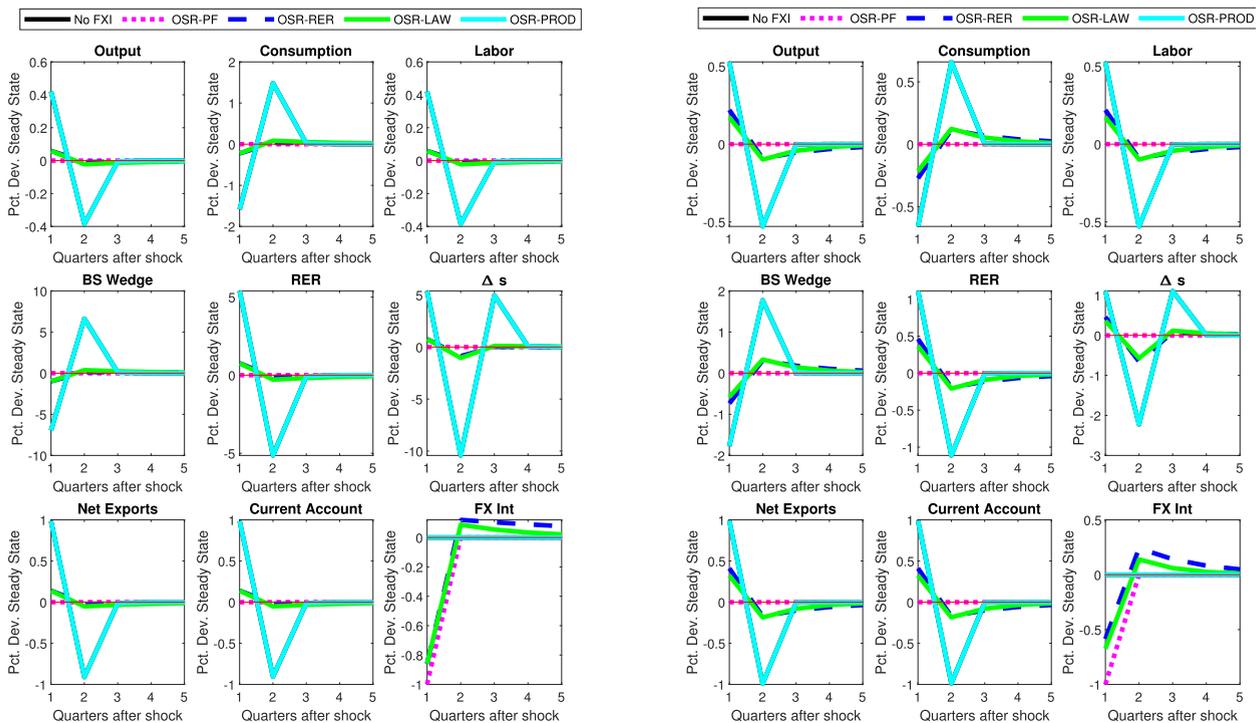
Fig. 5. Response to a 1% standard deviation shock to portfolio flow (Cole-Obstfeld case (left panel) and general case (right panel). Notes: Impulse response to a positive productivity shock under different FXI policies. (1) No FXI: Benchmark under no FXI; (2) OSR-PF: Optimal simple rule reacting to portfolio flow shocks; (3) OSR-LAW: optimal simple rule reacting to deviations of real exchange rate from its steady-state; (4) OSR-LAW: optimal simple rule reacting to expected exchange rate variations; (5) OSR-PROD: optimal simple rule reacting to deviations of TFP from its steady-state..

A.5. Robustness Exercises - Flexible Prices
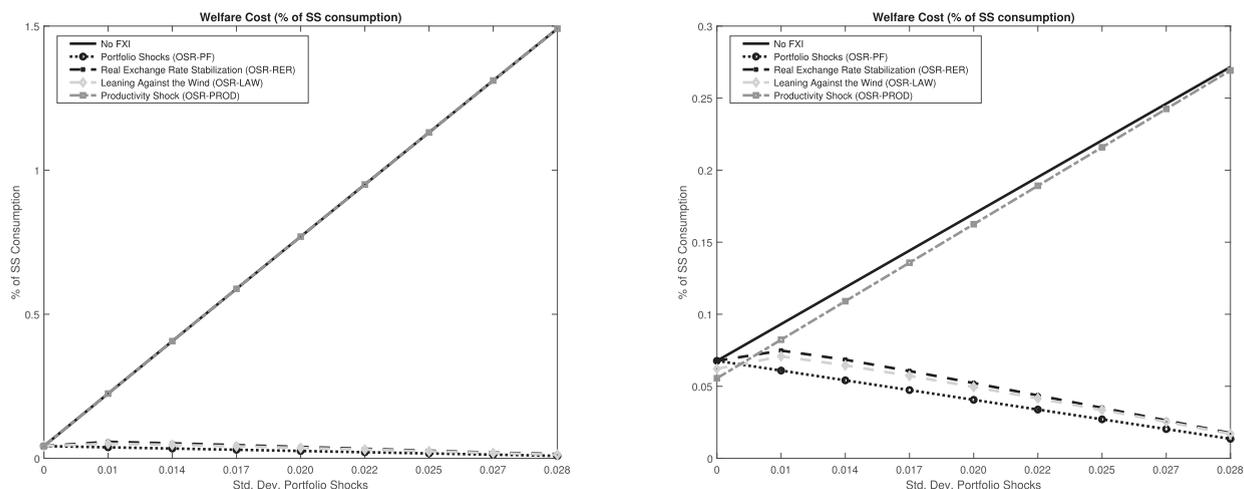
Fig. 6.

Fig. 6. Robustness to Shocks Relative Frequency Cole-Obstfeld case (left panel) and general case (right panel). Note: Figures show welfare measures as a percentage of steady-state consumption agents are willing to give up to achieve the non-stochastic steady-state welfare level. At each point of the calibration an optimal simple rule exercise is performed to obtain the optimal reaction conditional on the proposed rule.

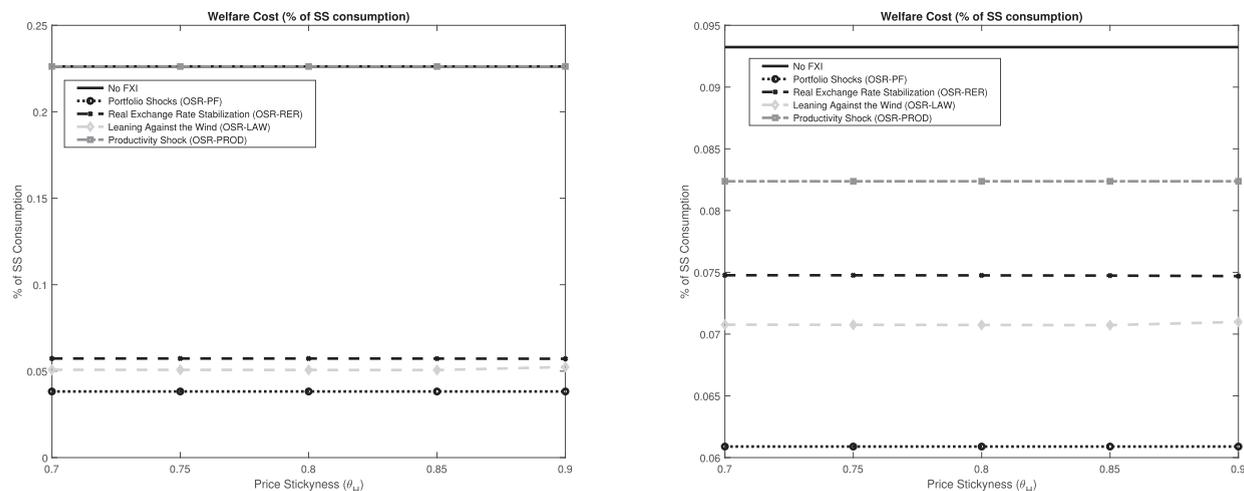*A.6. Robustness Exercises - Sticky Prices*

Fig. 7.

Fig. 7. Robustness to Calvo Pricing Parameter Cole-Obstfeld case (left panel) and general case (right panel). Note: Figures show welfare measures as a percentage of steady-state consumption agents are willing to give up to achieve the non-stochastic steady-state welfare level. At each point of the calibration an optimal simple rule exercise is performed to obtain the optimal reaction conditional on the proposed rule.

Appendix B. Supplementary material

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.jimonfin.2023.102825.

References

Aizenman, J., Jinjarak, Y., Park, D., Zheng, H., 2021. Good-bye original sin, hello risk on-off, financial fragility, and crises? J. Int. Money Finance, 117(C).
Amador, M., Bianchi, J., Bocola, L., Perri, F., 2020. Exchange rate policies at the zero lower bound. Rev. Econ. Stud. 87 (4), 1605–1645.
Armas, A. and M. Ortiz (2020, December). Exchange Rate Determination: The Role of Portfolio and Liquidity Shocks. SBS Working Paper 004–2020, Superintendencia de Banca y Seguros.
Bacchetta, P., Wincoop, E.V., 2006, June. Can information heterogeneity explain the exchange rate determination puzzle? Am. Econ. Rev., 96(3), 552–576.
Backus, D.K., Kehoe, P.J., Kydland, F.E., 1992, August. International real business cycles. J. Polit. Econ., 100(4), 745–775.
Backus, D.K., Smith, G.W., 1993. Consumption and real exchange rates in dynamic economies with non-traded goods. J. Int. Econ. 35 (3), 297–316.
Benes, J., Berg, A., Portillo, R., Vavra, D., 2015. Modeling sterilized interventions and balance sheet effects of monetary policy in a new-keynesian framework. Open Econ. Rev. 26 (1), 81–108.
Benigno, P., Woodford, M., 2012. Linear-quadratic approximation of optimal policy problems. J. Econ. Theory 147 (1), 1–42.
Born, B. and J. Pfeifer (2020, July). The New Keynesian Wage Phillips Curve: Calvo Vs. Rotemberg. Macroeconomic Dynamics 24(5), 1017–1041.
Calvo, G.A., 1983, September. Staggered prices in a utility-maximizing framework. J. Monet. Econ., 12(3), 383–398.
Cavallino, P., 2019, April. Capital flows and foreign exchange intervention. Am. Econ. J.: Macroecon., 11(2), 127–170.
Chang, R., 2019, November. Foreign Exchange Intervention Redux. In: Álvaro Aguirre, M. Brunnermeier, and D. Saravia (Eds.), Monetary Policy and Financial Stability: Transmission Mechanisms and Policy Implications, Volume 26, Chapter 7, pp. 205–247. Central Bank of Chile.
Chari, V.V., Kehoe, P.J., McGrattan, E.R., 2002, July. Can sticky price models generate volatile and persistent real exchange rates? Rev. Econ. Stud., 69(3), 533–63.
Christiano, L.J., Eichenbaum, M., Evans, C.L., 2005, February. Nominal rigidities and the dynamic effects of a shock to monetary policy. J. Polit. Econ., 113(1), 1–45.
Clark, P.B., MacDonald, R., 1999. Exchange rates and economic fundamentals: A methodological comparison of beers and feers. In: MacDonald, R., Stein, J.L. (Eds.), Equilibrium Exchange Rates. Springer, Netherlands, Dordrecht, pp. 285–322.
Cole, H., 1988, May. Financial structure and international trade. Int. Econ. Rev., 29(2), 237–259.
Cole, H.L., Obstfeld, M., 1991, August. Commodity trade and international risk sharing: How much do financial markets matter? J. Monet. Econ., 28(1), 3–24.
De Paoli, B., 2009, February. Monetary policy and welfare in a small open economy. J. Int. Econ., 77(1), 11–22.
Dieppe, A., van Roye, B., Legrand, R., 2016, July. The BEAR toolbox. Working Paper Series 1934, European Central Bank.
Dominguez, K., Frankel, J., 1990. Does Foreign Exchange Intervention Work? Peterson Institute for International Economics.
ECB, 2022. The transmission protection instrument. https://www.ecb.europa.eu/press/pr/date/2022/html/ecb.pr220721 973e6e7273.en.html. Accessed: 2023-01-20.
Faltermeier, J., Lama, R., Medina, J.P., 2022. Foreign exchange intervention for commodity booms and busts. Eur. Econ. Rev. 143(C).
Fanelli, S., Straub, L., 2021. A theory of foreign exchange interventions. Rev. Econ. Stud. 88, 2857–2885.
Filardo, A., McGregor, T., Gelos, M.R.G., 2022, July. Exchange-Rate Swings and Foreign Currency Intervention. IMF Working Papers 2022/158, International Monetary Fund.

Gabaix, X., Maggiori, M., 2015. International liquidity and exchange rate dynamics. Q. J. Econ. 130 (3), 1369–1420.

Galí, J., Monacelli, T., 2005, July. Monetary policy and exchange rate volatility in a small open economy. Rev. Econ. Stud., 72(3), 707–734.

Ghosh, A., Ostry, J., Chamon, M., 2016. Two targets, two instruments: Monetary and exchange rate policies in emerging market economies. J. Int. Money Finance, 60(C), 172–196.

Giannoni, M., Woodford, M., 2003. Optimal interest-rate rules: I. general theory. NBER Working Papers 9419, National Bureau of Economic Research Inc.

Giannoni, M., Woodford, M., 2004. Optimal inflation-targeting rules. National Bureau of Economic Research Inc, In The Inflation-Targeting Debate.

Gopinath, G., Boz, E., Casas, C., Díez, F.J., Gourinchas, P.-O., Plagborg-Møller, M., 2020, March. Dominant currency paradigm. Am. Econ. Rev., 110(3), 677–719.

Itskhoki, O., Mukhin, D., 2021. Exchange rate disconnect in general equilibrium. J. Polit. Econ. 129 (8), 2183–2232.

Jermann, U.J., 2002, March. International portfolio diversification and endogenous labor supply choice. Eur. Econ. Rev., 46(3), 507–522.

Liu, Z., Spiegel, M.M., 2015, September. Optimal monetary policy and capital account restrictions in a small open economy. IMF Econ. Rev., 63(2), 298–324.

Lyons, R.K. (2006). The Microstructure Approach to Exchange Rates. Number 026262205x in MIT Press Books. The MIT Press.

Maggiori, M., Neiman, B., Schreger, J., 2020. International currencies and capital allocation. J. Polit. Econ. 128 (6), 2019–2066.

Meese, R., Rogoff, K., 1983, September. The out-of-sample failure of empirical exchange rate models: Sampling error or misspecification? In Exchange Rates and International Macroeconomics, NBER Chapters, pp. 67–112. National Bureau of Economic Research Inc.

Mendoza, E.G., 1991, September. Real business cycles in a small open economy. Am. Econ. Rev., 81(4), 797–818.

Menkhoff, L. (2012, April). Foreign exchange intervention in emerging markets: A survey of empirical studies. Diskussionspapiere der Wirtschaftswissenschaftlichen Fakultät der Leibniz Universität Hannover dp-498, Leibniz Universität Hannover, Wirtschaftswissenschaftliche Fakultät.

Montoro, C. and M. Ortiz (2016, September). Foreign exchange intervention and monetary policy design: a market microstructure analysis. Working Papers 2016–008, Banco Central de Reserva del Perú.

Patel, N. and P. Cavallino (2019). FX intervention: goals, strategies and tactics. In B. for International Settlements (Ed.), Reserve management and FX intervention, Volume 104 of BIS Papers chapters, pp. 25–44. Bank for International Settlements.

Schmitt-Grohe, S., Uribe, M., 2003, October. Closing small open economy models. J. Int. Econ., 61(1), 163–185.

Stoll, H., 1978. The supply of dealer services in securities markets. Journal of Finance 33 (4), 1133–1151.

Svensson, L., Woodford, M., 2004. Implementing optimal policy through inflation-forecast targeting. In The Inflation-Targeting Debate. National Bureau of Economic Research Inc.

Vitale, P., 2006, May. A market microstructure analysis of foreign exchange intervention. Working Paper Series 629, European Central Bank.