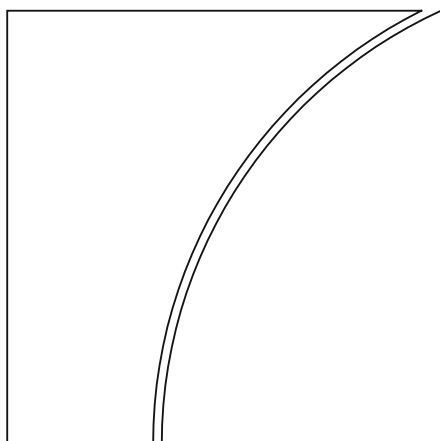




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FX intervention and domestic credit: evidence from high-frequency micro data*

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Abstract

We employ a unique central bank dataset of foreign exchange operations to study the impact of FX intervention on domestic credit. Using loan-level data in the credit registry, we find that sterilized purchases of dollars by the central bank dampen the flow of new domestic corporate loans. The impact is particularly strong for borrowers with larger currency mismatches and for banks with thinner capital buffers. Our analysis sheds light on the role of FX intervention as part of the macroprudential toolkit during credit booms associated with episodes of capital inflow surges.

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1 Introduction

Episodes of domestic credit booms have often been accompanied by a strong appreciation of the currency. Gourinchas and Obstfeld (2012) find in a wide-ranging study that two factors emerge consistently as the most robust and significant predictors of financial crises - namely, a rapid increase in leverage and a sharp real appreciation of the currency. Their finding holds both for emerging and advanced economies, but is especially apparent for emerging economies.

Our focus in this paper is to illuminate the economic mechanism linking currency appreciation and domestic credit through the lens of central bank market operations in the foreign exchange market. To the extent that FX interventions can dampen credit supply, such market operations can take on the attributes of a prudential tool that leans against credit booms. Indeed, Diamond, Hu and Rajan (2020) argue that FX intervention has precisely such prudential benefits on financial stability by leaning against domestic credit booms.

In focusing attention on the link between the exchange rate and domestic credit, we depart from traditional open economy macro models, which have tended to downplay the monetary policy implications of the exchange rate. The maxim is that central banks should pay attention to exchange rates only to the extent that they bear on inflation and output developments. However, in practice the doctrine of “benign neglect” of the exchange rate has been honored more in its breach than in its observance (see Frankel (2019)). More recent policy discussions have emphasized the macro-financial stability features of sterilized FX intervention as a tool that can help address the challenges from capital flows and financial stability risks (see e.g. BIS (2019), IMF (2020)).

An important element of our analysis is the role of financial intermediaries in a setting where risk constraints interact with market outcomes. Our analysis builds on the insights of Gabaix and Maggiori (2015) who proposed a conceptual approach to exchange rate determination based on risk-constrained intermediaries. Our analysis also has close contact points with recent contributions emphasizing the role of global financial conditions and the exchange rate for domestic credit developments. Rey (2013) argued that flexible exchange rates do not insulate countries from global financial spillovers and therefore do not ensure domestic monetary autonomy. This notion was subsequently supported by empirical evidence of a global financial cycle (Miranda-Agrippino and Rey (2020,2021))

and analytical work providing conceptual foundations of global spillovers (Gourinchas, Ray and Vayanos (2021)).

Meanwhile, sterilizing the FX purchase operation by selling bonds into the domestic bond market also has implications for financial intermediaries' lending capacity if they are balance sheet constrained. A full analysis of the impact of an FX purchase needs to take account of the bond market dimension of the intervention. In Céspedes, Chang and Velasco (2017), the sterilization leg of FX intervention has effects similar to reverse quantitative easing.

The core of our analysis is empirical, employing a confidential high frequency database of FX operations by the central bank of Colombia - the Bank of the Republic - and combining it with loan level data from the Colombian credit registry covering the entire Colombian banking system. The high frequency nature of the data coupled with the panel structure of the entire credit registry enables a rigorous study of the effects of FX intervention on domestic credit. We conduct panel analysis at the loan level with more than 6 million observations to assess how FX intervention affects new loans to firms.

We hone intuition through a model of credit supply from the banking sector facing corporate borrowers with varying degrees of currency mismatch. One key feature of the model is that currency fluctuations affect the tail risk of the credit loss density, feeding into credit supply through a Value-at-Risk (VaR) constraint. Sterilized FX intervention then has two mutually reinforcing effects on domestic credit. The first is to dampen credit supply by leaning against the excessive increase in bank leverage on the back of exchange rate appreciation. The second effect (through sterilization) is to increase the supply of domestic bonds to be absorbed by banks, thereby crowding out lending.

Our model has two empirical predictions. The first is that firms with higher currency mismatch experience greater shifts in credit supply from banks. The second prediction is that banks that are more leveraged react more sensitively to central bank interventions in their credit supply.

In the empirical analysis, all the key predictions of the model are shown to hold. First, we find that sterilized FX purchases significantly dampen domestic bank lending to corporates. This suggests that sterilized FX purchases have a systematic tightening effect on domestic credit conditions.

Second, we find that sterilized FX purchases have a stronger dampening effect on credit to firms that have higher foreign currency debt. This finding is consistent with

the notion that the effects of intervention work through a balance sheet channel that is linked to the currency composition of borrower debt.

Third, we find that the negative effects of sterilized FX purchases on credit supply are stronger for banks who are more leveraged. This finding suggests that FX intervention mainly dampens credit supply of vulnerable banks during capital flow surges and more strongly supports these banks when the flows reverse.

The remainder of the paper is organized as follows. This section ends with a brief overview of the related literature. Section 2 develops the theoretical banking model and derives its main predictions for the impact of sterilized FX intervention on domestic lending. Section 3 describes the data and the Colombian institutional background. Section 4 presents evidence on the dynamic impact of FX intervention on domestic credit in Colombia. Section 5 presents the results from the loan-level panel analysis testing the channels through which FX intervention affects domestic credit. Finally, section 6 concludes.

Related literature

The analysis of our paper contributes to various strands of the literature. Firstly, we contribute to the literature on the effectiveness of FX intervention. Recent conceptual contributions have shown that international liquidity conditions affect exchange rates in the presence of realistic financial frictions, making the case for the effectiveness of official FX intervention in influencing the exchange rate (Gabaix and Maggiori (2015), Cavallino (2019), Cavallino and Sandri (2019), Fanelli and Straub (2021)).¹ Our analysis builds on the insights of these studies. In our model, FX intervention moderates the appreciation of the domestic currency and thereby leans against the relaxation of the Value-at-Risk constraint and hence the expansion of the lending capacity of the banking sector. This is, in line with recent conceptual contributions that have shed light on the role of the exchange rate in credit developments resulting from currency mismatches (Bruno and Shin (2015), Diamond et al. (2020)).²

¹For a survey of the theoretical literature on the effectiveness of sterilized FX intervention, see Villamizar-Villegas and Perez-Reyna (2017). There is also accumulating supportive evidence from cross-country studies for the effectiveness of official FX intervention in EME currency markets (Fratzscher et al (2019), Ghosh et al (2018)).

²The occurrence of such mismatches has been related to an inherent inability of countries, in particular emerging market economies, to borrow abroad in their domestic currency, a situation that has been referred to as “original sin” (Eichengreen and Hausmann (1999), Eichengreen et al. (2002)). More recently, it has been related to a carry-trade associated with the differential between domestic interest rates and the interest rate levels prevailing in major foreign funding currency markets, in particular the United States (Bruno and Shin (2017), Huang et al. (2018)). In the presence of such mismatches, a

In this vein, our analysis is also related to the literature on the financial channel of the exchange rate. This literature has established a positive link between exchange rate appreciation and domestic financial conditions along several dimensions, including cross-border banking flows (Bruno and Shin (2015)), local currency bond spreads (Hofmann et al. (2020)) and firm leverage (Kalemli-Ozcan et al. (2021)). The evidence of the financial channel of the exchange rate suggests that FX intervention, by influencing the exchange rate, affects domestic financial conditions through this channel.

The literature directly assessing the impact of FX intervention on domestic financial conditions is rather limited. Gonzalez et al. (2019) analyze the Central Bank of Brazil's intervention in FX derivatives markets during the 2013 taper tantrum using data from the Brazilian credit registry. They find that the intervention mitigated the impact of currency depreciation on domestic credit supply. Ghosh et al. (2018) suggest, based on a stylized model and aggregate panel evidence, that sterilized FX intervention can absorb capital inflows by parking them in FX reserves. This notion is consistent with conceptual models where the balance sheet capacity of banks is limited due to capital or leverage constraints, so that an increase in the supply of bonds to banks through the sterilization leg of an FX intervention reduces their capacity to extend loans (Céspedes et al. (2017), Chang (2018), Cavallino and Sandri (2019)).

Finally, our analysis contributes to the literature on the co-movement of financial conditions across markets and the associated policy challenges. Rey (2013) argued that economies may not face a trilemma (incompatibility of fixed exchange rate, open capital account and independent monetary policy), but instead may face a dilemma between free capital flows and independent monetary policy. In this vein, Miranda-Agrippino and Rey (2020, 2021) provide evidence that a global financial factor plays an important role in shaping financial conditions around the world and that countries with flexible exchange rates are similarly affected by financial spillovers as those with fixed exchange rates. Gourinchas et al. (2021) show conceptually how preferred-habitat investors in asset and currency markets generate significant financial spillovers across countries. Such global financial spillovers bear on the design of macro-financial stability frameworks in emerging market economies, which are commonly characterized by the combination of

weaker exchange rate deteriorates the balance sheet of dollar borrowers as liabilities rise relative to assets (Krugman (1999), Frankel (2005)). Similarly, if corporates borrow from foreign lenders in domestic currency, financial effects of exchange rate fluctuations may arise through the balance sheets of the foreign lenders (Carstens and Shin (2019)).

inflation targeting, macroprudential frameworks and FX intervention (e.g. Agénor and Pereira da Silva (2019), Adrian et al. (2020), Basu et al. (2020)). Our contribution to this literature is to highlight the link between FX intervention and credit conditions, so that FX intervention takes on attributes of a financial stability tool that complements monetary and macroprudential policy.

2 Model

2.1 Loan demand

The first component of our model introduces loan demand. There is a continuum of risk-neutral borrowers (“entrepreneurs”) with access to a project that needs one unit of fixed capital and one unit of labour input. Entrepreneurs borrow 1 unit of the domestic currency (“peso”) from banks to finance the initial fixed investment. Loans are granted at date 0, and the project realization and repayment is due at date 1. The loan interest rate is r , so that borrowers need to repay $1+r$. The disutility of the entrepreneur’s labour input is distributed in the population according to cumulative distribution function $H(\cdot)$ with support on $[0, \infty]$.

We assume that borrowers have a legacy debt of 1 dollar, and experience valuation effects of exchange rate movements. Denote by θ the dollar value of the peso at date 0, so that a higher θ indicates a stronger peso. If the borrower takes on the project, the notional value of debt in pesos is thus $1 + 1/\theta$.

The realization of the borrower’s project follows the Merton (1974) model of credit risk, and is assumed to be the random variable V_1 , defined as:

$$V_1 = \exp \left\{ 1 - \frac{s^2}{2} + sW_j \right\} \quad (1)$$

where W_j is a standard normal and s is a constant. Borrowers are risk-neutral and have limited liability. Hence, borrower j with effort cost e_j undertakes the project if:

$$E(\max\{0, V_1 - (1+r)\}) - e_j \geq 0 \quad (2)$$

Denote by $e^*(r)$ the threshold cost level where (2) holds with equality when the loan rate is r . Loan demand is the mass of entrepreneurs with effort cost below $e^*(r)$. Denoting by $C_d(r)$ the loan demand at loan interest rate r , we have:

$$C_d(r) = H(e^*(r)) \quad (3)$$

Since $H(\cdot)$ has full support on $[0, \infty]$, $C_d(r) > 0$ for all $r > 0$ and is strictly decreasing in r .

2.2 Banks

The second component of our model is a theory of bank credit supply based on banks that operate under Value-at-Risk constraints, following Bruno and Shin (2015). There is a continuum of competitive banks. Each bank has two units - a loan unit which lends in pesos to corporate borrowers, and a bond unit which holds risk-free peso sovereign bonds. The bank allocates equity capital to the two units so as to maximize total bank profit subject to constraints on the portfolio choice of the two units, as described below.

For the loan book, the bank lends to many borrowers and can diversify away idiosyncratic risk. Credit risk follows the Vasicek (2002) model, a many borrower generalization of Merton (1974). The standard normal W_j in (1) is given by the linear combination:

$$W_j = \sqrt{\rho}Y + \sqrt{1 - \rho}X_j \quad (4)$$

where Y and X_j are mutually independent standard normals. Y is the common risk factor while each X_j is the idiosyncratic risk facing borrower j . The parameter $\rho \in (0, 1)$ determines the weight given to the common factor Y .

The borrower defaults when $V_1 < 1 + r + 1/\theta$, which can be written as:

$$\sqrt{\rho}Y + \sqrt{1 - \rho}X_j < -d_j \quad (5)$$

where d_j is *distance to default*:

$$d_j = \frac{-\ln(1 + r + 1/\theta) + 1 - \frac{s^2}{2}}{s} \quad (6)$$

Denote by $F_\theta(z)$ the cumulative distribution function (c.d.f.) of the realized value of one peso face value of loans when the exchange rate is given by θ . We have the following key feature of our model.

Lemma 1 $F_\theta(z) < F_{\theta'}(z)$ if and only if $\theta > \theta'$.

In other words, the c.d.f. of the bank's loan portfolio is lower when the peso is stronger. In this sense, the tail risk of the bank's loan portfolio from default declines as the peso appreciates in the sense of first-degree stochastic dominance. The intuition behind

Lemma 1 is that the bank can diversify away idiosyncratic default risk for individual borrowers, but cannot fully diversify away the tail risk due to the common component Y in the project outcomes. However, peso appreciation reduces individual borrower default, and has the effect of reducing tail risk. For a bank that is subject to a Value-at-Risk constraint, the smaller tail risk translates to higher lending.

The argument for Lemma 1 can be given as follows, and reveals additional features of the model that yield important empirical predictions.

Borrower j repays the loan when $Z_j \geq 0$, where Z_j is the random variable:

$$\begin{aligned} Z_j &= d_j + \sqrt{\rho}Y + \sqrt{1-\rho}X_j \\ &= -\Phi^{-1}(\varepsilon) + \sqrt{\rho}Y + \sqrt{1-\rho}X_j \end{aligned} \quad (7)$$

where ε is the probability of default of borrower j , defined as $\varepsilon = \Phi(-d_j)$ and Φ is the standard normal c.d.f.

Conditional on Y , defaults are independent. In the limit where the number of borrowers becomes large, the realized value of one peso face value of loans can be written as a deterministic function of Y , by the law of large numbers. The realized value of one peso face value of loans is the random variable $w(Y)$ defined as:

$$\begin{aligned} w(Y) &= \Pr\left(\sqrt{\rho}Y + \sqrt{1-\rho}X_j \geq \Phi^{-1}(\varepsilon) \mid Y\right) \\ &= \Phi\left(\frac{Y\sqrt{\rho} - \Phi^{-1}(\varepsilon)}{\sqrt{1-\rho}}\right) \end{aligned} \quad (8)$$

The c.d.f. of w is then given by

$$\begin{aligned} \Pr(w \leq z) &= \Pr(Y \leq w^{-1}(z)) \\ &= \Phi(w^{-1}(z)) \\ &= \Phi\left(\frac{\Phi^{-1}(\varepsilon) + \sqrt{1-\rho}\Phi^{-1}(z)}{\sqrt{\rho}}\right) \end{aligned} \quad (9)$$

where $\Phi(\cdot)$ is the c.d.f. of the standard normal. Hence,

$$F_\theta(z) = \Phi\left(\frac{\Phi^{-1}(\varepsilon(\theta)) + \sqrt{1-\rho}\Phi^{-1}(z)}{\sqrt{\rho}}\right) \quad (10)$$

and $\varepsilon(\theta)$ is the probability of default of an individual borrower, where $\varepsilon(\theta)$ a decreasing function of θ . This proves Lemma 1.

2.3 Bank portfolio choice

We now turn to the banks' portfolio choice between loans and bonds. Each bank has two units - a loan unit and a bond unit. The total capital of the bank i (its book equity) in pesos is denoted by E_i . The bond unit is allocated capital of E_i^B , while the loan unit is allocated capital of E_i^C , where "C" stands for "credit". The capital allocation satisfies:

$$E_i^B + E_i^C = E_i \quad (11)$$

The loan unit is subject to the Value-at-Risk (VaR) rule whereby the probability that loan losses exceed the capital of the unit is no higher than constant probability $\alpha > 0$. Denote by f the funding rate of the loan unit and by L_i the total non-equity funding amount of the loan unit. We assume for simplicity that f is constant.³ The VaR constraint is that the realized value of the loan portfolio is sufficient to cover the repayment owed by the loan unit with probability at least $1 - \alpha$. Formally, the VaR constraint is given by:

$$F((1 + f)L_i) \leq \alpha \quad (12)$$

where $F(\cdot)$ is the c.d.f. of the loan portfolio value. We then have the following feature of our model.

Lemma 2 *Total lending C_i by bank i satisfies $C_i = \lambda E_i^C$ where λ is an increasing function of θ .*

In other words, the leverage of the loan unit increases when the peso appreciates, so that an appreciation of the peso translates into an increase in total lending C_i given fixed capital E_i^C . The intuition for this result follows from the link between tail risk and the exchange rate described in Lemma 1. First, risk-neutrality implies that (12) binds, and holds as an equality. When the peso appreciates, the tail risk of the loan portfolio shrinks, relaxing the VaR constraint and allowing the bank to expand lending.

The argument for Lemma 2 starts with the observation that loan losses do not exceed E_i^C as long as the realized value of $w(Y)$ exceeds the unit's notional liabilities. Then, the VaR constraint of the loan unit binds, and lending is the maximum loan amount consistent with the VaR constraint. Denoting by C_i the total lending by bank i , the binding VaR constraint implies:

³Bruno and Shin (2015) solve for the general case where f is endogenously determined by market clearing of wholesale bank funding.

$$F((1+f)L_i) = \Phi\left(\frac{\Phi^{-1}(\varepsilon(\theta)) + \sqrt{1-\rho}\Phi^{-1}\left(\frac{(1+f)L_i}{(1+r)C_i}\right)}{\sqrt{\rho}}\right) = \alpha \quad (13)$$

Re-arranging (13), we can write the ratio of notional liabilities to notional assets of bank i 's loan unit as:

$$\frac{\text{Notional liabilities}}{\text{Notional assets}} = \frac{(1+f)L_i}{(1+r)C_i} = \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha) - \Phi^{-1}(\varepsilon(\theta))}{\sqrt{1-\rho}}\right) \quad (14)$$

We will use the shorthand:

$$\varphi(\alpha, \theta, \rho) \equiv \Phi\left(\frac{\sqrt{\rho}\Phi^{-1}(\alpha) - \Phi^{-1}(\varepsilon(\theta))}{\sqrt{1-\rho}}\right) \quad (15)$$

Clearly, $\varphi \in (0, 1)$. From (14) and the balance sheet identity $E_i^C + L_i = C_i$ of the bank's loan unit, we can solve for the supply of loans by bank i , which is given by

$$C_i = \frac{E_i^C}{1 - \frac{1+r}{1+f} \cdot \varphi} \quad (16)$$

We can re-write this expression as $C_i = \lambda E_i^C$ where λ is the leverage of the loan unit, given by

$$\lambda = \frac{1}{1 - \frac{1+r}{1+f} \cdot \varphi} \quad (17)$$

Finally, we note from (15) that λ does not depend on i . This completes the proof of Lemma 2.

Lemma 2 also suggests additional empirical predictions on differences in the impact of exchange rates on the cross-section of firms and banks. The expression for credit supply given in (16) reveals that the denominator is small when the bank has higher leverage through a higher φ . This follows from the fact that φ is an increasing function of the VaR threshold α which maps one-to-one with the equity to debt ratio. The smaller denominator amplifies the overall comparative statics of credit supply, both across firms and across banks.

2.4 Impact of sterilized FX intervention

Finally, we derive the effects of sterilized FX interventions by the central bank. Denote by B_i the peso bond holding of bank i . Further, denote by q the bond interest rate and g the (constant) funding cost of the bond unit. We assume that the bond holding of the

bank is determined as a constant leverage multiple μ of the capital allocated to the bond unit of the bank. From the adding up constraint (11), the capital of the bond unit is given by $E_i^B = E_i - E_i^C$, so that the bond holding is:

$$B_i = \mu (E_i - E_i^C) \quad (18)$$

The aggregate supply of peso lending is obtained by summing C_i across all banks i . Denoting by C the aggregate peso loan supply, we have:

$$C = E^C \cdot \lambda(\theta) \quad (19)$$

where E^C is the sum of E_i^C across the banking sector, and where we have indicated that leverage λ is a function of the peso exchange rate.

Aggregate bond holding by all banks i is denoted as B , and is obtained by summing (18) across all banks:

$$B = \mu (E - E^C) \quad (20)$$

From (19) and (20), the supply of credit for loans and bond holdings satisfies constant returns to scale. Therefore, it is without loss of generality to suppose that there is a single price-taking bank with capital E that is allocated across the two activities.

Let \bar{B} denote the stock of outstanding peso bonds, and assume that the total stock is held by the banking sector, as is often the case in practice for central bank sterilization bonds. The market clearing condition is that $B = \bar{B}$.

Combining (19) and (20) yields

$$C = (E - \bar{B}/\mu) \cdot \lambda(\theta) \quad (21)$$

From the impact of sterilized FX intervention on the exchange rate θ as well as on the aggregate bond supply \bar{B} we can derive the effects of intervention on peso loan supply.

As shown by Gabaix and Maggiori (2015), in the presence of real-world financial frictions, financial flows affect the exchange rate. Specifically, capital inflows would lead to an appreciation of the domestic currency. Through the same mechanism, FX intervention by the central bank can also influence the exchange rate, as demonstrated by Cavallino (2019). An FX purchase by the central bank would depreciate the domestic exchange rate and thus dampen domestic credit by lowering $\lambda(\theta)$. At the same time, the sterilization

leg of the intervention would affect loan supply through \bar{B} . Specifically, a sterilized FX purchase would increase \bar{B} and through this effect further dampen credit supply.

We summarize this key finding as follows.

Proposition 3 *A sterilized FX purchase of dollars dampens peso loan supply.*

To prove this result, note from (21) that:

$$\frac{dC}{dR} = \frac{-\lambda(\theta)}{\mu} \cdot \frac{d\bar{B}}{dR} + (E - \bar{B}/\mu) \cdot \lambda'(\theta) \cdot \frac{d\theta}{dR} < 0 \quad (22)$$

where R denotes FX reserves so that $\frac{d\bar{B}}{dR} > 0$ and $\frac{d\theta}{dR} < 0$.

In (22), the negative effect of sterilization (the first term on the right-hand side) is stronger for higher values of $\lambda(\theta)$. This implies that the effect is stronger the more a bank is leveraged.

To recap, our model yields the following testable hypotheses: (i) an FX purchase dampens domestic credit supply; (ii) the effect of an FX purchase is larger when firm FX debt is higher; and (iii) the effect of an FX purchase is larger when a bank is more leveraged.

3 Data and institutional background

We use daily and weekly data for Colombia, available for the period 2002 to 2015. Data on foreign exchange intervention are from the central bank - the Bank of the Republic (BoR) and loan-level data for new corporate loans of the entire Colombian banking sector are from the Colombian credit registry.

3.1 FX intervention

Since 2001, Colombia has operated an inflation targeting regime with a floating exchange rate. The inflation target has been set in terms of the consumer price index (CPI) at 3% by the BoR's Board of Directors, with a permissible deviation of \pm one percentage point. While operating under a flexible exchange rate regime, the BoR has regularly intervened in FX markets. The officially-stated aim (Vargas et al. (2013)) is to maintain an adequate level of international reserves, mitigate short-term exchange rate misalignments and curb excessive exchange rate volatility.

In the analysis that follows, we use confidential daily data for the BoR's sterilized FX interventions from the BoR's Market Operations and Development Department (*Departamento de Operaciones y Desarrollo de Mercados -Mesa de Dinero*). The data are for intervention flows, which are not affected by valuation changes of FX reserves due to exchange rate changes.⁴

Over the period of investigation, the BoR employed four different intervention methods (Table 1). First, and most important for our study, there are discretionary spot market interventions, consisting of sterilized FX interventions conducted in the centralized Colombian FX market (*ICAP-SETFX*). Over the sample period, the BoR purchased a total of \$11.7 billion dollars with these interventions.

Second, there are rule-based interventions in the options market aimed at smoothing exchange rate volatility, through which the central bank purchased (sold) a total of \$2.4 (\$2.3) billion dollars.

Third, there are discretionary interventions in the options market, which were operations conducted to accumulate international reserves in order to reduce external vulnerabilities. Over the period considered, the BoR purchased (sold) a total of \$3.4 (\$0.6) billion dollars. In total, the BoR purchased \$41 billion dollars in FX reserves, and sold \$3 billion dollars. Fourth, pre-announced FX interventions: Constant and pre-announced sterilized purchases of foreign currency intended to accumulate international reserves. Through these operations, the central bank purchased a total of \$23.9 billion dollars over the sample period.⁵

Pre-announced purchases through FX auctions amounted to more than half of all interventions over the sample period. Due to their pre-announced nature, these interventions were anticipated by markets, which greatly complicates identifying their impact. Given that this type of intervention was concentrated in the period after 2010, we focus in our empirical exercises on the period of 2002-2010 when interventions were discretionary, which allows for a better identification of their effects.

In the sterilization leg of the FX intervention, the central bank conducts open market operations (OMOs) in the bond market in order to sterilize the effects of the intervention on domestic liquidity supply, and to maintain short-term interest rates in the target range. OMOs adjust the day-to-day money supply in order to meet demand, so that the

⁴For a detailed review of the different FX intervention approaches employed by the BoR, see Banco de la República (2016).

⁵The asymmetry in purchases versus sales is analysed more in-depth in Villamizar-Villegas (2015).

Type of FX intervention	Total	Intervention days	Mean	Std.Dev	Quartile 25%	Quartile 75%
Discretionary spot market						
Purchases	11,708	294	39.8	78.04	2.5	40.6
Rule-based options						
Purchased (exercised)	2,373	41	57.9	51.89	18	77.1
Sales (exercised)	-2,330	34	-68.5	59.74	-117	-16.5
Discretionary options						
Purchased (exercised)	3,355	83	40.4	44.10	10	62
Sales (exercised)	-600	6	-100.0	103.79	-199.9	-20
Pre-Announced auctions						
Purchases	23,867	1,098	21.7	7.94	19.8	24.9

Table 1. **FX intervention statistics (1999-2015)**. Authors' calculations. Units are in million dollars.

short-term money market rates are kept close to the policy rate. The BoR targets the interbank overnight rate, which corresponds to the weighted average rate for all overnight non-collateralized transactions.

The mechanics of the BoR's OMOs work as follows. At the close of a business day, the BoR announces an OMO for the following day at rate i^* , corresponding to the policy rate set by the board of directors. A contractionary (expansionary) auction would take place the following day, if the market had excess (shortage of) liquidity. The OMO considers changes in both the money demand and supply. On the demand side, the staff of the central bank conducts bimonthly forecasts (of the money demand) based on the banking system's reserve requirements as well as seasonal factors (holidays, pay days, etc.). On the supply side, the central bank monitors the issuance of public debt, changes in the monetary base brought forth by FX interventions, and other supply-driven changes such as expiring liquidity operations and government transfers (see Cardozo et al. 2016).

3.2 Credit registry

Loan-level data for new corporate loans come from the Colombian Financial Superintendency (*Superintendencia Financiera de Colombia*). In order to be able to exploit the loan-level information of the credit registry in the analysis, we have to reduce the dimensionality of the data in a number of ways. First, we conduct the analysis in weekly frequency. Second, we only traced firms that had at least 10 new loans with a given bank over the sample period. That way, we created a data set with more than 6 million

	Loan level	Firm level	Bank level
	New firm loans (Bill. COP)	FX debt (% of debt)	Equity (% of assets)
Mean	1.31	28.50	3.713
Std.Dev	8.13	33.50	10.42
Median	0.16	12.70	0.92
Quartile 25%	0.03	0.77	0.18
Quartile 75%	0.61	49.60	3.10
Observations	6'473,376	308,356	8,7736
Between	15,561	741	21
Within	416	416	416

Table 2. **Credit registry data descriptive statistics (2002-2010).**

observations in total. The first column of Table 2 presents descriptive statistics for the amount of the disbursed new corporate loans. The figures show that the average weekly new corporate loan for a firm over the sample was 1.3 billion pesos. The dispersion of the amount disbursed is high, reflected in a high standard deviation of 8.1 billion pesos.

From the credit registry we further obtain firm- and bank level data that enable us to test the predictions of the model and to identify the effects of FX intervention in the panel analysis. We use firm FX debt (as a ratio to total debt) as a measure of firm balance sheet vulnerability. In our theoretical model, intervention induced exchange rate changes affect loan supply as a result of FX debt of the borrowing firms. Focusing on FX exposure of firms rather than banks in the transmission of FX intervention is also consistent with the structure of the Colombian financial system. In Colombia, firms borrow in foreign currency from foreign as well as from domestic lenders, often on an unhedged basis. By contrast, currency exposure of banks is limited by FX regulation so that the banks operate primarily as an intermediary of FX loans for the non-financial corporate sector (Alfonso et al. (2015)). On average, firm FX debt amounted to about 29% of total debt, with a high cross-sectional dispersion reflected in the large standard deviation of 33.5% (Table 2, second column).

In order to test the role of banks' leverage for the transmission of FX intervention as indicated by our model, we collect bank-level data on banks' equity to assets ratios as an inverse measure of bank leverage. Table 2 column 3 provides some descriptive statistics for the bank equity ratios, which average at 3.7% with a standard deviation of 10.4%. As additional bank-level controls to be included in the regressions, we also collect data

on liquidity (sum of cash, interbank loans and reserves in percent of total assets), size (assets in percent of all banks' assets), loan loss provisions and of the internal loan risk grading as a measure of the riskiness of the loan book. Finally, we also obtain the stock of corporate loans which we use in the aggregate time series analysis as well as in the panel analysis in order to normalize the cumulative flows of new corporate loans.

4 FX intervention and domestic credit

Before delving into the main analysis of the loan-level panel data, we assess as a first motivating empirical exercise the dynamic impact of the BoR's FX intervention on the peso exchange rate and on corporate loans using time series data. To trace out the dynamic effects of FX intervention, we run local linear projection regressions (Jordà (2005)) at the daily and weekly frequency, regressing respectively the cumulative log change in the COP/USD nominal exchange rate (daily) as well as the cumulative log change in corporate loans (weekly) on the BoR's sterilized FX intervention ΔR .

The estimating equation takes the form:

$$Y_{t+h} = \alpha_h + \lambda_h y_{t-1} + \beta_h \Delta R_{t-1} + \Psi_h X_{t-1} + \varepsilon_{t+h}. \quad (23)$$

for $h = 1, \dots, 200$ days for the log change in the exchange rate and $h = 1, \dots, 40$ weeks for the log change in corporate loans. y_t denotes the log change in the respective dependent variable in period t and Y_{t+h} the respective cumulative change over the period t to $t+h$.

We include a large range of control variables to capture the considerations motivating BoR's FX interventions discussed above. Specifically, the matrix X includes macro-financial controls such as net portfolio inflows, the change in the policy rate, the change in the long-term government bond yield, the deviation of inflation from the Bank of the Republic's target level, the Colombian government's net bond issuance, the log level of the VIX index and the change in the bilateral exchange rate of the Colombian peso against the US dollar.⁶ We include a dummy variable for the period from May 7, 2007 to October 8, 2008 when the central bank introduced controls on capital inflows requiring

⁶Data on daily portfolio capital inflows and outflows come from the International Affairs Department (*Departamento de Cambios Internacionales*) and the Statistical Department (*Departamento Técnico y de Información Económica*). The net issuance of sovereign bonds (primary market) is obtained from the central bank owned electronic platform (Deposito Central de Valores-DCV). All other financial variables were taken either directly from the central bank's public website or from Bloomberg.

foreign investors to deposit 40% of portfolio and debt investments at the BoR during a six-month period without interest payments (i.e. an unremunerated reserve requirements).⁷ We further include banks' total assets, the share of liquid assets (cash, interbank lending and reserves) in total assets, banks' capital ratio, loan loss provisions as well as their internal loan risk grading to control for banking sector developments. The regressions also include a lagged dependent variable y_{t-1} in order to capture persistence in the dynamics of the dependent variable.

The series of coefficient estimates $\widehat{\beta}_h$ for $h = 1, \dots, 200$ days and $h = 1, \dots, 40$ weeks respectively represents the cumulative impulse response of the Colombian peso (COP) to US dollar (USD) exchange rate and of the stock of corporate loans to an unexpected sterilized FX intervention shock. This is because of the inclusion of contemporaneous and lagged variables describing the FX intervention reaction function in the set of control variables X . Equation (23) thus estimates the effect of FX intervention conditional on these variables, which is equivalent to a standard Choleski decomposition of residuals from a VAR where FX intervention is ordered last. Plagborg-Møller and Wolf (2021) provide a formal derivation of the equivalence of impulse responses obtained from local projections and VARs for such recursive identification schemes.

The sample period of the estimations is 2002-2010. As discussed before, the BoR conducted primarily pre-announced FX interventions from 2010 onwards, which could complicate the identification of the effects of intervention. For this reason, we perform the analysis over the shorter sample period covering exclusively discretionary interventions. We further standardize the FX intervention series for ease of interpretation. The standard deviation of FX intervention is 30 million US dollars for the daily data and 90 million US dollars for the weekly data.

Figure 1 shows the estimated impulse response functions with a 10% confidence band, calculated using heteroskedasticity and autocorrelation robust Newey-West standard errors. The results suggest that a sterilized FX purchase is followed by a significant depreciation of the peso exchange rate against the dollar (Figure 1, left-hand panel). The immediate impact of a one standard deviation FX purchase is a depreciation of roughly 0.4%, but the peak impact is a depreciation of more than 1% after 20 days. The impact

⁷Other regulatory controls (*Posición Propia -PP*, *Posición Propia de contado -PPC*) required commercial banks to have a positive but limited exposure of foreign currency, defined as net assets denominated in foreign currency relative to total capital. However, this policy was never binding for *PP* and almost never binding for *PPC*.

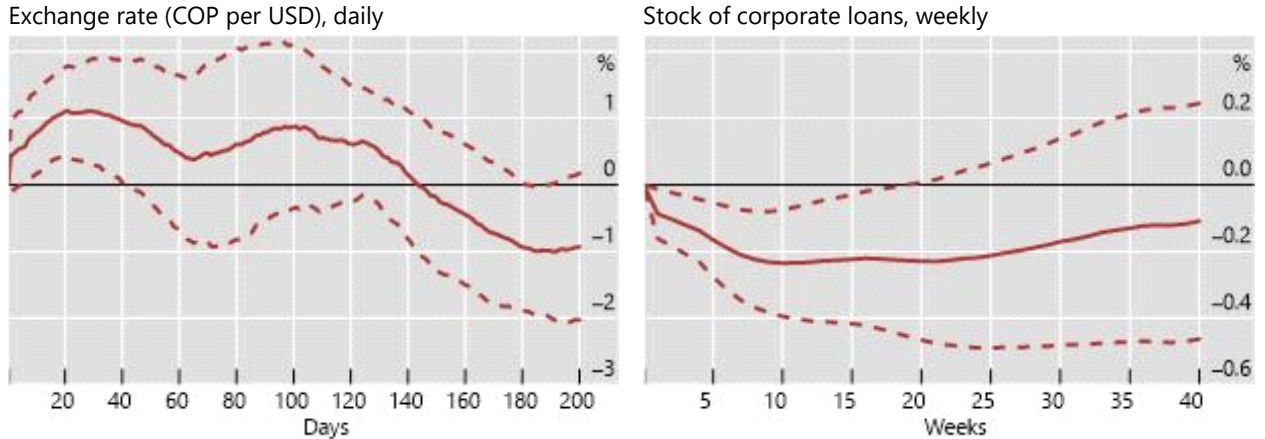


Figure 1. **Dynamic impact of sterilized FX intervention in Colombia.** Impulse responses from local linear projection regressions in 10% confidence bands based on heteroskedasticity and autocorrelation robust standard errors. The size of the impulse is 30 million US dollars for the daily regression and 90 million US dollars in the weekly regressions (daily and weekly sample standard deviations of all sterilized FX interventions respectively).

on the exchange rate is persistent, but fades out over time, with statistically significant effects lasting until 40 days after the shock. Quantitatively and qualitatively, the response pattern of the exchange rate that we find is consistent with the recent evidence of persistent effects of FX intervention in Israel reported in Caspi et al. (2018)).

We further find that an FX purchase significantly dampens corporate lending (Figure 1, right-hand panel). Quantitatively, the effect of a typical 90 million dollar FX purchase at the weekly frequency is a peak reduction (after about 20 weeks) of about 0.25% in the stock of corporate loans. The effect is persistent, but fades out after about 30 weeks. This finding suggests that, at the aggregate level, the effects of FX interventions go beyond their effects on the exchange rate. Specifically, an FX purchase exerts a significant tightening effect on credit conditions in the corporate loan market. Through which channels this occurs can of course not be assessed with aggregate data but requires deeper analysis using micro data which we turn to in the next section.

5 Loan-level analysis

This section presents the main part of the empirical analysis, the assessment of the impact of FX intervention on individual new firm loans using weekly loan-level data. We start by focusing on the role of firm FX debt in the transmission of intervention shocks. We then

extend the analysis to assess the role of bank leverage for the impact of FX intervention on new corporate loans.

5.1 Firm FX debt

In the conceptual analysis in Section 2, firm FX debt is at the core of the mechanism transmitting exchange rate changes and hence FX intervention to domestic financial conditions. In order to test this mechanism, we need to assess how firms' indebtedness in foreign currency shapes the transmission of FX intervention to firm loans. To this end, we regress the cumulative flow of new corporate loans by bank b to firm f on the BoR's sterilized FX intervention R , interacted with firm FX debt D_f (measured as a ratio to total debt in percent).

The weekly loan-level regressions are of the form:

$$\begin{aligned}
 Y_{f,b,t+h} = & \alpha_{b,h} + \alpha_{s,t,h} + \alpha_{f,y,h} + \rho_h y_{f,b,t-1} + \beta_h^R \Delta R_{t-1} \cdot D_{f,t-1} \\
 & + \beta_h D_{f,t-1} + \Phi_h X_{b,t-1} + \varepsilon_{f,b,t+h}.
 \end{aligned} \tag{24}$$

where $y_{f,b,t}$ denotes the face value of new corporate loans granted to firm f by bank b in period t and $Y_{f,b,t+h}$ refers to the cumulative flow of new individual firm-bank corporate loans over the period t to $t+h$. The loan flow variables are respectively normalized by the stock of corporate loans of bank b in period $t-1$ in order to facilitate interpretation and avoid upward trending dependent variables.

In light of the results of the time series analysis which suggested a lagged and persistent effect of FX intervention on bank lending to corporates, we estimate equation (24) for $h = 20$. In other words, we estimate the cumulative effects of FX intervention on new corporate loans in the 20 weeks after the intervention, in line with the peak impact of an intervention on corporate loans indicated by the time series analysis in the previous section. We also estimated equation (24) for shorter and for longer horizons, finding that the FX intervention effects are quantitatively smaller for shorter horizons and level off after 20 weeks, in line with the aggregate evidence reported in the previous section.⁸

The set of control variables $X_{b,t-1}$ includes individual banks' total assets, equity ratio, liquidity ratio, loan loss provisions as well as internal loan risk grading, thereby controlling for bank loan supply factors. The regressions further include bank fixed effects α_b as well

⁸The results of these regressions are available upon request.

as sector-time fixed effects $\alpha_{s,t}$. $\alpha_{f,y}$ denotes firm-year fixed effects controlling for firm-level factors over time. We estimate the equation both including and excluding the latter fixed effects as it has qualitative implications for the link between domestic lending and FX debt which are worthwhile highlighting. The estimation is based on weighted least squares, weighing the observations by firm assets. Finally, statistical inference is based on t-statistics calculated using Driscoll-Kraay (1998) standard errors which are robust to general forms of cross-sectional and temporal dependence.

The estimation results suggest that FX intervention exerts a highly significant negative effect on new corporate loans through firms' FX debt (Table 3). For the specification with firm-year fixed effects, the interaction coefficient is estimated at -0.006 and is statistically significant at the 1% level. A one percentage point increase in firm FX debt would therefore increase the negative effect of FX intervention on the flow of corporate loans by about 0.006 percent. Or put differently, for a firm with average FX debt (29%), a one standard deviation FX purchase lowers the flow of new corporate loans by about 0.17 percent relative to the base effect (which is in the estimation absorbed by the sector-time fixed effects).

This finding is consistent with the notion that the effects of intervention work to a significant extent through a balance sheet channel that is linked to the currency composition of borrower debt.

The finding also points to a distributional effect of intervention that would benefit macroeconomic and financial stability. It implies that the policy, if conducted in a symmetric way over the cycle, would mainly dampen credit to firms vulnerable to currency movements through FX purchases when capital flows in and exchange rates appreciate. Conversely, FX sales would mainly support credit conditions for exposed firms when capital flows out and the exchange rate depreciates. Specifically, the estimates imply that for the firm with the median level of FX debt (13%), an FX purchase lowers the flow of new loans over the next 20 weeks by 0.08%. For the firm with a level of FX debt at the upper quartile (50%), the effect is -0.3% while for the firm with a level of debt at the lower quartile of the distribution (0.8%), the effect is essentially zero.

Table 3 also reports the estimated coefficient of FX debt, which suggests that a one percentage point increase in FX debt reduces domestic new corporate loans by 0.15 percent. The effect is estimated at -0.4 percent when the interaction term with FX intervention is excluded. The finding of a negative link between FX balance sheet exposure

	Dependent variable: Cumulative flow of corporate loans			
	(1)	(2)	(3)	(4)
FX intervention*Firm FX debt	-0.0061*** (-21.7)		-0.0022*** (-8.34)	
Firm FX debt	-0.15* (-1.65)	-0.416*** (-4.61)	0.993*** (21.92)	0.878*** (20.32)
Controls	yes	yes	yes	yes
Bank fixed effects	yes	yes	yes	yes
Industry-time fixed effects	yes	yes	yes	yes
Firm-year fixed effects	yes	yes	no	no
R ²	0.065	0.065	0.090	0.090
# Observations	5'457,288	5'457,288	5'457,288	5'457,288
# Firms	15,164	15,164	15,164	15,164
# Banks	21	21	21	21
# Weeks	416	416	416	416

Table 3. **Firm FX debt and FX intervention.** The dependent variable is the 20-week cumulative change in the flow of new corporate loans as a ratio to the previous period's bank-level stock of loans. The FX intervention variable is standardized to its sample standard deviation (90 million US Dollars). t-statistics are based on Driscoll-Kraay standard errors.

and domestic credit is consistent with the evidence reported by Gonzalez et al. (2020) for the taper tantrum episode in Brazil.

The estimated direction of the effect however depends on the inclusion of the firm-year fixed effects. When this variable is excluded (columns (3) and (4)), the estimated relationship between FX debt and domestic loan flows turns significantly positive. This suggests that firm-level time factors give rise to a positive association between firm FX debt and their borrowing in domestic currency, probably reflecting higher domestic and FX borrowing going hand in hand. Only when firm-year fixed effects filtering out this positive association over time are included, the negative effects of balance sheet vulnerability through higher FX debt becomes visible. Also the negative interaction between FX debt and FX intervention is estimated to be somewhat smaller when firm-year fixed effects are excluded, but it remains significant at the 1% level.

5.2 Bank leverage

Our model developed in Section 2 also predicts that the negative impact of a sterilized FX purchase on domestic credit is larger the more a bank is leveraged. In order to test this prediction of the model, we extend the analysis to identify the effects of sterilized FX

	Dependent variable: Cumulative flow of corporate loans	
	(1)	(2)
FX intervention*Firm FX debt	-0.0061*** (-21.7)	-0.0022*** (-8.34)
FX intervention*Bank equity ratio	0.0139*** (3.16)	0.021*** (4.77)
Firm FX debt	-0.143 (-1.57)	1.00*** (22.07)
Bank equity ratio	13.96*** (7.83)	14.83*** (8.71)
Controls	yes	yes
Bank fixed effects	yes	yes
Industry-time fixed effects	yes	yes
Firm-year fixed effects	yes	no
R ²	0.065	0.090
# Observations	5'457,288	5'457,288
# Firms	15,164	15,164
# Banks	21	21
# Weeks	416	416

Table 4. **Bank leverage and FX intervention.** The dependent variable is the 20-week bank-firm cumulative flow of new corporate loans as a ratio to the previous period's bank-level stock of loans. The FX intervention variable is standardized to its sample standard deviation (90 million US Dollars). t-statistics are based on Driscoll-Kraay standard errors.

intervention on domestic financial conditions through the differences of the impact across banks depending on their leverage, measured through banks' equity to assets ratios. A higher equity ratio means lower leverage, so that banks with a higher equity ratio would be expected to be less affected by FX intervention.

We thus re-run loan-level panel regressions augmenting the specification to include interaction effects of FX intervention with the bank equity ratio (E). The estimating equation is given by:

$$\begin{aligned}
Y_{f,b,t+h} = & \alpha_{b,h} + \alpha_{s,t,h} + \alpha_{f,y,h} + \rho_h y_{f,b,t-1} + \beta_h^R \Delta R_{t-1} \cdot D_{f,t-1} + \beta_h D_{f,t-1} \\
& + \omega_h^R \Delta R_{t-1} \cdot E_{b,t-1} + \omega_h E_{b,t-1} + \Phi_h X_{b,t-1} + \varepsilon_{f,b,t+h}
\end{aligned} \tag{25}$$

Otherwise the specification is the same as before.

The results reported in Table 4 support the notion that FX intervention is transmitted through bank leverage. New corporate lending by banks with higher equity ratios and hence lower leverage is less negatively affected by an FX purchase. This is reflected in a significantly positive interaction coefficient between the bank equity ratio and FX

intervention. The interaction coefficient is estimated at around 0.02 and is statistically significant at the 1% level. Economically, this implies that a one percentage point increase in the equity ratio reduces the negative impact of FX intervention on the cumulative flow of new corporate loans by 0.02 percent.

Our findings further suggest that higher equity ratios are associated with higher corporate lending, consistent with the notion of positive credit supply effects through higher equity. Also here, the effects are statistically significant at the 1% level. Excluding firm-year fixed effects (column (2)) has little impact on the estimated effects of the bank equity ratio, of both its level and its interaction with FX intervention.

Adding the interaction effects with bank equity does not affect the previous finding of a negative interaction between firm FX debt and FX intervention in influencing new corporate lending. The interaction coefficient between the two variables remains statistically significant at the 1% level and also quantitatively remains essentially unchanged. Also the estimated link between new corporate loans flows and FX debt is not affected in a major way by the addition of the bank-level interaction effect. As before, it is negative when firm-year fixed effects are included and positive when they drop out.

6 Concluding remarks

Emerging market economies have come a long way since the crises of the 1990s. The combination of floating exchange rates, financial deepening and development and prudent monetary and macroprudential policy frameworks have helped to bring about significant improvements in terms of macroeconomic and financial performance and stability. However, these developments have not removed the policy challenges from capital flow and exchange rate swings. These challenges stem from the imperfect nature of exchange rates as shock absorbers that bring real macro variables back into equilibrium in the way that textbooks suggest. Specifically, capital inflows are associated with currency appreciation that in turn attracts more capital inflows as it flatters borrowers balance sheets and loosens lender value-at-risks constraints. The result is often a mutually reinforcing feedback loop fueling domestic financial imbalances.

Our theoretical and empirical analysis suggests that sterilized FX intervention leans against credit growth during periods of sustained capital inflows accompanied by currency appreciation and can buffer the adverse impact on the economy of the reverse situation.

The effects work through both firm and bank balance sheets.

Our findings imply that FX intervention can complement monetary policy and macroprudential policy in enhancing macro-financial stabilization. Specifically, in periods of large capital inflows and exchange rate appreciation, FX purchases could complement tighter monetary and macroprudential policy in counteracting the build up of domestic financial imbalances. Similarly, when capital flows out and the exchange rate depreciates, FX sales can help counteract the tightening of domestic financial conditions. These findings do not imply that FX intervention should be used as the primary tool to stabilize domestic credit conditions. But it does suggest that the effects of FX intervention on domestic credit have to be taken into account in the calibration of the policy mix in macro-financial stability frameworks that combine monetary policy, macroprudential tools and FX intervention.

The challenge with any systematic use of FX intervention is the charge of “beggar thy neighbor” currency manipulation for trade competitiveness reasons. One way to avoid this problem would be to conduct FX intervention with a view to reduce exchange rate volatility and by slowing the pace of currency appreciation and depreciation, as opposed to targeting a certain level of the exchange rate. FX interventions may be used in a targeted and symmetric way to lean against exchange rate swings during capital inflow surges and ebbs, and against associated building up financial imbalances. In this way, they can usefully complement monetary policy and macroprudential tools contributing to a policy approach that leans against capital flow volatility and its consequences.

Finally, the design and use of FX intervention as a complementary policy tool for financial stability purposes must of course be assessed in the broader context of FX reserve adequacy. Precautionary considerations are the main motive for reserve accumulation in emerging market economies, and the perceived benefits depend on the external exposure of the economy and on the risks of adverse external shocks. Our analysis suggests that dampening the impact of expansionary external factors on the domestic financial system could be another benefit. However, accumulating FX reserves is also associated with significant fiscal costs. The extent of precautionary reserve accumulation and of the use of intervention as a stabilization tool will depend on the assessment of the net benefits, taking into account all perceived benefits and costs, which will vary across countries and over time.

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