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An Investigation of FX Intervention in Response to Financial and Real Shocks*

Zvi Hercowitz† and Avihai Lifschitz‡

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Abstract

This paper reports an attempt to characterize an empirical FX intervention rule using a panel quarterly data set of 25 countries. The focus is on the types of shocks central banks tend to react to: financial and/or real. The empirical analysis is based on a theoretical framework combining a link between the real exchange rate and the current account, imperfect substitution between domestic and foreign assets, and a policy of moderating the effects of shocks on the real exchange rate. This framework allows the separation of the observations into different samples, each one dominated by one type of shock. The effects of each shock type on FXI policy are examined in the corresponding sample. The results indicate an important and statistically significant intervention in response to financial shocks, and a weaker and statistically insignificant response to real shocks.

JEL Codes: E58, F31, F41.

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1 Introduction

The literature on the stabilizing role of FXI focuses mainly on financial shocks as the source of inefficient fluctuations of the real exchange rate, as for example Gabaix and Maggiori (2015) and Blanchard, Adler, and Carvalho Filho (2015). In these papers, the presence of imperfect substitution between domestic and foreign assets makes it possible for FXI to moderate the effects of financial flows on the real exchange rate. However, FXI may be desirable in principle also in response to real shocks when domestic and foreign assets are imperfect substitutes, or with a mechanism like learning-by-doing as in Krugman (1987) and Faltermeier, Lama, and Medina (2017).

In this paper we address empirically the question of which shocks central banks usually react to, providing estimates of the quantitative importance of these interventions. Hence, this paper aims at characterizing an empirical FXI rule in this respect. For this purpose we use a panel data set of 25 countries.

The focus on FXI policy is closely to related but different from the question of whether FXI is effective—addressed for example by Adler, Lisack, and Mano (2015) and Caspi, Friedman, and Ribon (2018). Both papers find economically important effects of FXI on the real exchange rate. This literature faces the identification challenge due to the endogeneity of the intervention. Adler et al. use instrumental variables to deal with the problem. Caspi et al. identify the exogenous daily FXI shock as the nominal exchange rate change during the intra-day FX intervention spell.

Here, we face the different identification problem of separating the effects of various shocks on FXI. Our identification procedure is based on theoretical sign restrictions.

We do not attempt to identify individual shocks as is usually done in the SVAR literature, but rather periods dominated by each type of shock: financial, real, exogenous FXI, and a specific combination of the first two. In Section 3 we comment on this procedure and the SVAR approach. The current procedure has two stages. First, using basic theoretical principles we separate the data into four samples—each one composed of periods dominated by one of the shock types. Then, we examine the reaction function in each one of these samples. For example, if FXI reacts to financial shocks, we expect this to show in the sample dominated by financial shocks.

The conceptual framework we use in the identification of the shocks combines three considerations: a positive link between the real exchange rate and the current account, imperfect substitution between domestic and foreign assets, and FXI policy. Imperfect asset substitution in this framework can be interpreted as a reduced form of the mechanism presented in Gabaix and Maggiori (2015): imbalances in the denominations of each country's assets and liabilities are financed by international financiers who require a compensation to bear the currency risk. Cavallino (2016) uses a New Keynesian small open-economy model that incorporates the Gabaix and Maggiori financial friction, and characterizes optimal FXI as an additional central bank's policy tool when the economy is subject to financial flows. Adler, Lama, and Medina (2016) analyze a similar question, but focus on the implications of policy goal uncertainty. Imperfect substitution between domestic and foreign assets can also follow from transaction costs that generate segmented markets, as in Alvarez, Atkeson, and Kehoe (2002).

Our empirical methodology of separating different samples according to a key criterion, and then considering the question at hand by comparing the results across the different samples is similar to the procedure employed by Blanchard, Adler, and Carvalho Filho (2015)—albeit in a different context. They address the question of whether FXI moderates the effects of global financial flows on individual economies. The main aspect of their empirical approach is composed of two stages. The first is the estimation of the FXI dynamic response to the global financial shock for each country in the sample. Then, according to these reactions, the countries in the sample are divided into two groups according to the extent of the FXI response: "interveners" and "floaters." A third group is denoted "de-facto pegs," for which the exchange rate response was found small enough. Then, the second stage consists in estimating the exchange rate response to the global shock for each of the two groups. The main result is that in countries for which the FXI response is larger—the interveners—the exchange response is smaller. This finding supports the stabilizing role of FXI.

Although the FXI literature emphasizes financial flows, FXI can be called for also in response to real shocks if financial markets are imperfect. Consider, for example, a temporary increase in the demand for imports that leads to foreign exchange borrowing at the cost dictated by Gabaix and Maggiori's financiers. This should reduce the extent to which the desired demand for imports takes place, and raises the question of whether the central bank's sale of foreign exchange is called for. Given this consideration, we investigate whether central banks do intervene in response to real shocks.

The results indicate a quantitatively important and statistically significant intervention in response to financial shocks: at least 36 percent of exogenous financial inflows are absorbed by FXI. The response to real shocks is weaker and statistically insignificant.

The paper is organized as follows. Section 2 presents the conceptual framework we use and Section 3 elaborates on the empirical procedure based on this framework. The data and the empirical results are reported in Section 4. We use a panel data set with 25 countries that are not reserve currency countries and with flexible enough exchange rates. The period covered is 1990:1–2015:4. Section 5 summarizes the results and concludes.

2 A Real, Small Open-Economy Framework

We start with the balance of payments equation

$$CA_t = F_t + \Delta R_t, \tag{1}$$

where CA_t is the surplus in the current account in period t, F_t is the net financial outflow, and ΔR_t represents FXI, i.e., the change in the stock of foreign reserves held by the central bank.

The economy is subject to three types of exogenous stochastic disturbances: (1) financial shocks ($\widetilde{F}_t$) affecting directly the financial account, (2) real shocks ($\widetilde{CA}_t$) affecting directly the current account, and (3) FXI shocks ($\widetilde{\Delta R}_t$) affecting directly the change in reserves. The three shocks are assumed to be transitory, although they can be persistent, and independently distributed.[1] Furthermore, we assume that there

[1] In Footnote 3 we mention the case of a permanent real shock.

is no endogenous interaction between the shocks; in other words, we assume a linear framework.

The central bank follows the FXI rule:

$$\Delta R_t = \alpha_f \widetilde{F}_t + \alpha_r \widetilde{CA}_t + \widetilde{\Delta R}_t, \quad -1 < \alpha_f \leq 0, \quad 0 \leq \alpha_r < 1; \tag{2}$$

i.e., FXI policy may react to both financial and real shocks. The inequality restrictions on the parameters imply that the policy is either not to respond to one or both shocks, or, if intervention does take place, to moderate but not to eliminate the effects of these shocks. Hence, the central bank may purchase foreign exchange in response to a financial inflow shock ($\widetilde{F}_t < 0$) or to a real shock that increases excess exports ($\widetilde{CA}_t > 0$), and may sell at times of opposite shocks.

The endogenous determination of F_t and CA_t, as well as of the real exchange rate, S_t—defined as the relative price of the foreign good in terms of the domestic good—is illustrated in the four figures below. These figures are based on the following assumptions: (a) there are no errors and omissions in the balance of payments, (b) the expected future real exchange rate, $\bar{S}$, is constant, or at least it does not move as much as the current real exchange rate, and, for ease of exposition (c) the domestic and world real interest rates are equal.[2] The real exchange rate appears on the vertical axis, and both the current account surplus and net financial outflows on the horizontal axis.

The downward sloping F-curve in these figures reflects the following mechanism:

[2] Alternatively, this equality holds only in the long run, and deviations from it are part of the financial shocks.

given the expected future real exchange rate $\bar{S}$, a lower current S_t implies an expected depreciation, which makes foreign assets more profitable. Hence, as the real exchange rate goes down, the desired portfolio composition changes in favor of foreign assets, generating a larger net financial outflow. The slope of the curve depends on the degree of substitution between domestic and foreign assets: the higher the degree of substitution, the smaller is the expected depreciation that triggers a given amount of portfolio rearrangement. In other words, the degree of substitution between domestic and foreign assets reduces the slope of the F-curve. At the extreme, perfect substitution yields a flat curve, where UIP holds at all times given the assumption of equal interest rates at home and abroad. With imperfect substitution UIP does not hold in general; it does so only when all shocks are zero.

The F-curve can also represent the portfolio considerations of the international financiers in Gabaix and Maggiori (2015). Away from the vertical zero axis there are denomination imbalances. For example, to the right of the vertical axis there is excess demand for foreign assets, which the financiers are ready to finance given the expected depreciation. The F-curve can also be thought of as capturing financial behavior under portfolio adjustment costs as in Schmitt-Grohe and Uribe (2003). The point where the F-curve crosses the vertical axis corresponds to zero borrowing/lending, while deviations from it imply the equality of the additional return to the marginal portfolio adjustment costs.

The upward sloping CA-curve represents the standard positive link between the current account and the real exchange rate S_t: a depreciation induces an increase of excess exports. The long-run real exchange rate is $\bar{S}$, corresponding to the zero value of CA_t.

In a situation with zero shocks and $\Delta R_t = 0$, the equilibrium values are $F_t = CA_t = 0$ and $S_t = \bar{S}$. Starting from this situation, we now show graphically the effects of the shocks and FXI policy on the real exchange rate and the balance of payment variables.

1. A financial inflow shock, $\widetilde{F} < 0$, as for example an increase in the foreign demand for domestic assets, shifts the F-curve in Figure 1 to the left to F'. The resulting decline in the exchange rate represents a deviation from $\bar{S}$, which is the exchange rate determined by the real forces. With perfect asset substitution, i.e., with a horizontal F-curve, the real exchange rate would not be affected. The central bank's FXI policy is represented by the $F' + \Delta R^e$-curve, to the right of the F'-curve. The assumption that the central bank attempts only to moderate the effects of the shock implies that the new curve is still to the left of the initial F-curve. The results are that both F_t and CA_t decline along with a real appreciation: CA_t goes down to point A, F_t goes down to point B, and S_t goes down to the level of these two points. If instead of a financial inflow shock there was an outflow shock, the results would be symmetrically opposite. Hence, we can summarize the effects of the financial shocks by

$$F_t \cdot CA_t > 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) > 0. \tag{3}$$

2. A negative real shock, $\widetilde{CA}_t < 0$, as for example an increase in the domestic demand for imports, shifts the CA-curve in Figure 2 to the left. This shock

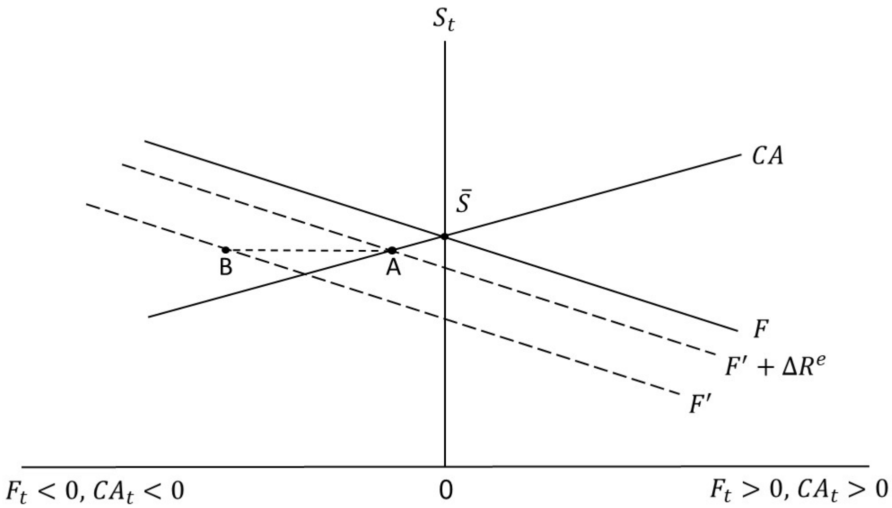

Figure 1: Financial Shocks

generates a temporarily high demand for foreign exchange, which causes a depreciation. Hence, imports increase by less than the desired amount, corresponding to the leftward shift of the CA-curve. The central bank may intervene by selling foreign exchange in order to moderate the depreciation, allowing imports to increase closer to the desired amount. Point A shows the current account, CA_t, and point B shows the capital inflow, F_t. The real exchange rate goes up to the level of these two points, which would coincide if there is there was no FXI.[3] With a positive real shock instead of a negative one we would have symmetric results. Hence, real shocks generate

$$F_t \cdot CA_t > 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) < 0. \tag{4}$$

[3] If the shock was permanent rather than transitory, the F-curve would shift upwards by the same distance as the CA-curve, increasing $\bar{S}$ while leaving CA_t and F_t equal to zero.

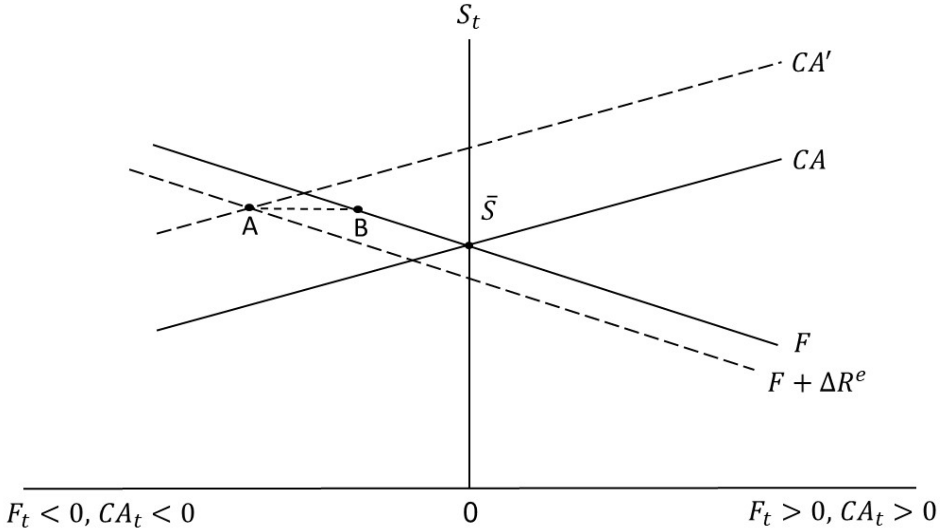

Figure 2: Real Shocks

3. The effects of an FXI shock, $\widetilde{\Delta R_t} > 0$, are shown in Figure 3. In this case, F_t and CA_t change in opposite directions. The resulting real depreciation encourages excess exports, and hence CA_t goes up to point A, and it discourages financial outflows, and hence F_t goes down to point B. If the $\widetilde{\Delta R_t}$ shock was negative, the responses would be symmetrically opposite. Hence, FXI shocks generate

$$F_t \cdot CA_t < 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) < 0. \tag{5}$$

4. Note that (3), (4), and (5) are three out of the four possible combinations of

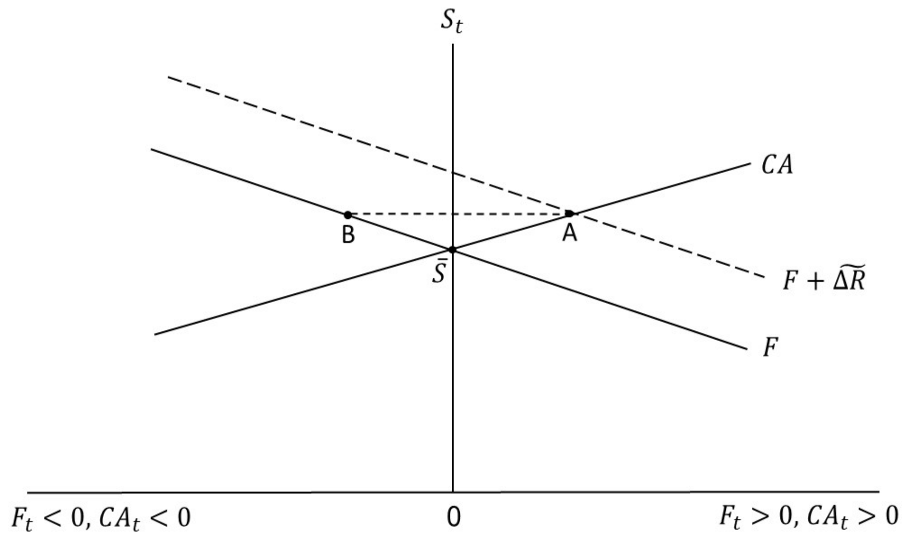

Figure 3: FXI Shocks

the two inequalities involved. The remaining combination is

$$F_t \cdot CA_t < 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) > 0. \tag{6}$$

This condition cannot be satisfied by a single shock. It can be shown that both financial and real shocks, along with FXI policy, should operate to satisfy condition (6). Furthermore, these shocks should have opposite signs in order to affect the real exchange rate in the same direction. Figure 4 shows this situation, with $\widetilde{CA}_t > 0$ shifting the CA-curve to the right to CA', and $\widetilde{F}_t < 0$ shifting the F-curve to the left to F'. Incorporating FXI generates the curve $F' + \Delta R^e$. The results are: CA_t goes up to point A, F_t goes down to point B, and S_t goes down to the level of these two points. These changes satisfy both inequalities in condition (6). Note that to comply with $F_t \cdot CA_t < 0$, it is necessary that the intervention is placed around the zero vertical axis. This implies that financial and real shocks should have similar quantitative effects on the real exchange rate.

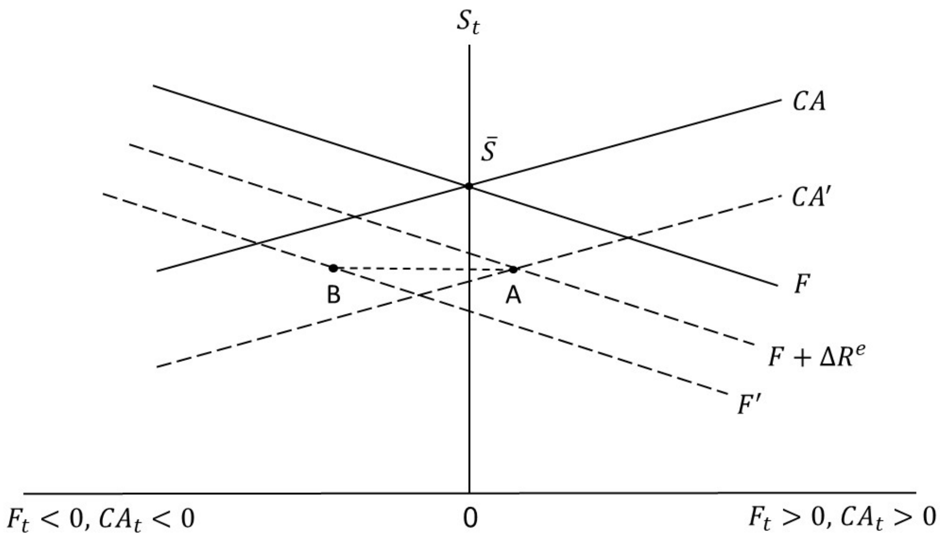

Figure 4: Combined Financial and Real Shocks

3 Empirical Procedure

The discussion in Section 2 is the basis of our identification procedure: We use the theoretical inequalities in conditions (3), (4), (5), and (6) to separate the periods (quarters) in the data set into four samples, based on satisfying one of these conditions:

Sample 1: Interpreted as dominated by financial shocks (condition (3) holds).

Sample 2: Interpreted as dominated by real shocks (condition (4) holds).

Sample 3: Interpreted as dominated by FXI shocks (condition (5) holds). We address this sample for completeness, although it sheds no light on the question of FXI reaction to financial or real shocks.

Sample 4: Interpreted as dominated by financial and real shocks affecting the real exchange rate in the same direction (condition (6) holds).[4]

We investigate which shocks FXI reacts to by addressing separately each one of the samples. For each sample, we consider the question directly by looking at an FXI equation, and then we address the FXI indirectly using a real exchange rate equation. We reach a conclusion on the question at hand on the basis of the results from the different samples.

In principle, an alternative identification and estimation procedure would have been to use the theoretical inequalities in Section 2 to constrain a structural VAR. Along these lines, for example, Uhlig (2005) estimates the effects of monetary shocks by imposing sign restrictions on the impulse responses to these shocks, and Kilian and Lütkepohl (2017, Ch. 13) survey identification methods by sign constraints on structural VARs. A general feature of these methods is that the sign restrictions by themselves generate a range of values for each relevant shock and a corresponding set of estimates of their effects. We preferred the procedure followed here because of its simplicity. Additionally, intervention in the FX market takes place quite fast after the central bank realizes the need for intervention. Hence, the VAR structure is not necessary in the current case.

[4] We delete observations with $(CA_t - F_t) \cdot \Delta R_t < 0$ because the balance of payments equation is violated; i.e., these observations are too contaminated by errors and omissions.

Appendix B uses a schematic algebraic solution of the model to provide the background for the current estimation procedure, and to derive the biases it may generate. In Section 4.3, we analyze these biases empirically.

The equations estimated for each sample, which include fixed country effects, are as follows:

Sample 1: Financial shocks dominate

Here we consider whether FXI policy reacts to financial flows. The main tool is the FXI regression equation

$$\mathbf{\Delta R}_{it} = \hat{\alpha}_f \mathbf{F}_{it} + resid_{it}, \tag{7}$$

where i is the country index, bold symbols indicate ratios to GDP, and $\hat{\alpha}_f$ is the estimate of the parameter α_f in the policy rule—equation (2). Given that this sample is dominated by financial shocks, we presume that the financial flows on the right-hand side are dominated by financial shocks. Finding that $\hat{\alpha}_f < 0$ and statistically significant would support the notion that the central bank purchases foreign exchange in the face of financial inflows, i.e., $\mathbf{F}_{it} < 0$, and sells when $\mathbf{F}_{it} > 0$. Intervention to moderate the effects of financial shocks but not to eliminate them completely would imply that $-1 < \hat{\alpha}_f < 0$.

We conduct an additional test, considering the question indirectly, using the pair of real exchange rate equations

$$\ln\left(S_{it}/\bar{S}_{it}\right) = \lambda_f \mathbf{\Delta R}_{it} + resid_{it}, \tag{8}$$

and

$$\ln\left(S_{it}/\bar{S}_{it}\right) = \zeta_{f,1}\mathbf{\Delta R}_{it} + \zeta_{f,2}\mathbf{F}_{it} + resid_{it}. \tag{9}$$

Equation (8) has only FXI as an explanatory variable. If central banks do intervene in the FX market in this sample, then $\mathbf{\Delta R}_{it}$ tends to be positive when $\ln\left(S_{it}/\bar{S}_{it}\right)$ tends to be negative. Hence, λ_f should include a negative endogeneity bias. Equation (9) controls for financial flows, and hence if FXI does respond to financial shocks we should find that $\zeta_{f,1} > \lambda_f$. We also expect $\zeta_{f,2} > 0$, i.e., that a financial outflow causes a depreciation.

Note that $\zeta_{f,1} > 0$ indicates that interventions are effective regardless of whether FXI reacts to financial shocks or not. If it does react, the positive effect of $\mathbf{\Delta R}_{it}$ should be detectable since financial flows are held constant. If it does not react to financial shocks, then $\mathbf{\Delta R}_{it}$ reflects independent central bank demand for foreign exchange—i.e., an FXI shock—as we saw above in Figure 3.

Sample 2: Real shocks dominate

To test for FXI in response to real shocks we use a symmetric set of equations to those in the previous sample, adapted for the present case. Given that this sample is dominated by real shocks, we presume that the current account is dominated by these shocks. A positive real shock increases $\mathbf{CA}_{it}$ and causes an appreciation. If the central bank wishes to moderate the appreciation, it should purchase foreign exchange. Correspondingly, in the FXI equation

$$\mathbf{\Delta R}_{it} = \hat{\alpha}_r\mathbf{CA}_{it} + resid_{it}, \tag{10}$$

$\hat{\alpha}_r > 0$ would be an indication that FXI responds to real shocks.

Regarding the additional test, the parallel equations to (8) and (9) are

$$\ln S_{it} - \ln \bar{S}_{it} = \lambda_r \mathbf{\Delta R}_{it} + resid_{it}, \quad (11)$$

and

$$\ln S_{it} - \ln \bar{S}_{it} = \zeta_{r,1} \mathbf{\Delta R}_{it} + \zeta_{r,2} \mathbf{CA}_{it} + resid_{it}. \quad (12)$$

Similarly to the previous sample, $\zeta_{r,1} > \lambda_r$ indicates FXI in response to real shocks. Here, we expect $\zeta_{r,2} < 0$—as an exogenous current account surplus should cause an appreciation.

Sample 3: FXI shocks dominate

In this case we do not have an FXI equation, and the real exchange rate equation is

$$\ln S_{it} - \ln \bar{S}_{it} = \hat{\theta}_x \mathbf{\Delta R}_{it} + resid_{it}, \quad (13)$$

where $\hat{\theta}_x$ is the estimate of the true effect of FXI on the real exchange rate, and $\mathbf{\Delta R}_{it}$ represents the dominating FXI shocks. We expect $\hat{\theta}_x > 0$.

Sample 4: Combined financial and real shocks dominate

Unlike in the previous three cases, all variables here reflect a combination of shocks of comparable strength. Hence, the lack of a single dominant shock in these periods will not allow us to reach a clear conclusion for this sample. However, descriptive statistics and the estimation of similar equations to those in Sample 1 will make it possible to obtain some insights into FXI in this case.

4 Empirical Results

4.1 The Data and Descriptive Statistics

We use a panel data set consisting of 25 countries covering the period 1990–2015 in quarterly intervals. The countries and periods in each one sample are listed in Appendix A, Table A2. Countries in the sample do not include reserve currency countries. Additionally, exchange rates in these countries are flexible enough (effective bands of more than 2 percent around a path) and are not in a free-falling period according to Ilzetzki, Reinhart, and Rogoff (2011). Given these criteria and data availability, the panel is not balanced.

The data on the change in the stock of reserves are expressed in US dollars. Hence, these data reflect FXI but also fluctuations in the US dollar rates of the other reserve currencies. To facilitate the interpretation of ΔR as FXI, the cross reserve currency valuation effects were "cleaned" first by regressing the changes in reserves on the US dollar rates of the Euro/Mark,Yen, and British Pound.

Table I presents descriptive statistics of the four samples, which include the number of observations in each sample and the average absolute magnitudes of the relevant variables: the deviations of the real exchange rate from a country-specific logarithmic linear trend and the balance of payment variables as ratios to GDP.

Table I: Average Absolute Magnitudes

Dominating Shock	Obs.	$ln\left(S/\bar{S}\right)$	$\mathbf{\Delta R}$	**F**	**CA**
1. Financial	781	0.119	0.024	0.058	0.047
2. Real	547	0.111	0.024	0.055	0.047
3. FXI	145	0.098	0.043	0.035	0.030
4. Financial and Real Combined	179	0.091	0.051	0.034	0.031

The largest is Sample 1, dominated by financial shocks, with 47 percent of the observations, and the second largest is Sample 2, dominated by real shocks, with 33 percent. The other two samples are smaller.

The two largest samples have similar magnitudes to the four variables: in the sample dominated by financial shocks the real exchange rate is slightly more volatile—11.9 percent compared to 11.1 percent in the sample dominated by real shocks. Financial flows are also slightly more volatile—5.8 percentage points of GDP compared to 5.5 percentage points—while the current account magnitudes are equal at 4.7 percentage points.

The smaller samples, 3 and 4, differ from the two larger samples in two respects: the magnitude of **F** and **CA** is much smaller—between 3.0 and 3.5 percentage points of GDP compared to 4.7–5.8 in Samples 1 and 2—and the magnitude of FXI is much larger—between 4.3 and 5.1 percentage points compared to 2.4 percentage points in the first two samples.

The similar average sizes of $\mathbf{\Delta R}$ in Samples 1 and 2—0.024 after rounding—hints that FXI may apply to a similar extent to financial and real shocks. However, the econometric results to be presented next do not support this.

Regarding Sample 3, the larger FXI magnitude can be expected in periods dominated by FXI shocks, and the smaller magnitudes of the other two balance of payments variables can follow from the fact that FXI shocks do not affect these variables directly as the financial and real shocks.

The smaller magnitude of **F** and **CA** in Sample 4 can be explained by the fact that although financial and real shocks work in the same direction in terms of the real exchange rate, they offset each other with respect to **F** and **CA**—as it can be seen in Figure 4. This sample has the largest magnitude of FXI: 5.1 percentage points of GDP. This hints that in this case FXI may respond to both shocks. We return to this issue in Section 4.2.4.

4.2 Regression Analysis by Sample

The following tables show the results of a panel regression with country fixed effects for each one of the samples. Standard errors—the smaller numbers under the coefficients—are corrected for 25-country clusters.

4.2.1 Sample 1: Financial Shocks Dominate

Table II reports the results for this sample. Column (i) presents the results of the direct test. It shows a negative and highly significant coefficient for **F**, interpreted as the FXI response to exogenous financial flows—FX purchases in case of an inflow, and sales in case of an outflow—of 30 percent of the flow.

Columns (ii) and (iii) show the results of the indirect test—via the real exchange rate. The coefficient of FXI in Column (ii) is negative, interpreted as resulting from reverse causality: a positive $\mathbf{\Delta R}$, indicating FX purchases, takes place when the exchange rate is low. However, when financial flows are controlled for in Column (iii), the coefficient of $\mathbf{\Delta R}$ turns positive and significant at the 5% level. The coefficient of $\mathbf{F}$ is positive, reflecting the positive effect of exogenous financial outflows on the real exchange rate.[5]

Column (iv) shows the coefficient of financial outflows alone, which is somewhat lower than in Column (iii). Because FXI is not held constant here, the coefficient in Column (iv) should capture also the moderating effect of FXI.

Overall, the results in Table II support the hypothesis that central banks do intervene in the FX market in response to financial shocks in a quantitatively important manner.

Table II: Sample Dominated by Financial Shocks

	Dependent Variable			
	$\mathbf{\Delta R}$	$ln\left(S/\bar{S}\right)$		
	(i)	(ii)	(iii)	(iv)
$\mathbf{F}$	-0.300^{***} 0.037		1.417^{***} 0.198	1.243^{***} 0.133
$\mathbf{\Delta R}$		-0.556^{***} 0.190	0.580^{**} 0.276	
Obs.	781	781	781	781

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects included.

[5] This column can also be thought of as a test of the efficacy of FXI: the coefficient of $\mathbf{\Delta R}$ in a real exchange rate regression is estimated holding constant financial flows, which are hypothesized to affect FXI. In this sense, the coefficient of $\mathbf{\Delta R}$ is small: FX purchases of one percent of GDP cause a depreciation of 0.57 percent.

4.2.2 Sample 2: Real Shocks Dominate

In this sample, given that real shocks dominate, we presume that the current account reflects primarily these shocks. In Column (i) of Table III, the coefficient of **CA** is positive—as FXI to moderate real exchange fluctuations requires—but it is small and statistically insignificant. Hence, the hypothesis that FXI does not react to real shocks cannot be rejected.

The indirect results via the exchange rate in Columns (ii) and (iii) convey a similar message. In Column (ii), the coefficient of $\mathbf{\Delta R}$ is positive but statistically insignificant, in contrast to the negative and significant parallel coefficient in Table II. When **CA** is added in Column (iii), the coefficient of $\mathbf{\Delta R}$ increases and becomes significant at the 5% level.[6] The higher and more significant coefficient of $\mathbf{\Delta R}$ in Column (iii)—relative to Column (ii)—can be rationalized by the weak FXI in response to real shocks shown in Column (i), which biases downwards the coefficient in Column (ii). This bias is reduced when **CA** is controlled for in Column (iii). The coefficient of **CA** is negative and significant, as expected when **CA** reflects mainly real shocks. Column (iv) shows that the coefficient of **CA** is practically insensitive to the exclusion of $\mathbf{\Delta R}$. Hence, we conclude that FXI responds to real shocks either very weakly or not at all.

[6] The coefficient of $\mathbf{\Delta R}$ in this sample, 0.319, is smaller than in Sample 1 (footnote 5).

Table III: Sample Dominated by Real Shocks

	Dependent Variable			
	$\mathbf{\Delta R}$	$ln\left(S/\bar{S}\right)$		
	(i)	(ii)	(iii)	(iv)
CA	0.076 0.078		-1.066^{***} 0.295	-1.042^{***} 0.299
$\mathbf{\Delta R}$		0.240 0.151	0.319^{**} 0.136	
Obs	547	547	547	547

Notes: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Fixed effects included.

4.2.3 Sample 3: FXI Shocks Dominate

The $\mathbf{\Delta R}$ variable in interpreted here as reflecting primarily FXI shocks. As mentioned above, we include this sample for completeness, although it does not address the issue of the reaction of FXI to financial or real shocks. The only relevant regression equation here is that of $ln\left(S/\bar{S}\right)$ on $\mathbf{\Delta R}$.[7] The estimated coefficient is 1.47, with a standard error of 0.243. Hence, the coefficient is highly significant: a p-value of less than 0.001. In other words, the impact of FXI on the real exchange rate is found to be around 1.5 percent depreciation for an FXI shock of 1 percent of GDP, which is quantitatively similar to that estimated by Adler, Lisack, and Mano (2015). This effect is much larger than in Samples 1 and 2, reported in footnotes 5 and 6. We interpret this difference as the result of a cleaner identification of FXI shocks in this sample, where FXI shocks dominate.

[7] The number of observations is 144.

4.2.4 Sample 4: Combined Financial and Real Shocks Dominate

Because the two types of shocks occur simultaneously in this sample, each one of the variables $\mathbf{F}$ and $\mathbf{CA}$ reflects both. Hence, unlike in the previous samples, we cannot test here how FXI reacts to one type of shock. To illustrate the problem, we regressed $\mathbf{\Delta R}$ on $\mathbf{F}$, as we did in Sample 1 to test the FXI response to financial shocks. The estimated coefficient is -1.009 with a standard error of 0.08 (a p-value of less than 0.001).[8] The large size of the coefficient of $\mathbf{F}$—three times the magnitude of the corresponding coefficient in Table II—can be explained in two different ways.

One explanation follows the hint mentioned when discussing Table I, that when financial and real shocks affect the real exchange rate in the same direction, e.g., a positive financial shock is accompanied by a negative real shock, the FXI response to the financial shocks is much stronger than usual. This is equivalent to saying that in these cases FXI responds also to real shocks. This explanation is consistent with the large average magnitude of $\mathbf{\Delta R}$ in this sample reported in Table I; i.e., FXI responds strongly because it reacts to both the financial and the real shocks.

However, there is also a reverse causality explanation for the large coefficient of $\mathbf{F}$. A negative real shock, which affects the real exchange rate in the same direction as a contemporaneous positive financial shock, reduces endogenously the size of $\mathbf{F}$ for any *given* $\mathbf{\Delta R}$; hence, the size of the coefficient on $\mathbf{F}$ in the equation for $\mathbf{\Delta R}$ increases accordingly. This second explanation for the large coefficient on $\mathbf{F}$ implies that the hint provided by Table I about FXI responding to real shocks in this sample cannot be verified with the present methodology.

[8] The number of observations here is 180.

4.3 Analysis of the Endogeneity Bias

The analysis in this paper is based on dividing the data into separate samples, each one dominated by one type of shock. Given that the non-dominant shocks are included in the residuals of the regressions, this procedure leads to biases in the estimates of α_f and α_r, as shown in Appendix B. Here, we test the implications of reducing these biases by sequentially tightening the criteria for a shock to be dominant. Along this sequence the bias declines because the relative importance of the other shocks in the residual diminishes. This, of course, reduces progressively the size of each sample. Practically, we replace conditions (3) and (4):[9]

$$F_{it} \cdot CA_{it} > 0 \text{ and } F_t \cdot \left(S_{it} - \bar{S}_{it}\right) > 0 \text{ for the financial shock sample, and}$$
$$F_{it} \cdot CA_{it} > 0 \text{ and } F_{it} \cdot \left(S_{it} - \bar{S}_{it}\right) < 0 \text{ for the real shock sample,}$$

with sequences of constraints constructed as follows. Separately for each sample, we attach to each observation the index

$$I_{it}^1 = \frac{F_{it} \cdot CA_{it}}{StDev(F_{it} \cdot CA_{it})} + \frac{F_{it} \cdot \left(S_{it} - \bar{S}_{it}\right)}{StDev(F_{it} \cdot \left(S_{it} - \bar{S}_{it}\right))},$$
$$I_{it}^2 = \frac{F_{it} \cdot CA_{it}}{StDev(F_{it} \cdot CA_{it})} - \frac{F_{it} \cdot \left(S_{it} - \bar{S}_{it}\right)}{StDev(F_{it} \cdot \left(S_{it} - \bar{S}_{it}\right))},$$

which captures the combined degree to which the values of the two interaction terms deviate from zero in the corresponding direction. By construction, these indices are all positive. Then, for each sample we order the values of I_{it}^s by magnitude and define the cutoffs: $0 \equiv I_0^s < I_1^s < I_2^s < I_3^s < I_4^s ...$, $s = 1, 2$, so that between

[9] We do not proceed with condition (5) because Sample 3 is small, nor with (6) because Sample 4 it is not only small but also dominated by different simultaneous shocks. Hence, tightening condition (6) cannot help in the identification of individual shocks.

I_j^s and I_{j+1}^s there are five percent of the observations in the corresponding sample. Given these cutoffs, we repeat the regressions of $\mathbf{\Delta R}$ on $\mathbf{F}$ or $\mathbf{CA}$ for Samples 1 and 2 sequentially, deleting each time the observations in the lowest remaining bin $I_j^s - I_{j+1}^s$. This implies that the criterion for each shock to be dominant in its corresponding sample becomes increasingly more selective. Hence, the effects of the other shocks and thus the endogeneity bias weaken along the sequence.

Figure 5 shows the results for Sample 1, dominated by financial shocks. The horizontal axis indicates the size of the remaining sample. The full (red) line shows the coefficient of financial flows on FXI, i.e., α_f—measured along the vertical axis on the left—and the dashed (green) line shows the corresponding t-statistics—measured along the vertical axis on the right. The sequence of coefficients are all highly significant statistically.

The main result in Figure 5 is that as the relative importance of the financial shock increases, the size of the negative coefficient increases—or, in other words, the positive bias in $\hat{\alpha}_f$ diminishes. According to Appendix B, this positive bias is due to the presence of the non-dominant real shock $\widetilde{CA}_t$ in the residual, which is positively correlated with F_t. Quantitatively, the magnitude of the coefficient increases from -0.30 to -0.36 along the sequence of regressions. Given the methodology, we cannot obtain a "limiting" estimate, i.e., an estimate that is completely clean of the endogeneity bias. Our result here is that *at least* 36 percent of the exogenous financial inflows are absorbed by FXI.

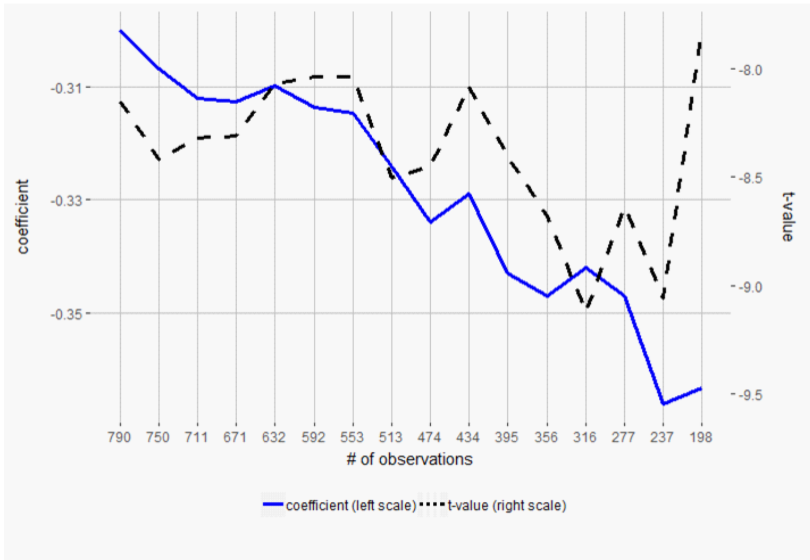

Figure 5: Sequential Coefficients of $\mathbf{F}$ $(\hat{\alpha}_f)$ and t-Values

Figure 6 shows the results for Sample 2, dominated by real shocks. The coefficients along the sequence are all positive but small—between 0.076 and 0.14—and statistically insignificant. The low significance levels, especially towards the end of the sequence, do not allow us to assign importance to the positive trend in the size of the coefficients. Hence, these results are similar to those presented in Section 4.2.2: the evidence of an FXI in response to real shocks so as to moderate fluctuation of the exchange rate is weak.[10]

[10]Regarding Sample 3, the coefficient of 1.47 for the effect of FXI on the real exchange rate should be considered a lower bound of the effect for two reasons. First, the financial (outflow) shock component of the residual should be negatively correlated with $\mathbf{\Delta R}$ according to the results in Table 2, and positively correlated with $ln\left(S/\bar{S}\right)$. This should bias the coefficient downwards. Second, the real shock component of the residual should be uncorrelated with $\mathbf{\Delta R}$ according to the results in Table 3, and negatively correlated with $ln\left(S/\bar{S}\right)$. This generates an errors-in-variables bias towards zero. Both considerations together imply a negative bias.

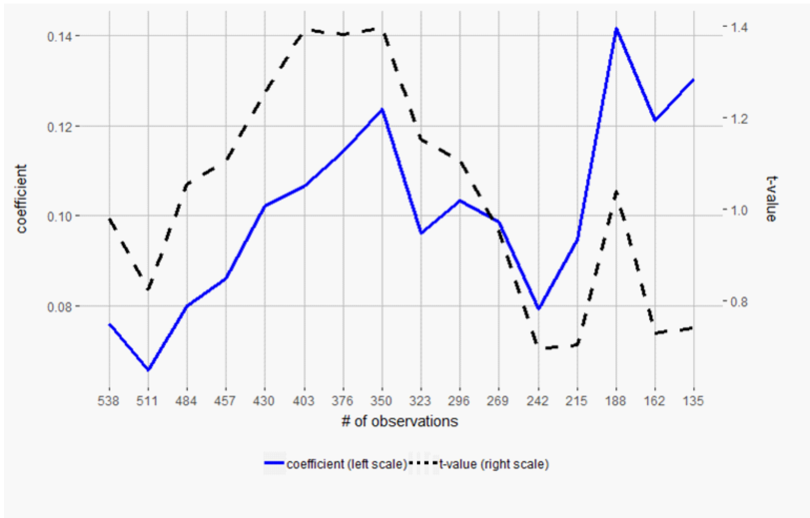

Figure 6: Sequential Coefficients of **CA** ($\hat{\alpha}_r$) and t-Values

4.4 Testing for a Change in 2008

Here we compare the period from 2008:1 onwards to the earlier period. Table IV reports the results from adding to the previous regressions interaction terms with a dummy variable with 1 for the period 2008:1 onwards and 0 otherwise. These interaction variables are denoted by $\mathbf{F}', \mathbf{CA}'$, and $\mathbf{\Delta R}'$.

Table IV: Change From 2008 Onwards

	Financial			Real			FXI
	$\mathbf{\Delta R}$	$ln\left(S/\bar{S}\right)$		$\mathbf{\Delta R}$	$ln\left(S/\bar{S}\right)$		$ln\left(S/\bar{S}\right)$
	(i)	(ii)	(iii)	(iv)	(v)	(vi)	(vii)
$\mathbf{F}$	-0.34^{***} 0.04		1.33^{***} 0.21				
$\mathbf{F}'$	0.07 0.08		0.22 0.24				
$\mathbf{CA}$				0.11 0.10		-0.97^{***} 0.29	
$\mathbf{CA}'$				-0.08 0.06		-0.25 0.18	
$\mathbf{\Delta R}$		-0.48 0.23	0.77^{**} 0.32		0.40^{**} 0.13	0.40^{***} 0.15	1.57^{***} 0.25
$\mathbf{\Delta R}'$		-0.27 0.37	-0.46 0.32		-0.31 0.20	-0.18 0.17	-0.16 0.38
Obs	790	790	790	538	538	538	144

Notes: $^{*}p < 0.10$, $^{**}\ p < 0.05$, $^{***}\ p < 0.01$

Fixed effects included.

Table IV shows that none of the interactions with the dummy variable for 2008:1 onwards is statistically significant. However, the table shows that the interaction term $\mathbf{F}'$ has positive coefficients in Columns (i) and (iii), both hinting at a weaker FXI response to financial shocks after 2008. Additionally, the interaction term $\mathbf{\Delta R}'$ has negative coefficients in the real exchange rate regressions in all three samples. This can be taken as weak evidence that also the FXI effects on the exchange rate attenuated from 2008 onwards. Together, this evidence suggests a decline in both the response and the effect of FXI.

5 Concluding Comments

This paper addresses the types of shocks FXI empirically responds to, financial and/or real, and the quantitative dimension of these interventions. The basic theoretical presumption is that domestic and foreign assets are imperfect substitutes. Hence, both financial flows and FX intervention can affect the real exchange rate. Imperfect asset substitution implies that FXI can be desirable in response not only to financial shocks, but also to real shocks.

The methodology we use is based on separating samples with one dominating shock in each one. Net financial outflows capture the financial shocks in the sample dominated by financial shocks, and the current account balance captures the real shocks in the sample dominated by real shocks. Then, we test the FXI response to the dominant shock in the corresponding sample. Identification using this method is partial due to the endogeneity bias generated by the weaker shocks operating in each sample alongside the dominant shock. These other shocks, which compose the residual in the regressions, are in principle correlated with the corresponding explanatory variable—the net financial outflows in the first sample and the current account balance in the second. By sequentially tightening the criteria for a shock to be dominant we reduce the relative importance of the non-dominant shocks along the sequence. Because the samples become smaller along this sequence, this methodology cannot detect the limiting FXI reaction. However, the serial estimation allows us to determine the sign of each bias and to progressively reduce it.

The results provide strong evidence of FXI in response to financial shocks. Our estimate in this respect is that central banks tend to intercept at least 36 percent of these financial flows. This is consistent with a willingness to moderate fluctuations in the exchange rate. Regarding real shocks, we detect a positive but small and statistically insignificant FXI response. The differences in the estimates before and after 2008 are not statistically significant, although they are consistent with a weak decline in the FXI response and efficacy in the second sub-period.

A Data Appendix

Table A1: Definition of Variables

Name	Symbol	Construction
Real exchange rate	S_t	US dollar rate in domestic currency× US GDP deflator/GDP deflator [1]
Current account surplus/GDP ratio	$\mathbf{CA}_t$	Current account surplus in US$× Exchange rate/nominal GDP [2]
Financial account/GDP ratio	$\mathbf{F}_t$	Financial net outflow in US$× Exchange rate/nominal GDP [2]
FXI intervention/GDP ratio	$\boldsymbol{\Delta}\mathbf{R}_t$	Change in reserves in US$× Exchange rate/nominal GDP [2],[3]
% change of the Dollar/Euro exchange rate	–	1990:1–1998:4–Deutche mark [4] 1999:2–2015:4–Euro
% change of the Dollar/Yen and Dollar/Pound exchange rates	–	

(1) The real exchange rates are detrended with a country-specific logarithmic linear trend.

(2) Given that the balance of payment variables are expressed in US dollars, nominal GDP was also expressed in US dollars using a third-order polynomial fitted to the nominal exchange rate of the US dollar. The nominal exchange rate itself was not used in order not to introduce a spurious positive correlation between the balance of payment variables and the real exchange rate.

(3) To facilitate the interpretation of ΔR as FXI, the cross reserve currency valuation effects were "cleaned" first by regressing the data on changes in reserves on the US dollar rates of the Euro/Mark, Yen, and British Pound.

(4) The two series are linked in 1999:1.

The data are seasonally unadjusted.

Table A2: Sample

	Country	IMF Code	Period
1	Australia	193	1990:1–2015:3
2	Belarus	913	2003:1–2015:4
3	Brazil	223	1999:4–2015:4
4	Canada	156	1990:1–2015:4
5	Chile	228	1999:4–2015:4
6	Colombia	233	2000:1–2015:4
7	Czech Rep.	935	1996:1–1997:2, 2002:1–2015:4
8	Hungary	944	1999:1–2009:2, 2010:2–2015:4
9	Indonesia	536	1999:3–2015:3
10	Israel	436	1990:1–2015:4
11	Korea	542	1998:3–2015:4
12	Mexico	273	1996:2–2015:4
13	New Zealand	196	2000:2–2015:4
14	Norway	142	1994:1–2015:4
15	Paraguay	288	2000:1–2010:2
16	Philippines	566	1992:3–1995:2, 1998:1–2015:4
17	Poland	964	1995:3–2015:4
18	Romania	968	2001:3–2015:4
19	Russian Fed.	922	2000:1–2015:3
20	South Africa	199	1995:2–2015:4
21	Sri Lanka	524	2009:1-2015:3
22	Sweden	144	1993:1–2015:4
23	Thailand	578	1998:3–2014:3
24	Turkey	186	1998:2–2015:4
25	Uruguay	298	2005:1–2015:4

Data Sources:

IMF, file BOP:

Balance of payment variables — quarterly flows in US dollars.

IFS:

Nominal exchange rates. National currency per US dollar — quarterly averages.

Nominal GDP — national currency (except for the countries listed below).

GDP deflator — index (except for the countries listed below).

OECD:

Nominal GDP for Australia, New Zealand, and Mexico.

GDP deflator for Australia, New Zealand, Mexico, and Canada.

Other Sources for Nominal GDP:

Canada from CANSIM.

South Africa from SARB.

Colombia from National Administrative Department of Statistics (DANE).

B Estimation Biases

In this appendix we present first a schematic solution of the model, based on the linearity being assumed for its equations, and then we derive the biases that the estimation should produce based on this structure.

The solution to the three variables as functions of the shocks has the form

$$\Delta R_t = \alpha_f \widetilde{F}_t + \alpha_r \widetilde{CA}_t + \widetilde{\Delta R}_t,$$

$$F_t = \widetilde{F}_t + \beta_r \widetilde{CA}_t + \beta_x \widetilde{\Delta R}_t, \tag{14}$$

$$CA_t = \gamma_f \widetilde{F}_t + \widetilde{CA}_t + \gamma_x \widetilde{\Delta R}_t, \tag{15}$$

where the first equation is the FXI rule from (2). Each shock is defined in terms of its equilibrium effect on the corresponding variable.

We wish to obtain estimates of the parameters of the FXI equation: α_f and α_r. According to the graphical analysis in Section 2, the signs of the parameters in (14) and (15) are

$$\beta_r, \gamma_f, \gamma_x > 0, \tag{16}$$

$$\beta_x < 0.$$

To obtain estimates of α_f and α_r we proceed as follows. If the shocks $\widetilde{F}_t$ and $\widetilde{CA}_t$ were known, equation (2) could be estimated as is. However, given that the shocks are not known, we use two separate samples: for Sample 1, dominated by financial shocks, we estimate $\hat{\alpha}_f$, and for Sample 2, dominated by real shocks, we estimate $\hat{\alpha}_r$. In terms of the unobservable shocks, the two equations are:

$$\Delta R_t^{(1)} = \alpha_f \widetilde{F}_t^{(1)} + \widetilde{\Delta R}_t^{(1)}$$

and

$$\Delta R_t^{(2)} = \alpha_r \widetilde{CA}_t^{(2)} + \widetilde{\Delta R}_t^{(2)},$$

where the superscripts denote the sample used. We then replace the shocks $\widetilde{F}_t$ and $\widetilde{CA}_t$ with the observables F_t and CA_t using (14) and (15). The resulting equations are

$$\begin{aligned} \Delta R_t^{(1)} &= \hat{\alpha}_f F_t^{(1)} + \varepsilon_{f,t}, \\ \varepsilon_{f,t} &= -\alpha_f \beta_r \widetilde{CA}_t^{(1)} + (1 - \alpha_f \beta_x) \widetilde{\Delta R}_t^{(1)} \end{aligned} \tag{17}$$

and

$$\begin{aligned} \Delta R_t^{(2)} &= \hat{\alpha}_r CA_t^{(2)} + \varepsilon_{r,t}, \\ \varepsilon_{r,t} &= -\alpha_r \gamma_f \widetilde{F}_t^{(2)} + (1 - \alpha_r \gamma_x) \widetilde{\Delta R}_t^{(2)}. \end{aligned} \tag{18}$$

Let us first consider first (17). Given the structure of the residual $\varepsilon_{f,t}$, equation (14), and the mutual independence of the shocks, the bias in the estimate of α_f is[11]

$$\frac{Cov\left[F_t^{(1)}, \left(-\alpha_f \beta_r \widetilde{CA}_t^{(1)} + (1 - \alpha_f \beta_x) \widetilde{\Delta R}_t^{(1)}\right)\right]}{Var\left(F_t^{(1)}\right)},$$

[11] This assumes that there are no other components in the residual, like measurement errors.

or

$$\frac{Cov\left[\left(\widetilde{F}_t^{(1)}+\beta_r\widetilde{CA}_t^{(1)}+\beta_x\widetilde{\Delta R}_t^{(1)}\right),\left(-\alpha_f\beta_r\widetilde{CA}_t^{(1)}+\left(1-\alpha_f\beta_x\right)\widetilde{\Delta R}_t^{(1)}\right)\right]}{Var\left(\widetilde{F}_t^{(1)}+\beta_r\widetilde{CA}_t^{(1)}+\beta_x\widetilde{\Delta R}_t^{(1)}\right)}$$

$$=\frac{-\alpha_f\left(\beta_r\right)^2Var\left(\widetilde{CA}_t^{(1)}\right)+\beta_x\left(1-\alpha_f\beta_x\right)Var\left(\widetilde{\Delta R}_t^{(1)}\right)}{Var\left(\widetilde{F}_t^{(1)}\right)+\left(\beta_r\right)^2Var\left(\widetilde{CA}_t^{(1)}\right)+\left(\beta_x\right)Var\left(\widetilde{\Delta R}_t^{(1)}\right)}.$$

Given that the variance of the dominant shock $\widetilde{F}_t^{(1)}$ appears only in the denominator, there is a negative relationship between this bias and the variance of the dominant shock relative to the variances of the other shocks. Regarding the sign of the bias, the term involving $Var(\widetilde{CA}_t^{(1)})$ is positive, assuming that, as expected, $\alpha_f<0$. The term involving $Var(\widetilde{\Delta R}_t^{(1)})$ could have either sign according to $1-\alpha_f\beta_x \lesseqgtr 0$. Hence, in general we cannot determine the sign of the bias. However, the results in Section 4.3 indicate a positive bias, implying that the magnitude of the estimated coefficient $\hat{\alpha}_f$ is a lower bound of the magnitude of α_f.

Let us now consider (18), which is the equation for estimating α_r with the sample dominated by real shocks—Sample 2. In a similar fashion to the estimation of α_f, and using (15), the bias in the estimation of α_r is:

$$\frac{Cov\left[\left(\gamma_f\widetilde{F}_t^{(2)}+\widetilde{CA}_t^{(2)}+\gamma_x\widetilde{\Delta R}_t^{(2)}\right),\left(-\alpha_r\gamma_f\widetilde{F}_t^{(2)}+\left(1-\alpha_r\gamma_x\right)\widetilde{\Delta R}_t^{(2)}\right)\right]}{Var\left(CA_t^{(2)}\right)}$$

$$= \frac{-\alpha_r (\gamma_f)^2 Var\left(\widetilde{F}_t^{(2)}\right) + \gamma_x (1-\alpha_r\gamma_x) Var\left(\widetilde{\Delta R}_t^{(2)}\right)}{Var\left(\widetilde{CA}_t^{(2)}\right) + (\gamma_f)^2 Var\left(\widetilde{F}_t^{(2)}\right) + (\gamma_x)^2 Var\left(\widetilde{\Delta R}_t^{(2)}\right)}.$$

Once again, the larger the variance of the dominating shock, $\widetilde{CA}_t$ in this sample is, the smaller the size of the bias. In general, we cannot determine the direction of the bias. For example, if FXI does not respond to real shocks and thus $\alpha_r = 0$, the bias is positive, and hence the results will indicate $\hat{\alpha}_r > 0$. However, if $\alpha_r > 0$, the bias can be negative.

Finally, we consider the bias in the estimation of the FXI effect on the real exchange rate with Sample 3. We start with the solution of the real exchange rate, which has the form:

$$\ln\left(\frac{S_t}{\bar{S}_t}\right)^{(3)} = \theta_x \widetilde{\Delta R}_t^{(3)} + \theta_f \widetilde{F}_t^{(3)} + \theta_r \widetilde{CA}_t^{(3)}. \tag{19}$$

From the graphical analysis in Section 2, these coefficients have the signs:

$$\theta_x > 0,\ \theta_f > 0,\ \theta_r < 0,$$

where θ_x is the coefficient of interest here. Replacing the unobservable $\widetilde{\Delta R}_t$ in (19) with ΔR_t using the FXI rule (2) yields the regression equation:

$$\ln\left(\frac{S_t}{\bar{S}_t}\right)^{(3)} = \hat{\theta}_x \Delta R_t^{(3)} + \varepsilon_{x,t}, \tag{20}$$
$$\varepsilon_{x,t} = (\theta_f - \theta_x\alpha_f)\, \widetilde{F}_t^{(3)} + (\theta_r - \theta_x\alpha_r)\, \widetilde{CA}_t^{(3)},$$

with $\theta_f - \theta_x\alpha_f > 0$, and $\theta_r - \theta_x\alpha_r < 0$ if $\alpha_r \geqslant 0$. Using (2), the bias in the estimate of θ_x is:

$$\frac{Cov\left[\left(\alpha_f\widetilde{F}_t^{(3)} + \alpha_r\widetilde{CA}_t^{(3)} + \widetilde{\Delta R}_t^{(3)}\right), \left(\left(\theta_f - \theta_x\alpha_f\right)\widetilde{F}_t^{(3)} + \left(\theta_r - \theta_x\alpha_r\right)\widetilde{CA}_t^{(3)}\right)\right]}{Var\left(\Delta R_t^{(3)}\right)}$$

$$= \frac{\alpha_f\left(\theta_f - \theta_x\alpha_f\right)Var\left(\widetilde{F}_t^{(3)}\right) + \alpha_r\left(\theta_r - \theta_x\alpha_r\right)Var\left(\widetilde{CA}_t^{(3)}\right)}{Var\left(\Delta R_t^{(3)}\right)}.$$

If $\alpha_f < 0$, the coefficient of $Var(\widetilde{F}_t^{(3)})$ is negative, and if $\alpha_r \geqslant 0$ the coefficient of $Var(\widetilde{CA}_t^{(3)})$ is non-positive. Accordingly, the positive estimate of the effect of FXI on the real exchange rate reported in Section 4 for Sample 3 should be considered a lower bound.

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