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

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November 12, 2018

Preliminary

Abstract

This paper reports an attempt to characterize the 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 theoretical framework on which the empirical analysis is based combines three elements: 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 to separate the observations into different samples, each one dominated by one type of shock. The effects of a particular shock on FXI policy is carried out using the corresponding sample.

*We thank Sapir Yakar, Jonathan Gunsburg and Yona Hackett for skillful research assistance.
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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 in 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 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). These papers focus on the question referred to as the Dutch Disease.

In this paper we address the empirical question of which shocks central banks usually react to, providing estimates of the quantitative importance of these interventions. Hence, this paper aims at characterizing the 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 related but different from the question 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. use intra-day data and identify the exogenous daily FXI shock as the nominal exchange rate change during the spell of FXI during the day.

Here, we face the different identification problem of separating the effects of various shocks on FXI. Our procedure does not identify individual shocks but periods dominated by each type of shock: financial, real, exogenous FXI, and a specific combination of the first two. The procedure has two stages. First, using basic theoretical principles we separate four sub-samples—each one composed of periods dominated by one of the shock types. Then, we examine the reaction function within each one of these sub-samples. For example, if FXI reacts to financial shocks, we expect this to show in the sub-sample dominated by financial shocks.

The conceptual framework we use in the identification of the shocks—linking the real exchange rate to these shocks and FXI policy—combines three considerations: A link between the real exchange rate and the current account, imperfect substitution between domestic and foreign assets, and the effects of FXI. Imperfect asset substitution in this framework can be interpreted as a reduced form of the mechanism presented in Gabaix and Maggiori (2015). They analyze the effects of financial flows on the real exchange rate in a model in which imbalances in the denomination of each country's assets and liabilities are financed by international financiers who bear the risks involved in these imbalances. To increase their holdings of a given denomination, the financiers require a higher return on that denomination. For example, absorbing an increased supply of domestic assets should be accompanied by a current depreciation and an expected appreciation. The central bank can moderate the resulting exchange fluctuations by absorbing domestic assets in exchange for foreign assets. Cavallino (2016) uses a New Keynesian small open-economy model which incorporates the Gabaix and Maggiori financial friction, and characterizes the optimal FXI as an additional policy tool by the central bank when the economy is subject to financial flows.[1] Imperfect substitution between domestic and foreign assets could also follow from transaction costs which generates segmented markets, as in Alvarez, Atkeson and Kehoe (2002).

Our empirical methodology of separating sub-samples, and then considering the question at hand by comparing the results across the different sub-samples has a similarity with the procedure employed by Blanchard, Adler and Carvalho Filho (2015)—although 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 this reaction, 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 countries for which the FXI response is larger—the interveners—the exchange response is smaller—supporting the stabilizing role of FXI.

Although the FXI literature emphasizes financial flows, FXI could 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 Gavaix and Maggiori's financiers. This should reduce the extent to which the desired demand for imports takes place, and opens the question whether 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 paper is organized as follows. Section 2 presents the conceptual framework we use and Section 3 elaborates on the empirical procedure based on this conceptual

[1] Adler, Lama and Medina (2016) analyze a similar question, but they focus on the implications of policy goals uncertainty.

framework. The data and the empirical results are reported in Section 4. We use a panel data set with 25 countries which do not include the reserve currency countries, and with flexible enough exchange rates and other conditions. 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 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 and independently distributed.[2] Furthermore, we assume that there is no endogenous interaction between the shocks; in other words, we assume a linear framework.

Defining F_t^e, CA_t^e, and ΔR_t^e as the endogenous components, we express the three balance of payments variables as

$$F_t = F_t^e + \widetilde{F}_t, \tag{2}$$

$$CA_t = CA_t^e + \widetilde{CA}_t, \tag{3}$$

and

$$\Delta R_t = \Delta R_t^e + \widetilde{\Delta R}_t. \tag{4}$$

Each endogenous component includes its reaction to the *other* shocks, e.g., F_t^e includes the effects of $\widetilde{CA}_t$ and $\widetilde{\Delta R}_t$ on financial outflows. The symbol $\widetilde{F}_t$ represents the equilibrium effect of a shock to financial outflows on financial outflows. In other words, it expresses the change in F_t in an experiment where the only shock operating is of financial nature. The same applies to $\widetilde{CA}_t$ and CA_t if the only shock operating in period t is of real nature.

[2] In Footnote 2 we mention the case of a permanent real shock.

The endogenous component of FXI follows the rule:

$$\Delta R_t^e = \alpha^f \widetilde{F}_t + \alpha^r \widetilde{CA}_t, \quad -1 < \alpha^f \leq 0, \quad 0 \leq \alpha^r < 1, \tag{5}$$

i.e., FXI policy may react to both financial and real shocks. The central bank moderates the effects of these shocks on the real exchange rate by purchasing foreign exchange in response to a financial inflow shock ($\widetilde{F}_t < 0$) or to a real shock increasing excess imports ($\widetilde{CA}_t > 0$), and sells 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—are illustrated in the diagrams below. These diagrams 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, $\bar{S}$ does not move as much as the current real exchange rate, and (c) the domestic and world real interest rates are equal.

Consider for example Figure 1. The downward slopping F-curve reflects the following mechanism: Given the expected future exchange rate, a lower current exchange rate implies a higher expected depreciation which makes foreign assets relatively more profitable. Hence, the desired portfolio composition changes in favor of foreign assets. The negative slope reflects imperfect substitution between domestic and foreign assets: The higher the degree of substitution between the two assets, the more moderate is the expected depreciation that triggers a given amount of portfolio rearrangement. Hence, the higher the degree of substitution, the smaller is the slope of the F-curve. Accordingly, perfect substitution yields a flat curve, where UIP holds at all times given the assumption of equal interests rates at home and abroad. With imperfect substitution UIP does not hold in general; It does only when all shocks are zero.

The mechanism generating imperfect asset substitution in the F-curve can be the portfolio considerations of international financiers as in Gabaix and Maggiori (2015). In their model, imbalances in the denomination of each country's assets and liabilities are financed by financiers who bear the risks involved in being exposed to these imbalances. To increase their holdings of a given denomination, the financiers require a higher return on that denomination. For example, absorbing an increased supply of domestic assets should be accompanied by a current depreciation and an expected appreciation. This example amounts to a movement upwards/leftwards along the F-curve.[3]

[3] The F-curve can also be thought of capturing financial behavior under portfolio adjustment costs as represented in Schmitt-Grohe and Uribe (2003)—their equation (30). The point $\bar{S}$ corresponds to their steady state of zero borrowing/lending, while deviations from it involve the equality of the

The upward slopping curve, CA, 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 balanced 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 on the real exchange rate and the balance of payments 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 assets substitution, i.e., with an horizontal F-curve, the real exchange rate would not be affected. The central bank's FXI policy is represented by the curve $F' + \Delta R^e$, to the right of the F'-curve. The assumption that the central bank attempts only to moderate the effect of the shock implies that the new curve is still to the left of 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 and F_t goes down to point B. These two points would overlap without FXI.

   If instead of a financial inflow shock there is an outflow shock we would have opposite and symmetric results. Hence, financial shocks generate

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

additional return with the marginal portfolio adjustment cost.

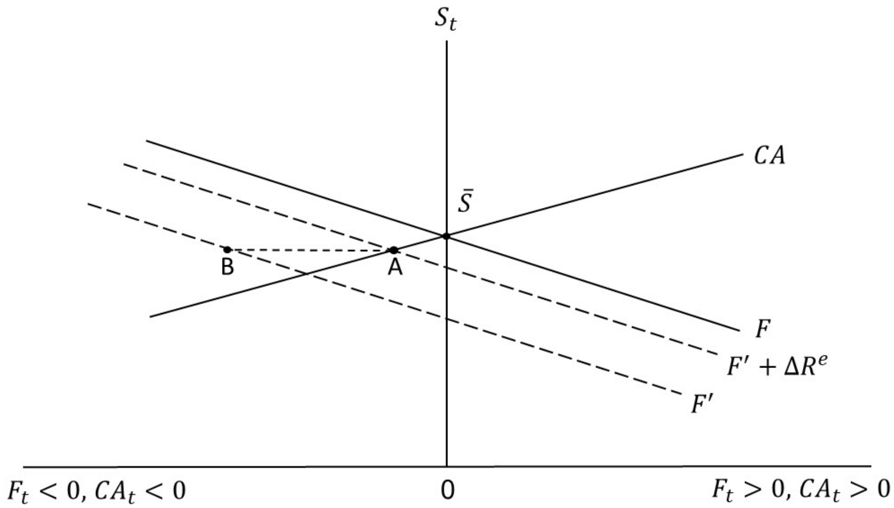

Figure 1: Financial Shocks

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 generates a temporarily high demand for foreign exchange which causes a temporary depreciation that would not prevail if the F-curve is flat. 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. These two points would overlap if there is there is no FXI.[4]

   With a positive real shock instead of a negative one we would have symmetric results; hence, real shocks generate

$$F_t \cdot CA_t > 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) < 0. \tag{7}$$

[4]Note that if the shock is 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.

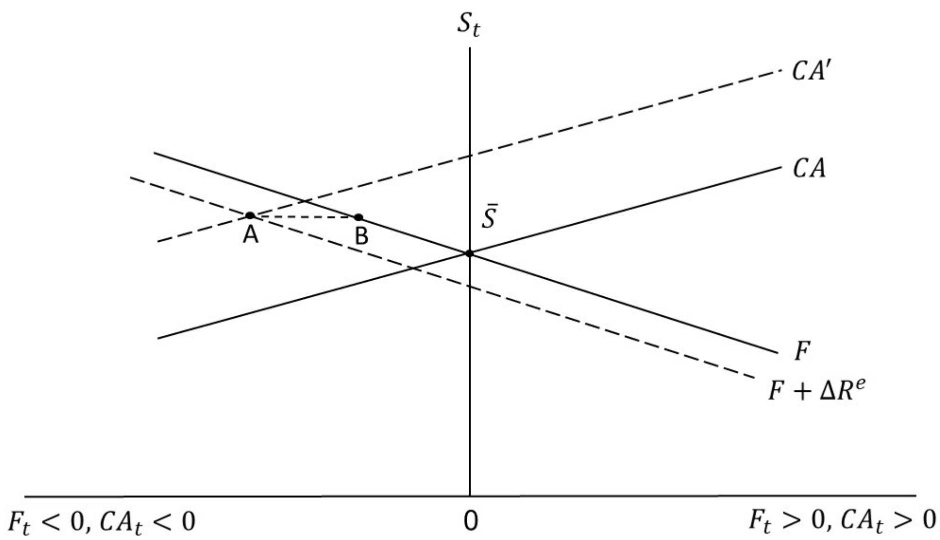

Figure 2: Real Shocks

3. The effects of a FXI shock, $\widetilde{\Delta R_t} > 0$, are shown in Figure 3. Unlike with the financial and the real shocks, F_t and CA_t change here 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 thus F_t goes down to point B. If the $\widetilde{\Delta R_t}$ shock is negative, the responses are symmetrically opposite. Hence, FXI shocks generate

$$F_t \cdot CA_t < 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) < 0. \tag{8}$$

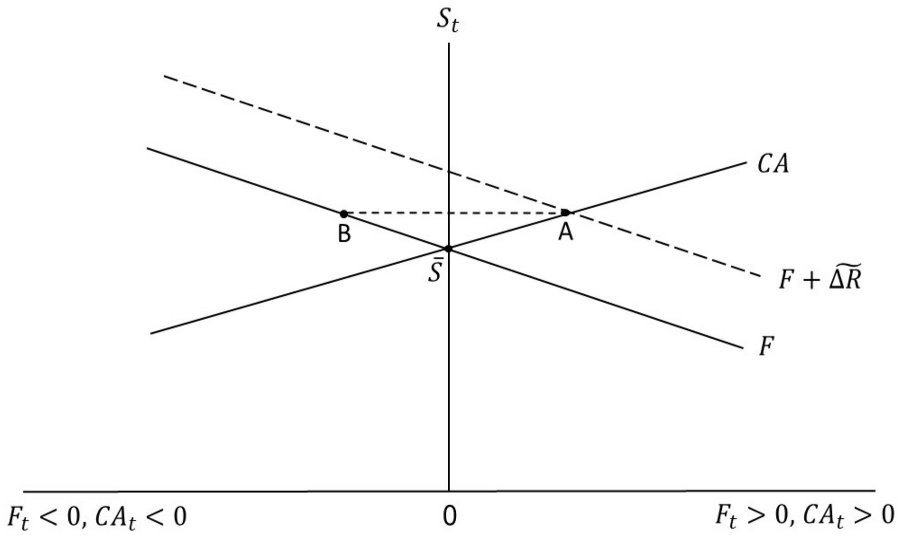

Figure 3: FXI Shocks

4. Note that (6), (7) and (8) are three out of the four possible combinations of the two inequalities involved. The remaining combination is

$$F_t \cdot CA_t < 0 \text{ and } F_t \cdot \left(S_t - \bar{S}\right) > 0. \tag{9}$$

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 (9). 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'. Now we incorporate FXI, generating the curve $F' + \Delta R^e$. The results are: $S_t - \bar{S} < 0$, $CA_t > 0$ in point A, and $F_t < 0$ in point B—satisfying both inequalities in condition (9). Note that to satisfy $F_t \cdot CA_t < 0$, it is necessary that the intervention is placed around the zero vertical axis. This implies that the financial and the real shocks should have similar quantitative effects on the real exchange rate.

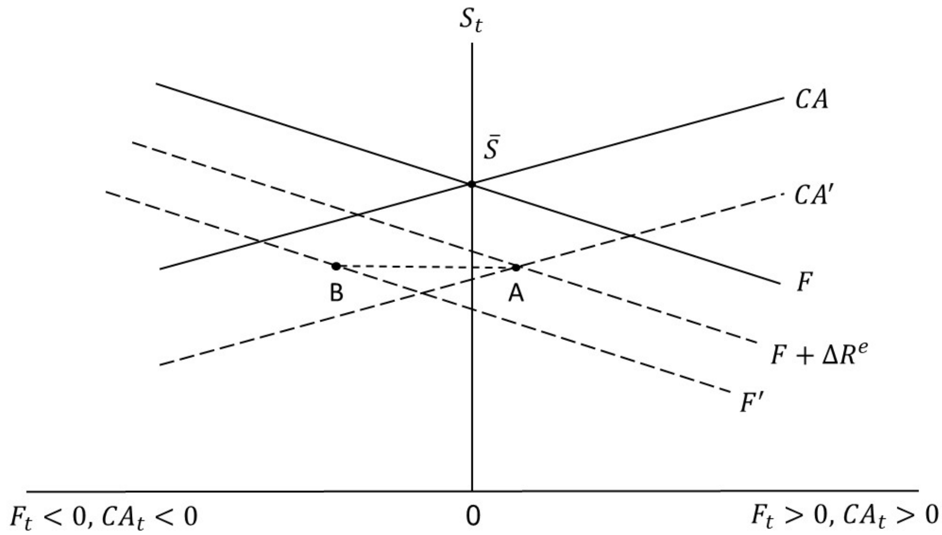

Figure 4: Combined Financial/Real Shocks

3 Empirical Procedure

First, we use the discussion in Section 2 to separate the periods (quarters) in the data set into four samples, based on satisfying one of the conditions (6), (7), (8) or (9):

Sample 1: Interpreted as dominated by financial shocks (condition (6) holds).
Sample 2: Interpreted as dominated by real shocks (condition (7) holds).
Sample 3: Interpreted as dominated by FXI shocks (condition (8) 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 (9) holds).[5]

We investigate which shocks FXI reacts to by addressing separately each one of the samples. Within 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

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

equation. We form a conclusion on the question at hand on the basis on the results from the different samples.

The empirical equations for each sample are the following.

Sample 1: Financial shocks dominate

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

$$\mathbf{\Delta R}_{it} = \alpha_{0i}^{f} + \alpha_{1}^{f}\mathbf{F}_{it} + residual_{it}, \tag{10}$$

where i is the country index, and bold symbols indicate ratios to GDP. 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 $\alpha_1^f < 0$ 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 $-1 < \alpha_1^f < 0$.

Given our definition of the shocks, if the financial shocks were the only shocks operating, then, with perfect data, $\mathbf{F}_{it}$ would correspond exactly to the current financial shock and there would be no residual. However, given that financial shocks dominate but they are not the only shocks in this sample, the residual includes the effects of the other shocks—in addition to errors and omissions. Given the effects of these other shocks on $\mathbf{F}_{it}$, the estimated coefficient α_1^f will in general contain an endogeneity bias relative to the structural parameter α^f. In Section 4.3 we analyze this bias empirically by choosing samples which sequentially strengthen the degree to which the financial shocks dominate—and thus the endogeneity bias weakens.

We also consider the question indirectly, using the pair of real exchange rate equations

$$\ln\left(S_{it}/\bar{S}_{it}\right) = \beta_{0i}^{f} + \beta_{1}^{f}\mathbf{\Delta R}_{it} + residual_{it}, \tag{11}$$

and

$$\ln\left(S_{it}/\bar{S}_{it}\right) = \gamma_{0i}^{f} + \gamma_{1}^{f}\mathbf{\Delta R}_{it} + \gamma_{2}^{f}\mathbf{F}_{it} + residual_{it}. \tag{12}$$

Equation (11) has only FXI as explanatory variable. If central banks do intervene in the FX market in this sample, then $\mathbf{\Delta R}_{it}$ should be positive when $\ln\left(S_{it}/\bar{S}_{it}\right)$ is negative. Hence, β_1^f should include a negative endogeneity bias. Equation (12) controls for financial flows, and hence if FXI does respond to financial shocks we should find that $\gamma_1^f > \beta_1^f$. We also expect $\gamma_2^f > 0$, i.e., that financial outflows cause a depreciation.

Note that $\gamma_1^f > 0$ indicates that the intervention is effective, and this holds regardless of whether FXI reacts to financial shocks or not. If it does react, $\mathbf{\Delta R}_{it}$ should have a positive effect because financial flows are held constant. If it does not react, then $\mathbf{\Delta R}_{it}$ reflects independent central bank demand for foreign exchange—i.e., an FXI shock—as we see below in Sample 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.* In order to moderate it, the central bank *buys* foreign exchange. Correspondingly, in the FXI equation

$$\mathbf{\Delta R}_{it} = \alpha_{0i}^r + \alpha_1^r \mathbf{CA}_{it} + residual_{it}, \tag{13}$$

$\alpha_1^r > 0$ would be an indication that FXI responds to real shocks.

Similarly as in Sample 1, also α_1^r contains an endogeneity bias relative to the structural parameter α^r. We return to this issue in Section 4.3.

The parallel equations to (11) and (12) are

$$\ln S_{it} - \ln \bar{S}_{it} = \beta_{0i}^r + \beta_1^r \mathbf{\Delta R}_{it} + residual_{it}, \tag{14}$$

and

$$\ln S_{it} - \ln \bar{S}_{it} = \gamma_{0i}^r + \gamma_1^r \mathbf{\Delta R}_{it} + \gamma_2^r \mathbf{CA}_{it} + residual_{it}. \tag{15}$$

Similarly as for the previous sample, $\gamma_1^r > \beta_1^r$ indicates FXI in response to real shocks. Here, we expect $\gamma_2^r < 0$—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

$$\ln S_{it} - \ln \bar{S}_{it} = \gamma_{0i}^x + \gamma_1^x \mathbf{\Delta R}_{it} + residual_{it}, \tag{16}$$

where $\mathbf{\Delta R}_{it}$ should represent the dominating FXI shocks. Here we expect $\gamma_1^x > 0$.

Sample 4: Combined financial and real shocks dominate

Unlike the previous three cases, all variables here reflects 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 for Sample 1 will make 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 at quarterly intervals. The countries and the sample period for each one are listed in Appendix A, Table A2. Countries included do not issue currencies used as reserves by other 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, Reinhard 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 1 presents descriptive statistics for the four samples, which include the number of observations in each sample and the average absolute magnitudes of the key 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 1: Average Absolute Magnitudes

Dominating Shocks	Obs	$ln\left(S/\bar{S}\right)$	$\mathbf{\Delta R}$	**F**	**CA**
1. Financial	790	0.122	0.024	0.058	0.046
2. Real	538	0.117	0.024	0.055	0.047
3. FXI	144	0.102	0.042	0.034	0.029
4. Financial/Real Combined	180	0.095	0.051	0.035	0.032

The largest is Sample 1, dominated by financial shocks, with 48 percent of the observations, and the second largest is Sample 2, dominated by real shocks, with 32 percent. The other two samples are smaller.

The two largest samples have similar magnitudes of the four variables: With financial shocks, the real exchange rate is slightly more volatile—12.2 percent compared to 11.7 percent with 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 4.6 and 4.7 percentage points.

The smaller samples, 3 and 4, differ from the two larger samples in two respects: The magnitudes of **F** and **CA** are much smaller—between 3.0 and 3.5 percentage points of GDP compared to $4.6 - 5.8$ in Samples 1 and 2—and the magnitude of FXI is much larger—4.3 and 5.1 percentage points compared to 2.4 percentage points.

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 are inconsistent with this.

Regarding Sample 3, the larger FXI magnitude could be expected from periods dominated by FXI shocks, and the smaller magnitudes of the Balance of Payment variables could follow from the fact that these shocks do not affect them directly as the financial and real shocks.

The smaller magnitude of **F** and **CA** in Sample 4 could 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 from panel regression with country fixed effects for each one of the samples. Standard errors—the smaller numbers under the coefficients—are corrected for 25 countries clusters.

4.2.1 Sample 1: Financial Shocks Dominate

Table 2 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 about 30 percent of the flow.

Columns (ii) and (iii) show the results from 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, take 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 **F** is positive, reflecting the positive effect of exogenous financial outflows on the real exchange rate.[6]

[6]This column can also be thought of as a test for the efficacy of FXI: The coefficient of $\mathbf{\Delta R}$ in a

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 2 support the hypothesis that central banks do intervene in the FX market in response to financial shocks in a quantitatively important manner.

Table 2: Sample Dominated by Financial Shocks

	Dependent Variable			
	$\mathbf{\Delta R}$	$ln\left(S/S\right)$		
	(i)	(ii)	(iii)	(iv)
F	-0.300^{***}		1.417^{***}	1.243^{***}
	0.037		0.198	0.133
$\mathbf{\Delta R}$		-0.556^{***}	0.580^{**}	
		0.190	0.276	
Obs	790	790	790	790

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

4.2.2 Sample 2: Real Shocks Dominate

In this sample, given that real shocks dominate, the current account should reflect shocks to exports or imports. In Column (i) of Table 3 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) are not very different. In Column (ii), the coefficient of $\mathbf{\Delta R}$ is positive but statistically insignificant, in contrast with the negative and significant parallel coefficient in Table 2. When **CA** is added in Column (iii), the coefficient of $\mathbf{\Delta R}$ goes up and becomes significant at the 5% level.[7] The higher and more significant coefficient of $\mathbf{\Delta R}$ in Column (iii)—relative to Column (ii)—could 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 $\mathbf{\Delta R}$.

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.

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

Hence, we conclude that FXI either responds very weakly or it does not respond to real shocks.

Table 3: Sample Dominated by Real Shocks

	Dependent Variable			
	$\mathbf{\Delta R}$	$ln\left(S/S\right)$		
	(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	538	538	538	538

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

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 address this sample for completeness, although it does not address the issue the reaction of FXI to financial or real shocks. The only relevant regression equation here is of $ln\left(S/\bar{S}\right)$ on $\mathbf{\Delta R}$. The estimated coefficient is 1.47, with a standard error of 0.243.[8] Hence, the coefficient is highly significant—p-value of less than 0.001. In other words, the impact of FXI on the real exchange rate is 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 6 and 7. We interpret this difference as the result of a cleaner identification of FXI shocks in this sample where FXI shocks dominate.

4.2.4 Sample 4: Combined Financial/Real Shocks Dominate

Because the two types of shocks occur simultaneously in this sample, each one of the variables **F** and **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 **F**, as we did for Sample 1 to test the FXI response to financial shocks. The estimated coefficient is -1.009 with a standard error of 0.08 (p-value of less than 0.001).[9] The large size of the coefficient of **F**—three times the magnitude of the corresponding coefficient in Table 2—could be explained in two different ways.

[8] The number of observations is 144.

[9] The number of observations here is 180.

One explanation follows the hint mentioned when discussing Table 1, that in cases where 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 say that in these cases FXI responds also to the real shocks. This explanation is consistent with the large average magnitude of $\mathbf{\Delta R}$ for this sample reported in Table 1, i.e., FXI responds strongly because it reacts to both the financial and the real shocks.

However, there is also a reverse causality explanation to 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 1 about FXI responding to real shocks in this sample cannot be verified with the current methodology.

4.3 Analysis of the Endogeneity Bias

Here we focus on the estimates of FXI in response to financial and real shocks. The analysis in this paper is based on dividing the data into separate samples in which one type of shock is dominant. Given that presumably the other shocks are also active in each sample leads to endogeneity biases in the estimates within each sample. Here, we test the implications of reducing these biases by sequentially tightening the criteria for a shock to be dominant. This, of course, reduces progressively the size of each sample. Practically, we replace conditions (6) and (7):[10]

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

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

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

[10] We do not proceed with condition (8) because Sample 3 is small,and not with (9) for Sample 4 because it is not only small but also dominated by two simultaneous shocks. Hence, tightening this condition cannot weaken the bias.

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 I_j^s and I_{j+1}^s there are five percent of the observations in the corresponding sample.

Then, the regressions of $\mathbf{\Delta R}$ on $\mathbf{F}$ or $\mathbf{CA}$ for Samples 1 and 2 are estimated sequentially, deleting each time the observations in lowest remaining bin $I_j^s \longrightarrow I_{j+1}^s$. This implies that the criteria 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 weakens 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 red line shows the coefficient of financial flows on FXI, i.e., α_1^f—measured along the vertical axis on the left— and the green line shows the corresponding t-statistics—along the vertical axis on the right. All the coefficients are highly significant statistically.

The main result in Figure 5 is that as the importance of the endogeneity bias diminishes relative to the effects of the financial shock, the coefficient becomes more negative. We interpret this result as reducing the errors-in-variables bias towards zero due to the fluctuations of $\mathbf{F}$ in response to real shocks.[11]

Quantitatively, the size 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 completely clean of the endogeneity bias. Our result here is that *at least* 36 percent of the exogenous financial inflows are absorbed by FXI.

[11] This interpretation is based on the following considerations. The bias in the coefficient of $\mathbf{F}$ in this sample is due to the endogenous responses of $\mathbf{\Delta R}$ to the other two shocks, FXI and real, which represent the residual in the regressions. (1) FXI shocks included in the residual should be negatively correlated with $\mathbf{F}$—as indicated in the discussion of Figure 3 above. This should generate a negative bias. Hence, as this bias becomes less important along the sequence of regressions, we should expect that the coefficient moves towards zero. We observe the opposite, and thus this consideration cannot be the dominant one. (2) According to the results in Table 3, $\mathbf{\Delta R}$ responds very weakly to real shocks. Hence, no important endogeneity bias is generated on this account. However, real shocks are accompanied by endogenous movements in $\mathbf{F}$ without affecting $\mathbf{\Delta R}$. In the present context, this generates an errors-in-variables bias towards zero. This is the bias that is interpreted to diminish along the sequence of regressions.

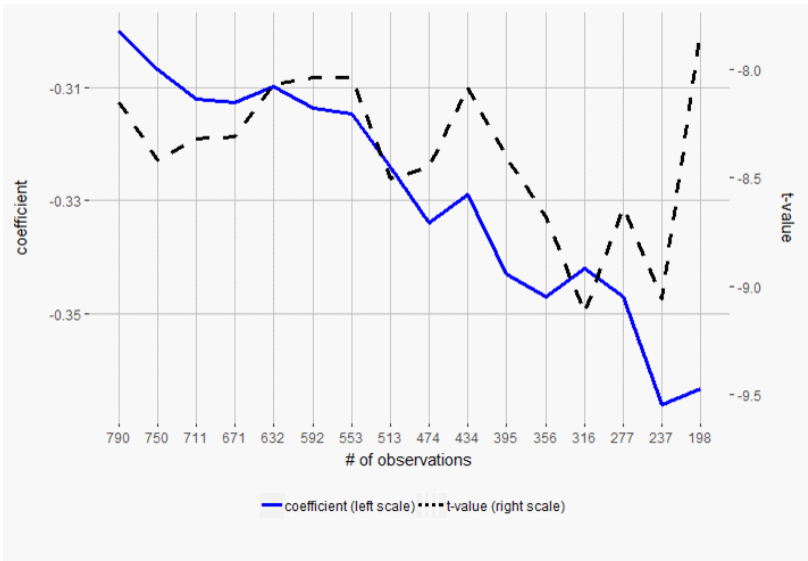

Figure 5: Sequential Coefficients of $\mathbf{F}$ (α_1^f) and t-Values

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, specially towards the end of the sequence, do not allow 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 a FXI in response to real shocks to moderate fluctuation of the exchange rate is weak.[12]

[12] Regarding Sample 3, the coefficient 1.47 CORRECT for the effect of FXI on the real exchange rate should be considered a lower bound to 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.

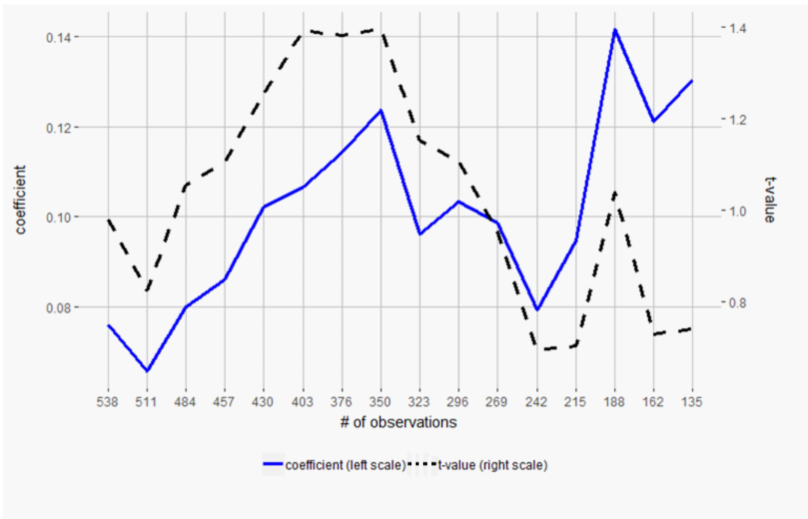

Figure 6: Sequential Coefficients of **CA** (α_1^r) and t-Values

4.4 Testing for a Change in 2008

Here we compare the period from 2008:1 onwards to the earlier period. Table 4 reports the results from adding interactions between the right-hand side variables and a dummy variable with 1 for the period 2008:1 onwards and 0 otherwise. These interaction variables are indicated by $\mathbf{F}', \mathbf{CA}'$ and $\mathbf{\Delta R}'$.

Table 4: Change From 2008 Onwards

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

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

Table 4 shows that none of the interactions with the dummy from 2008:1 onwards is statistically significant. However, the table shows that the interaction term $\mathbf{\Delta R}'$ has negative coefficients in the real exchange rate regressions in all three samples. This could be taken as weak evidence that the FXI effects on the exchange rate attenuated from 2008 onwards. Additionally, the interaction term $\mathbf{F}'$ has positive coefficients in Columns (i) and (iii), both hinting a weaker FXI response to financial shocks after 2008. 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 not only in response 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 besides 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 the financial flows. This is consistent with a willingness to moderate the fluctuations in the exchange rate. Regarding real shocks, we detect a positive but small and statistically insignificant FXI response. The estimates are stable across two sub-periods: Before and after 2008.

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A Data Appendix

Name	Symbol	Construction
Real exchange rate	S_t	Nominal US dollar rate in domestic currency/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	$\mathbf{\Delta R}_t$	Change in Reserves in US$× Exchange Rate/Nominal GDP [2],[3]
Rate of Change of the Dollar/Euro Exchange Rate	–	1990:1–1998:4–Deutche Mark [4] 1999:2–2015:4–Euro
Rates of 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 the Balance of Payments 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 to deflate nominal GDP 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	1990:1–2015:4
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 Payments 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).