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Sergio Da Silva and Mauricio Nunes

Federal University of Santa Catarina

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Sergio Da Silva
Department of Economics, Federal University of Santa Catarina

Mauricio Nunes
Department of Economics, Federal University of Rio Grande Do Sul

Abstract

We examine Latin American foreign exchange intervention in a framework where the exchange rate regime is endogenous and there exists an inefficient, equilibrium foreign exchange intervention bias. The model suggests that greater central bank independence is associated with lesser intervention in the foreign exchange market, and also with leaning-against-the-wind intervention. Both results are confirmed by data from 13 Latin American countries.

JEL classification: F31, F41

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1. Introduction

A stylized fact of foreign exchange markets is that sterilized interventions by central banks cannot influence exchange rates on a permanent basis. Unlike the costs, the benefits of intervention are far from being obvious. So why do central banks continue to intervene? One possible answer is that intervention is not exogenously carried out by central banks. Rather, it may be an endogenous outcome of the strategic interaction between central banks and private market participants.

The model in this paper thus endogenizes foreign exchange intervention only to find a nonzero equilibrium amount of intervention as a result. Such an "intervention bias" is analogous to the well-known "inflationary bias" of Kydland-Prescott and Barro-Gordon games of monetary policy. These explain why zero inflation cannot occur as the central bank intervenes to stabilize its currency's domestic value. Central banks of industrialized countries are mainly concerned with the management of the domestic value of their currencies, not the external. Thus the literature on monetary policy games has received widespread attention. Does one need an exchange rate policy game still? Why not use two separate monetary policy games (one for the domestic and one for the foreign country) to explain the countries' relative price levels?

Two separate monetary policy games may lead to optimal price levels that might conceivably be at odds with purchasing power parity. PPP cannot be dismissed because it is the basis for most theories of international price determination and sets the conditions under which international markets adjust to attain long-term equilibrium. To properly evaluate the external value of a currency, one thus needs to replace two separate monetary policy games with an exchange rate policy game.

Section 2 fills this gap and sets an exchange rate policy game to model endogenous intervention. We find an inefficient, equilibrium foreign exchange intervention bias, and that greater central bank independence is associated with both lesser intervention in the foreign exchange market and leaning-against-the-wind intervention. Section 3 shows that these results are confirmed by data from 13 Latin American countries. Section 4 concludes.

2. Model

Foreign exchange intervention is modeled by policy rule

$$\frac{M_t}{M_t^T} = \left(\frac{E_t}{E_t^T}\right)^{\phi} \tag{1}$$

where M_t is domestic money supply at t, M_t^T is money supply target, E_t is nominal exchange rate (home currency price of foreign currency), and E_t^T is domestic central bank target for the nominal exchange rate. Central bank parameter ϕ tracks the degree of intervention in the foreign exchange market. It is zero under free float and approaches plus or minus infinity for a fixed exchange rate. Leaning-against-the-wind intervention occurs if $\phi \in (-\infty, 0)$, whereas leaning-into-the-wind intervention occurs if $\phi \in (0, \infty)$. This rule was pioneered by Marston (1985), and was subsequently employed by Obstfeld and Rogoff (1996, p. 632).

If $\phi = 0$, the central bank focuses exclusively on money supply target, refraining from any intervention in the foreign exchange market. If $\phi \to \pm\infty$, the central bank focuses exclusively on its nominal exchange rate target, and shows no concern about money supply.

Leaning against the wind is the intervention operation that attempts to move the exchange rate in the opposite direction from its current trend, and leaning into the wind is motivated by the central bank's desire to support current exchange rate trends. Here both types of intervention are carried out by changes in M_t^T. Whether such changes are sterilized is not discussed. Non-sterilized intervention is just a combination of monetary change and (sterilized) intervention. So we consider the influence of monetary policy on exchange rates, not overall intervention. This can be more useful for Latin America and other emerging countries than perhaps to the United States and Japan, where the monetary authority plays a negligible role in foreign exchange intervention. The target level for the exchange rate is exogenous. In a leaning-against-the-wind intervention, for instance, E^T might represent past levels of the exchange rate. This follows from the idea of smoothing exchange rate fluctuations. If the exchange rate was at a desirable level in the previous period, then deviations from the target level are countered.

The domestic central bank is assumed to intervene in the foreign exchange market at the end of time period s to react to shocks that materialized between the end of $s-1$ and the end of s. Central bank's loss function L_t^{CB} is

$$L_t^{CB} = \sum_{s=t}^{\infty} \rho^{s-t} \left[\frac{(\psi\phi_s)^2}{2} + \frac{\mu\left(\phi_s - \phi_s^e\right)^2}{2} + \frac{\gamma\left(E_s - E_s^T\right)^2}{2} \right] - U_t \tag{2}$$

where parameter $\rho \in (0,1)$ is a discount factor applied to future losses of the central bank related to its exchange rate management, $\psi \in (0,\infty)$ is a factor of proportionality for the costs of intervention through the portfolio balance channel, $\mu \in (0,\infty)$ is a parameter capturing the costs of the expectations channel of intervention, $\gamma \in (0,\infty)$ weighs the central bank aversion to deviations from its exchange rate target, $\phi_s^e \in (-\infty,\infty)$ is the central bank intervention expected by a representative speculator, and U_t is a domestic residents' generic utility function.

Domestic speculator's loss function L_t^S is

$$L_t^S = \sum_{s=t}^{\infty} \sigma^{s-t} \left[\frac{(\phi_s^e - \phi_s)^2}{2} \right] - U_t \tag{3}$$

where $\sigma \in (0,1)$ is a discount factor related to the speculator's future losses.

The first and second terms in brackets on the right-hand side in (2) proxy the costs of intervention through the portfolio balance channel and expectations channel respectively. Central bank losses are assumed to increase more than proportionately with the volume of these interventions. Compared to individual private currency dealers, central banks are bigger participants in the market. Yet intervention volumes are very tiny if compared to daily turnovers on foreign exchange markets. So it is possible for the exchange rate not to be affected by the volume of intervention itself. But intervention can still affect the exchange rate through the portfolio balance channel (first term in brackets on the right-hand side in (2)). The volume of intervention does not matter if $\psi = 0$, and it matters if $\psi > 0$, in which case purchases (sales) of foreign currency impact the exchange rate positively (negatively).

In equation (2) there is also room for central bank intervention to work through the expectations channel. Actual higher-than-expected intervention may catch the speculator off balance, thereby leading to a correction in the exchange rate. So the second term in brackets on the right-hand side in (2) allows the central bank to exploit the divergence between actual and expected intervention in order to influence the exchange rate. The expectations channel does not matter if $\mu = 0$, and it is operative if $\mu > 0$, in which case actual larger-than-expected purchases (sales) of foreign currency impact the exchange rate positively (negatively).

The third term in brackets on the right-hand side in (2) tracks the fact that central bank losses increase more than proportionately with nominal exchange rate changes that are not caused by the relative state of domestic macroeconomic "fundamentals". The last term on the right-hand side in (2) shows that the central bank not only cares about exchange rate policy but also considers the utility (wellbeing) of domestic residents.

The first term in brackets on the right-hand side in (3) captures the speculator's aversion to being fooled by the central bank. When that actually happens, the speculator's losses increase more than proportionately. The second term on the right-hand side in (3) shows the speculator considering the losses coming from exchange rate policy after correcting for his gains from utility. The strategic interaction between central bank and speculator is assumed to come into play only after a shock to the nominal exchange rate has materialized. Since such a shock can also result from the interaction between the various sorts of decision made by a number of market participants, the assumption above rules out intra-speculators' behavior, thereby making it possible to treat distinct traders as a unique representative speculator.

Time periods are disconnected, and thus minimization of (2) and (3) is carried out as a repeated play of one-shot games. Moreover, although foreign exchange intervention is assumed to affect the nominal exchange rate from the start, this is not a full model of exchange rate determination. Yet wherever exchange rate model is in the black box, we assume the utility function not to depend on the nominal exchange rate, as in models where classical dichotomy holds (e.g. Stockman 1987, p. 17, n. 13, and Da Silva 2002).

Choice variables of central bank and speculator are ϕ and ϕ^e respectively. Because interaction takes place after the occurrence of a shock, this can be perceived by both central bank and speculator, who simultaneously set ϕ_t and ϕ_t^e. As in Barro-Gordon-type models, equal status of players leads to Nash equilibrium.

Central bank's reaction function to the speculator's expectation can be found from minimization of its loss at t, taking ϕ_t^e as given. Partially differentiating (2) relative to ϕ_t, and setting the result to zero yields

$$\phi_t = \frac{1}{\mu + \psi^2}\left[\frac{\partial U_t}{\partial \phi_t} - \gamma\left(E_t - E_t^T\right)\frac{\partial E_t}{\partial \phi_t} + \mu\phi_t^e\right] \tag{4}$$

In reaction function (4), ϕ affects both utility and nominal exchange rate in particular ways that are left implicit in $\partial U_t / \partial \phi_t$ and $\partial E_t / \partial \phi_t$ respectively.

Partially differentiating (3) relative to ϕ_t^e (taking ϕ_t as given), and setting the result to zero yields the speculator's reaction function, i.e.

$$\phi_t^e = \phi_t \tag{5}$$

The intervention corresponding to Nash equilibrium is found by plugging (5) into (4), i.e.

$$\phi_t = \frac{1}{\psi^2}\left[\frac{\partial U_t}{\partial \phi_t} - \gamma\left(E_t - E_t^T\right)\frac{\partial E_t}{\partial \phi_t}\right] \tag{6}$$

Thus equilibrium intervention is more than proportionately lower, the greater the costs of intervention through the portfolio channel (the bigger ψ). And there exists a nonzero equilibrium "intervention bias" ($\phi_t \neq 0$). For instance, $\partial U_t/\partial\phi_t = \gamma(E_t - E_t^T)\partial E_t/\partial\phi_t$ for $E_t > E_t^T$ obtains only by chance. Equilibrium intervention will be leaning against the wind ($\phi_t < 0$) if the central bank considers the management of the exchange rate ($|\gamma(E_t - E_t^T)\partial E_t/\partial\phi_t|$) more important than the domestic residents' wellbeing ($|\partial U_t/\partial\phi_t|$). Leaning-into-the-wind intervention ($\phi_t > 0$) will be optimal otherwise.

The intervention bias is arguably inefficient because the costs involved are not offset by any benefits. There are no benefits because the nonzero amount of intervention is fully anticipated by the speculator (equation (5)). So intervention cannot succeed in preventing the impact of the shock to the exchange rate. Almekinders (1995) has pioneered this intervention bias of discretionary exchange rate policy. But our model is simpler and further considers both alternative types of intervention and domestic wellbeing. Unlike in Almekinders' model, where central bank leadership removes the intervention bias, this persists in our model regardless of the players' status.

The central bank acts as a Stackelberg leader if it takes action before the speculator and thus knows the exact shape of the speculator's reaction function. So it is able to pick the point on the speculator's reaction function that minimizes its own losses. It thus sets ϕ_t, and ϕ_t^e gets determined endogenously. Equation (6) again obtains in the Stackelberg equilibrium. (To see this, substitute (5) into (2), partially differentiate relative to ϕ_t, and set the result to zero.) The speculator acts as a Stackelberg leader if he sets ϕ_t^e, and ϕ_t gets determined endogenously. The Stackelberg equilibrium is again equation (6). (To see this, insert (4) into (3), partially differentiate relative to ϕ_t^e, set the result to zero, and then plug the resulting expression for the expected volume of intervention into (4).)

3. Equilibrium intervention and central bank independence

Central bank independence to conduct monetary policy has been related to low inflation rates with no consequences to economic growth (Grilli *et al.* 1991, Alesina and Summers 1993, Cukierman 1992, Eijffinger and Haan 1996, Jacome 2001, and Jacome and Vasquez 2005). Yet independence can also be interpreted in terms of exchange rate management, in which case heightened independence is associated with lesser intervention in the foreign exchange market. This issue will be our major concern in this section. We will also consider whether intervention leans against the wind or leans with the wind.

In terms of the model in Section 2, here we focus on parameter γ. This parameter gauges the importance the central bank places in preventing exchange rate fluctuations away from its target. In the monetary policy game literature, the parameter associated with the importance given to output stability is seen as the inverse of the degree of central bank independence (Rogoff 1985). The idea behind this is that the central bank knows that in the long run it cannot systematically stimulate output by means of surprise inflation. So it will only engage in larger-than-expected monetary expansions if it is forced to do so by politicians and if it is not protected from their influence by law. Similarly, if the central bank lacks independence, it is frequently forced to intervene in the foreign exchange market. The more independent a central bank is, the lesser it is influenced by political pressure to counteract speculative shocks to the exchange rate. Our model in Section 2 tracks such a stylized fact because parameter γ is negatively related to equilibrium intervention in equation (6). Likewise the greater the central bank independence, the lower the variability of intervention volume (Almekinders 1995).

Analogous to the negative relationship between inflation rate and central bank independence, Almekinders (1995) finds evidence favoring a negative relationship between foreign exchange intervention and central bank independence for 20 industrialized countries. He employs changes in currency reserves as proxies for intervention, and uses the central bank independence index of Eijffinger and Schaling (1993). A negative relationship is found for the variability of intervention and independence. However, the use of changes in reserves as a good proxy for intervention activity can be criticized on the basis that they are too noisy and that reserves can change for reasons having nothing to do with intervention. For instance, if the currency of a country depreciates, this will automatically increase the relative value of any foreign exchange holdings in central bank's portfolio. In such a situation the positive correlation between intervention (proxied by reserve changes) and lack of central bank independence could be explained by the fact that countries with a lesser independent central bank have more expansionary (and variable) monetary policy, which in turn leads to a more depreciating (and volatile) exchange rate, and therefore to larger (and more variable) foreign reserves.

Rather than relying on net foreign reserves, we take policy rule (1) to proxy for intervention and extend Almekinders' results to the emerging markets of Latin America. We consider 13 countries, namely Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Guatemala, Mexico, Paraguay, Peru, Uruguay, and Venezuela, and take monthly data over the period January 1990–December 2003 (the only available). The source is IMF's *International Financial Statistics*. The central bank (legal) independence index is that of Jacome and Vasquez (2005). This index takes into account not only economic and political sovereignty (as in Cukierman 1992) but also financial sovereignty, responsibility, transparency, and the role of the central bank as a lender in the last resort.

Latin America recently pursued more central bank independence through major reforms, mainly in Argentina (1992 and 2002), Bolivia (1995), Chile (1989), Colombia (1992), Costa Rica (1995), Mexico (1993), Paraguay (1995), Peru (1993), Uruguay (1995), and Venezuela (1992 and 2001). Table 1 shows the countries' central bank intervention index taking into account the reforms. Reform countries are indicated with a "0" (pre-reform sub-period) or "1" (post-reform sub-period). We assessed the relationship between central bank independence and intervention employing both individual-country estimation (Table 2) and cross-country estimation through panel data (Table 3).

In the individual country estimation, policy rule (1) was used to proxy for intervention. Actually we replaced nominal money supply deviation from its target with a target for nominal interest rate i^T. We also stylized departures of nominal exchange rate from its target as the deviations of real exchange rate R from its PPP value of one. This is justified because a central bank's main concern is to counteract speculative nominal exchange rate changes. The modified rule in natural logs is then

$$\ln\left(i_t^T\right) = \phi \ln\left(R_t - 1\right) \tag{9}$$

The intervention coefficients employed were obtained by individually estimating (via OLS) equation (9) for every country (Table 2). Data on nominal interest rates, nominal exchange rates, and price levels were collected from IMF's *International Financial Statistics*. In Table 2, Δ represents a series' first differences in natural logs, and D is deviation of the real exchange rate from the PPP value of one. Estimates in the regressions of Table 2 were backed by standard econometric treatment. To preventing spourious regressions, ADF and Phillips-

Peron tests were employed in order to check for stationarity. We also run a CUSUM test to check for parameter stability. Moreover, whenever autocorrelation and heteroscedasticity in residuals were detected, they were fixed through Newey-West correction.

That leaning against the wind is the usual type of intervention can be seen in the negative sign of the deviations of the real exchange rate from its PPP value of one in the regressions for Argentina(1), Bolivia(1), Brazil, Chile, Colombia(0 and 1), Paraguay(1), Peru, and Venezuela(0 and 1) (Table 2). The positive sign of the regressions in Table 2 refers to the countries with leaning-with-the-wind intervention.

With an endogenous intervention the target variable becomes the central bank independence index. Here one can think of a banking crisis dummy, for instance, as one control variable. Countries experiencing crises over the period were Argentina (2002), Colombia (1998–1999), Dominican Republic (2002–2003), Mexico (1995), Uruguay (2002), and Venezuela (1994–1995). However, since central bank reforms are usually part of broader structural reforms that include privatizations, trade reform, and other structural macro policies (Jacome and Vasquez 2005), there is a possible omitted variable bias if one considers only the banking crisis dummy. To circumvent this, we considered the index of structural reform of the Inter-American Development Bank as an extra control variable (Lora 2001, Lora and Panizza 2002).

The four panels in Table 3 show a negative relationship between the foreign exchange intervention coefficient and the central bank independence index over the period 1990–2003. The coefficients were estimated by feasible generalized least squares (FGLS) and robust coefficient covariances (White robust covariances), allowing for heteroscedasticity across countries and computing White-type robust standard errors, together with an AR(1) autocorrelation structure within countries, with a ρ coefficient common to all countries.

Regression [1] considered only the central bank index, regression [2] added the structural reform index, and regression [3] alternatively added the banking crisis dummy. Regression [4] took all these into account. Apart from the dummy for banking crisis, Table 3 shows that the variables are related at a significance level of up 10 percent. Thus the proposition that increased central bank independence can be associated with lesser intervention in foreign exchange markets holds for Latin America. Also, the structural reforms helped to reduce the need for foreign exchange intervention. The banking crises did not matter for intervention, however. Indeed the R^2 in regression [3] suggests that nearly 79 percent of the changes occurring in the intervention coefficient can be explained solely by the independence and structural reform indices.

4. Concluding remarks

We evaluate Latin American foreign exchange intervention in a framework where the exchange rate regime is endogenous and there exists an inefficient, equilibrium foreign exchange intervention bias. The intervention bias appears in an exchange rate policy game regardless of the (first-mover) status of the players (central bank vs market participants). The model suggests that greater central bank independence is associated with both (1) lesser intervention in the foreign exchange market and (2) leaning-against-the-wind intervention. Equilibrium intervention is of the leaning-against-the-wind type if the central bank considers exchange rate management more important than domestic residents' wellbeing. Both results are confirmed by data from 13 Latin American countries. Our findings are thus in accordance with those of

Almekinders for industrialized countries, who employed OLS cross-country regressions and took foreign reserves as a proxy for intervention. We dismiss the use of reserves and assess the relationship between central bank independence and intervention employing both individual-country estimation (via a policy rule from our model) and cross-country estimation through panel data.

	Time Period	CBII
Group 1		0.84
ARG–1	1993–2003	
BOL–1	1996–2003	
CHI	1990–2002	
COL–1	1993–2003	
MEX–1	1994–2003	
PER–1	1994–2003	
Group 2		0.70
CRC–1	1996–2003	
PAR–1	1996–2003	
URU–1	1996–2003	
VEN–1	1993–2003	
Group 3		0.44
ARG–0	1990–1992	
BOL–0	1990–1995	
BRA	1990–2003	
COL–0	1990–1992	
CRC–0	1990–1995	
GUA	1990–2003	
DOM	1990–2003	
MEX–0	1990–1993	
PAR–0	1990–1995	
PER–0	1990–1993	
URU–0	1990–1995	
VEN–0	1990–1992	

Table 1. Latin American central bank independence and reform

Notes
Reform countries are indicated with a “0” (pre-reform sub-period) or “1” (post-reform sub-period)
CBII is central bank independence index
Source: Jacome and Vasquez (2005)

$\Delta i^T = 1.3621^* \Delta D$ (8.75)	Adjusted $R^2 = 0.45$	(ARG–0)
$\ln i^T = -0.18^* \ln D$ (−3.65)	Adjusted $R^2 = 0.03$	(ARG–1)
$\ln i^T = 0.006^* + 0.805^* \ln D$ (2.45) (2.58)	Adjusted $R^2 = 0.24$	(BOL–0)
$\ln i^T = -0.050^* \ln D$ (−3.50)	Adjusted $R^2 = 0.02$	(BOL–1)
$\ln i^T = 1.336^* - 0.0512^* \ln D$ (7.54) (−2.73)	Adjusted $R^2 = 0.03$	(BRA)
$\ln i^T = 1.456^* - 0.216^* \ln D$ (11.24) (−10.6)	Adjusted $R^2 = 0.33$	(CHI)
$\Delta i^T = 0.02^* + 0.048^* \Delta D$ (2.72) (2.29)	Adjusted $R^2 = 0.14$	(COL–0)
$\ln i^T = 0.404^* - 0.238^* \ln D$ (26.03) (−13.42)	Adjusted $R^2 = 0.77$	(COL–1)
$\Delta i^T = 0.51^* \Delta D$ (2.43)	Adjusted $R^2 = 0.17$	(CRC–0)
$\ln i^T = -0.05^* \ln D$ (−4.18)	Adjusted $R^2 = 0.13$	(CRC–1)
$\Delta i^T = -0.38^* + 0.155^* \Delta D$ (−6.43) (9.12)	Adjusted $R^2 = 0.46$	(DOM)
$\Delta i^T = 0.116^* \Delta D$ (6.52)	Adjusted $R^2 = 0.06$	(GUA)
$\ln i^T = -1.44^* + 0.675^* \ln D$ (−3.35) (3.84)	Adjusted $R^2 = 0.65$	(MEX–0)
$\ln i^T = -1.22^* + 0.599^* \ln D$ (−8.62) (9.78)	Adjusted $R^2 = 0.71$	(MEX–1)
$\ln i^T = 0.019^* \ln D$ (12.3)	Adjusted $R^2 = 0.005$	(PAR–0)
$\ln i^T = -1.33^* \Delta D$ (−3.54)	Adjusted $R^2 = 0.71$	(PAR–1)
$\ln i^T = 0.807^* \ln D$ (3.67)	Adjusted $R^2 = 0.003$	(PER–0)
$\ln i^T = 0.435^* - 0.265^* \ln D$ (4.75) (−3.10)	Adjusted $R^2 = 0.19$	(PER–1)
$\Delta i^T = 1.443^* \Delta D$ (6.80)	Adjusted $R^2 = 0.41$	(URU–0)
$\Delta i^T = 0.369^* \Delta D$ (3.43)	Adjusted $R^2 = 0.03$	(URU–1)
$\ln i^T = 2.43^* - 0.271^* \ln D$ (2.37) (−2.04)	Adjusted $R^2 = 0.28$	(VEN–0)
$\ln i^T = -0.049^* \ln D$ (−26.52)	Adjusted $R^2 = 0.07$	(VEN–1)

Table 2. Policy rule: individual-country regressions
Note: * means significance at the 5 percent level, and figures in brackets show the *t*-statistic

Regression	[1]	[2]	[3]	[4]
Constant	0.0008* (66.82)	0.000* (67.07)	0.0008* (58.03)	0.0008* (51.39)
Central Bank Independence Index	–0.199* (–2.53)	–0.176* (–2.03)	–20.05* (–2.49)	–20.06* (–2.48)
Structural Reform Index		$-2.20E^{-0.7**}$ (–1.76)		–0.02** (–2.52)
Dummy for Banking Crisis			–0.03 (–0.75)	–0.03 (–0.75)
R^2	0.033	0.79	0.032	0.030
Observations	2.184	2.184	2.184	2.184
Number of Countries	13	13	13	13
ρ	0.98	0.98	0.98	0.98

Table 3. Panel regressions using feasible generalized least squares (FGLS)

Note
** means significance at the 10 percent level, and figures in brackets show the *t*-statistic

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