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Interdependencies between Monetary Policy and Foreign Exchange Intervention under Inflation Targeting

The Case of Brazil and the Czech Republic

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Abstract

The bulk of recent literature on foreign exchange interventions has overlooked the potential interdependencies that may exist between these operations and the conduct of monetary policy. This is the case even under inflation targeting and especially in emerging-market economies, because central banks often explicitly reserve the right to intervene to calm disorderly markets and to accumulate foreign reserves, and when the exchange rate is perceived as being out of step with fundamentals. This paper uses a friction model to estimate intervention reaction functions and the associated marginal effects for Brazil and the Czech Republic since the adoption of inflation targeting in these countries in 1999 and 1998, respectively. The main findings are that: (i) in both countries interventions occur predominantly to reduce exchange rate volatility, while in

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Keywords: monetary policy, interventions, inflation targeting, friction model, Brazil, Czech Republic

JEL classification: C24, E52, F31

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Brazil the central bank also reacts to exchange rate deviations from medium-term trends; (ii) there are strong, asymmetric threshold effects in the reaction functions, and interventions are more likely and of higher magnitudes when they are carried out to depreciate than to appreciate the domestic currency; and (iii) interventions seem to take place independently of contemporaneous monetary policy in Brazil, but not in the Czech Republic, where both policies appear to be interrelated.

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1 Introduction

The bulk of recent literature on foreign exchange interventions has overlooked the potential interdependencies that may exist between these operations and the conduct of monetary policy. Because price stability is the overriding policy objective in a monetary regime combining inflation targeting with a floating exchange rate, the central bank is assumed not to use foreign exchange interventions as a policy tool in pursuit of an independent policy goal. Nevertheless, inflation-targeting central banks often explicitly reserve the right to intervene in the foreign exchange market—by selling or purchasing foreign currency in the spot market with the aim of influencing currency parities—when the exchange rate 'deviates from fundamentals' and/or 'displays excessive volatility'.[1] The problem is that the conditions under which foreign exchange interventions are allowed are difficult to define and communicate. Market participants may therefore perceive interventions as an attempt by the central bank to target a specific level of the exchange rate, which would create interdependencies between interventions and monetary policy.

It has also been argued that the 'benign neglect' of exchange rate developments by the central bank when setting monetary policy is a particularly strong assumption in the context of emerging market economies. This is because these economies typically suffer from sizeable currency mismatches in debt portfolios, which aggravate the balance sheet effects of exchange rate fluctuations. Also, central banks may lack *de facto* operational autonomy, and the pass-through of exchange rate changes to prices tends to be higher than in more mature economies. In such an environment, monetary policy itself may be responsive to exchange rate developments, which creates a potential simultaneity between intervention and monetary policies. This hypothesis has so far been tested empirically by including the exchange rate in Taylor rule-type monetary reaction functions (e.g., Mohanty and Klau 2005; de Mello and Moccero 2006).

Another argument for shedding further light on interdependencies between interventions and monetary policy is the fact that interventions may convey information about future monetary stance. For example, interventions may signal a perception that the exchange rate is misaligned, which might subsequently trigger a change in the monetary stance. On the other hand, the monetary stance itself may be a good predictor of interventions. Establishing the direction of causality is essentially an empirical question. Evidence based on temporal causality tests tends to favour the hypothesis that interventions signal monetary policy moves, at least for the United States (Lewis 1995; Kaminsky and Lewis 1996; Fatum and Hutchison 1999). Recent empirical evidence for emerging markets has focused some attention on testing for inconsistencies between interventions and monetary policymaking under inflation targeting, at least as far as the Czech Republic is concerned (Holub 2004; Gersl and Holub 2006). This is the case, for example, when the central bank purchases foreign currency while tightening monetary policy.

Against this background, the empirical analysis reported in this paper focuses on the experiences of Brazil and the Czech Republic. Both countries abandoned exchange rate targeting (although the Czech Republic maintains a managed float) and have pursued

[1] See Moser-Boehm (2005) for cross-country information on the institutional settings for monetary, exchange rate and intervention policies.

monetary policy within an inflation-targeting framework since 1998-99, while periodically intervening in the foreign exchange market. Information is therefore available for a long enough timespan at the monthly frequency, which is more appropriate for capturing changes in the monetary stance than the higher frequencies (i.e., daily or intraday) at which the effects of intervention on the exchange rate are conventionally tested. A distinctive feature of both the Brazilian and Czech experiences, as well as other emerging-market economies, is that both interventions and monetary policymaking are under the purview of the central bank. This makes a clear distinction with respect to several more mature economies, where monetary policy is conventionally decided by the central bank and exchange rate policy by the ministry of finance (Humpage 2003), although it is still implemented by the central bank in the latter case. This distinction in institutional settings is important, because it may increase the scope for interdependencies between interventions and the conduct of monetary policy. It may also facilitate policy coordination: if interventions and monetary policy are coordinated, purchases of foreign currency should be accompanied by interest rate cuts and vice versa.

Our empirical contribution is two-fold. First, we use a friction model to estimate intervention reaction functions for Brazil and the Czech Republic. In friction models, the dependent variable is insensitive to its determinants over a range of values (Neely 2005). This is an appealing feature of the model, because the intervention series are discontinuous (i.e., there often are long spells of no intervention). The friction model therefore predicts zeros in periods when there is no intervention. Our model specifications include exchange rate volatility and deviations of the exchange rate from trend, as well as variables capturing the monetary stance, such as the policy interest rate. We use realized volatility (defined as the sum of squared daily returns within a month), because it is less noisy than other measures estimated from GARCH models (Andersen et al. 2003). We compute robust standard errors to deal with potential serial correlation in the disturbance terms, given the persistency of interventions, and heteroscedasticity in the data, because of the clustering of small and large-scale interventions around specific periods of time. Second, we compute the marginal effects associated with the estimated coefficients to discuss the presence of asymmetries that might exist in intervention reaction functions. This is the case, for example, when the central bank reacts more strongly to currency appreciations than depreciations. To our knowledge, this paper is the first one in the empirical literature to compute the marginal effects associated with intervention reaction functions estimated on the basis of a friction model.

Our main empirical findings are as follows:

- The main motive for intervening in the spot foreign exchange market in Brazil and the Czech Republic appears to be to calm disorderly markets, rather than to target a specific level of the exchange rate. Interventions were found to be strongly affected by exchange rate volatility in both countries, and by exchange rate deviations from medium-term trends in Brazil;
- There appears to be strong, asymmetric threshold effects in the intervention reaction functions for both Brazil and the Czech Republic. The monetary authorities in these countries tend to react more strongly when aiming at depreciations than appreciations of the domestic currency; and

– Interventions seem to take place independently of current monetary policy in Brazil, but not in the Czech Republic, where both policies appear to be interrelated. There is no evidence that interventions provide strong signals about future monetary policy moves in either country.

The paper is organized as follows. Section 2 discusses possible sources of interdependencies between monetary and intervention policies and reviews the empirical literature. Section 3 presents the estimation strategy and describes the friction model and the data used in the econometric analysis. Section 4 summarizes the institutional set-up for monetary and intervention policies in Brazil and the Czech Republic. In Section 5 we empirically assess the determinants of interventions and report the corresponding marginal effects. Section 6 concludes.

2 The literature on foreign exchange interventions

There is a sizeable, predominantly empirical, literature on central bank interventions in developed countries, surveyed by Sarno and Taylor (2001) and Humpage (2003), among others. For emerging-market economies, the empirical literature is more recent and far less voluminous. By intervening in the foreign exchange market, the monetary authority aims to affect the exchange rate through three main channels. First, if interventions are not sterilized, they alter the money supply and hence the exchange rate directly. In this case, interventions and the monetary stance are clearly interconnected Second, when sterilized, interventions change the supply of bonds denominated in domestic and foreign currency. Because these securities are not perfectly substitutable, the exchange rate is affected by an ensuing change in portfolio composition. Finally, interventions may signal future monetary policy moves, even when they are sterilized; purchases of foreign currency should indicate an impending monetary easing, which also has a bearing on the exchange rate (Mussa 1981). Of course, only through sterilized interventions can the central bank pursue an exchange rate objective in a manner that is independent of monetary policy setting.

The empirical literature focuses on the estimation of 'intervention reaction functions' to predict the timing and magnitude of interventions, as well as for testing whether or not the motives stated by the authorities for intervening are borne out by the data (Almekinders 1995; Almekinders and Eijffinger 1996; Baillie and Osterberg 1997; Ito and Yabu 2007; Kearns and Rigobon 2005; Bernal 2006; Beine et al. 2008). Appendix 1 provides an overview of the empirical literature. Motivation comes essentially from the need to accurately identify the monetary authority's policy objectives when intervening in the foreign exchange market, so that the effectiveness of such interventions can be empirically gauged. The conventional strategy is to regress spot-market interventions on measures of exchange rate deviation from fundamentals and volatility (Ito 2003), as well as controls. General functional specifications are as follows:

$$I_t = \beta X_t + \varepsilon_t , \qquad (1)$$

where I_t denotes the magnitude of interventions at time t, X_t is a set of explanatory variables, and ε_t is an error term.

Empirical studies on intervention reaction functions often lack explicit theoretical foundations. A plausible hypothesis is that exchange rate volatility and/or misalignments (i.e., deviations from fundamentals) reduce welfare, especially when price-setting is affected by a risk premium associated with exchange rate uncertainty (Obstfeld and Rogoff 1998). Empirical evidence nevertheless suggests that these welfare losses are small for industrial economies, but may be large in emerging-market economies (Bergin 2004).[2] Also, spot-market interventions are not free of bureaucratic, political, and financial costs (Almekinders 1995; Almekinders and Eijffinger 1996). These costs create threshold effects in the reaction function; therefore, central banks intervene only sporadically, when the benefits of interventions outweigh their associated cost. Therefore, in practice, interventions are discontinuous over time and tend to be clustered around specific periods of time.

Although the idea of an intervention reaction function is conceptually fairly straightforward, the statistical distribution of intervention data, as noted above, and the potential endogeneity of the exchange rate level and volatility pose important econometric challenges. Because the dependent variable is censored, the disturbance terms of regressions of interventions on continuous variables are most likely not normally distributed. Therefore, standard linear estimators, such as ordinary least squares, should not be applied, since they produce inconsistent parameter estimates. Two estimators have been used instead: probit or ordered probit models, to estimate the probability of interventions (purchases or sales) or the probability of purchases and sales separately (Ito and Yabu 2007), and the friction model, to estimate both the occurrence and the magnitude of purchases and sales of foreign exchange (Neely 2006).

In addition, current interventions tend to depend strongly on past interventions, so that care needs to be taken when estimating reaction functions with serially correlated errors. To deal with this problem, lagged interventions are often included among the regressors in Equation 1. Although this is fine in linear models, the statistical properties of non-linear models with a lagged dependent variable among the regressors are not yet entirely known.[3] Instead, robust standard errors should be computed to take account of serially correlated errors in non-linear models. With regard to options for dealing with simultaneity biases, the use of instrumental variable techniques is problematic, because it is difficult to find good instruments for the exchange rate that are orthogonal to the shocks affecting intervention.

The problem of simultaneity has featured more prominently—although it remains by and large unresolved—in the literature on the effectiveness of interventions than in that on the estimation of intervention reaction functions. Options for dealing with the endogeneity of interventions in exchange rate equations include the use of high-frequency (typically intra-day) data, which allow for restrictions on contemporaneous

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2 This is because, as noted above, balance sheet effects due to liability dollarization are typically large in emerging markets, the pass-through of changes in the exchange rate to prices is also high, and there are limited instruments for hedging against exchange rate risk.

3 This strategy has often been used for linear models (Ito 2003; Gersl and Holub 2006). But, for non-linear models (Ito and Yabu 2007), the dependent variable is observed only when the latent variable is above a certain threshold, making the specification by far more complex. Only recently have the asymptotic properties of a limited number of non-linear models been explored when the lagged (observed, rather than latent) dependent variable is included among the regressors. See de Jong and Woutersen (2003) for a probit model, and de Jong and Herrera (2004) for a Tobit model.

effects of interventions on exchange rate movements (Dominguez 2005), and through different identification strategies, when the interrelations between interventions and the exchange rate are modelled explicitly (Neely 2005, 2006). It has been argued that changes in policy settings can be used for identification (Kearns and Rigobon 2005). The problems with these strategies are that, first, it is not easy to identify contemporaneous effects even when high-frequency data are used and, second, changes in policy highlight the problems of structural breaks in the intervention reaction function and, therefore, parameter instability. In this regard, it can be argued that changes in policy reduce the scope for interventions to convey information about future policy moves, which is one of the channels through which sterilized interventions are expected to affect the exchange rate. An alternative strategy for dealing with simultaneity is to use event studies (Fatum and Hutchison 2006). Accordingly, a success criterion is defined a priori and the frequency of success is computed over a pre-determined period of time.

3 The estimation strategy

3.1 The friction model

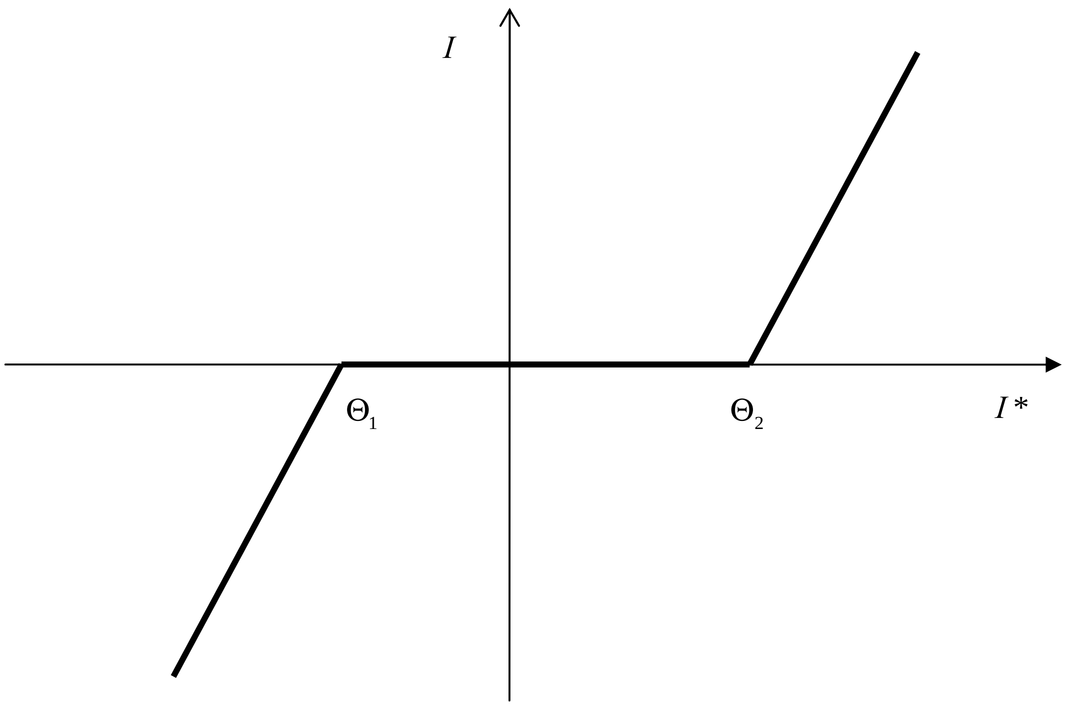
Our dataset contains information on both the date of occurrence and the magnitude of interventions. The friction model is preferred to the (ordered) probit and Tobit estimators, because it allows for all the information available on interventions to be fully used: probit models do not to take the magnitude (only the timing) of interventions into account, while the Tobit specification assumes perfect symmetry in interventions on both sides of the market. The friction model is a censored dependent-variable model (Rosett 1959) and can be written as:

$$I_t = \begin{cases} I_t^* - \Theta_1 = \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} - \Theta_1 + \varepsilon_t & \text{if} \quad I_t^* < \Theta_1 \\ 0 & \\ I_t^* - \Theta_2 = \beta_1 X_{1t} + \beta_2 X_{2t} + \beta_3 X_{3t} - \Theta_2 + \varepsilon_t & \text{if} \quad \Theta_2 < I_t^* \end{cases} \qquad (2)$$

where I_t^* is the desired level of intervention in period *t*, $X_t = (X_{1t}, X_{2t}, X_{3t})$ is a set of explanatory variables capturing the exchange rate dynamics, factors related to monetary policymaking and a set of controls, I_t is the actual level of intervention, $\varepsilon_t \sim N(0, \sigma^2)$ is an error term, $0 > \Theta_1$, and $0 < \Theta_2$.

The basic intuition of the model is that, due to the costs associated with interventions (discussed above), the central bank only sells or purchases foreign exchange when there is a significant change in exogenous conditions. These costs are explicitly captured by Θ_1 and Θ_2, which are the intervention thresholds. Figure 1 illustrates this mechanism: the central bank intervenes only if the optimal level of intervention is below Θ_1 or above Θ_2.

Figure 1
The friction model



The parameters of the model ($\Theta = (\Theta_1, \Theta_2)'$, $\beta = (\beta_1, \beta_2, \beta_3)'$, and σ) can be estimated by maximum likelihood. The likelihood function can be written as:

$$L(\Theta, \beta, \sigma \mid I, X_1, X_2, X_3) = \begin{array}{l} \prod_1 \frac{1}{\sigma}\phi\left(\frac{I_t + \Theta_1 - (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}{\sigma}\right) \times \\ \prod_2 \left[\Phi\left(\frac{\Theta_2 - (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}{\sigma}\right) - \Phi\left(\frac{\Theta_2 - (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}{\sigma}\right)\right] \times \\ \prod_3 \frac{1}{\sigma}\phi\left(\frac{I_t + \Theta_2 - (\beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3)}{\sigma}\right) \end{array} \quad (3)$$

where $I = (I_1, \ldots, I_T)'$, $X_1 = (X_{11}, X_{12}, \ldots, X_{1T})'$, $X_2 = (X_{21}, X_{22}, \ldots, X_{2T})'$ and $X_3 = (X_{31}, X_{32}, \ldots, X_{3T})'$

The product is computed over three sets of observations for which $I_t^* < \Theta_1$ (set 1), $\Theta_1 \le I_t^* \le \Theta_2$ (set 2), and $\Theta_2 < I_t^*$ (set 3). In addition, ϕ refers to the standard normal density, and Φ is the cumulative normal distribution.[4]

The interpretation of the estimated coefficients is nevertheless less trivial than in a linear setting. In a friction model, the estimated coefficients of a regression, such as Equation 1, refer to the desired (I_t^*), rather than actual (I_t), amount of intervention. Additional information (e.g., thresholds) needs to be considered to compute the observed amount of interventions. In addition, at least six types of marginal effects can be computed in a friction model: one for the desired level of intervention, one for the observed level of intervention, two for the observed level of intervention conditional on

4 For more information see Maddala (1983).

the sign of intervention (i.e., negative or positive, depending on sales or purchases of foreign exchange, respectively), and two for the probability of observing either a negative or positive intervention. These cases are discussed in detail in Appendix 2.

3.2 Data sources and definition of the variables of interest

Monthly data are used in the regressions. Information on central bank interventions, available from national sources, refers to the spot foreign exchange market. The data available from the Central Bank of Brazil (BCB) are defined in USD millions (a positive sign implies a net purchase of foreign exchange). Information is also available for Brazil on interventions in derivatives markets (exchange rate swaps) defined as the monetary authority's foreign exchange exposure (also in USD millions, a negative sign implies a net creditor position). For the Czech Republic, information readily available from the Czech National Bank (CNB) contains not only spot-market interventions but also other spot-market foreign exchange transactions, although operations related to the management of privatization proceeds are excluded. Information on pure interventions is confidential. The data are defined in EUR millions (a positive sign implies a net purchase of foreign exchange).

The additional data are available predominantly from the CD-ROM version of the International Monetary Fund's International Financial Statistics (IFS). The exchange rate is the log of the end-of-period market rate expressed in local currency units per USD in the case of Brazil, and per EUR for the Czech Republic (series AE). We computed exchange rate deviations from fundamentals as the log difference between the exchange rate and its lagged value (short-term deviation), and as the log difference between the exchange rate and its 6-month moving average (medium-term deviation). To deal with potential simultaneity, these variables will enter the reaction function lagged one period. The interest rate is the discount rate (series ZF) for the Czech Republic and the overnight SELIC rate for Brazil (available from the BCB). The output gap was constructed as the difference between output (log of the seasonally-adjusted industrial production, series CZF) and its HP-filtered series. Inflation expectations are the one-period-ahead first-difference of the log of CPI (series XZF).[5] The ratio of imports to international reserves is defined as the log difference between series DZF (cumulated over a 12-month period) and SZF (times 100).

We follow Andersen et al. (2003) and use realized, rather than parametric estimates of volatility, such as those based on GARCH models. Realized volatility is computed as the sum of squared daily returns (available from DATASTREAM) within a month.[6] The advantage of using realized volatility is that it is less noisy than measures based on GARCH modelling for the same frequency. As higher volatility may lead to both positive (purchases) or negative (sales) interventions, including it directly in the regression would weaken the statistical link between these two variables. To be able to

5. Market survey inflation expectations started to be collected in July 2001 for Brazil and in June 1999 for the Czech Republic. Using these series would have significantly shortened the estimation sample.

6 Realized volatility in month t (RV_t) is computed as $RV_t = \sum_{i=2}^{N_t} r_i^2$, where $r_i = 100 * (\ln e_i^t - \ln e_{i-1}^t)$, N_t is the number of working days in month t, and e_i^t is the end-of-day nominal exchange rate in day i of month t.

recover an interpretable coefficient, we opted for signing volatility positively for purchases and negatively for sales of foreign currency. For the days with no intervention, we followed Almekinders and Eijffinger (1996) and signed volatility according to the sign of the deviation of the exchange rate from trend: volatility takes a positive sign if the deviation of the exchange rate from trend is negative (i.e., the domestic currency is overvalued) and a negative sign when the exchange rate deviation is positive (*i.e.,* the domestic currency is undervalued).[7] To deal with potential simultaneity, the variable enters the reaction function lagged one period.

The time periods for the empirical analysis are country-specific and were selected on the basis of adoption of inflation targeting as the policy framework for the conduct of monetary policy. The sample spans the period 1999:7-2007:3 for Brazil and 1998:1-2007:3 for the Czech Republic.[8]

4 Monetary policy regimes in Brazil and the Czech Republic, and empirical studies

Both Brazil and the Czech Republic conduct monetary policy within an inflation-targeting framework and have intervened occasionally in the foreign exchange market since adoption of inflation targeting in 1998-99. Although Brazil has allowed the exchange rate to float freely since the peg was abandoned in January 1999, the Czech exchange rate regime can be characterized as a managed float. Intervention and monetary policies are under the purview of the central bank in both countries. Against this background, empirical studies for these countries have been mainly directed to assess the effectiveness of interventions in shaping exchange rate dynamics.

4.1 Brazil

Brazil formally adopted inflation targeting in July 1999. The central bank is allowed to intervene in the foreign exchange market to smooth excessive exchange rate volatility and build up international reserves. Interventions are sterilized through open-market operations.

Over the period of analysis, the nominal exchange rate depreciated steadily after the abandonment of the peg in January 1999 until end-2002, despite short-lived periods of appreciation, and began to appreciate thereafter. A lack of confidence in the policies to be pursued by the frontrunner fuelled a speculative attack on the *real* in the run-up to the presidential election of October 2002, leading to a sharp depreciation during May-

7 The Almekinders-Eijffinger strategy is based on the idea that the central bank may purchase (sell) foreign exchange to reduce volatility even when the exchange rate is perceived as already undervalued (overvalued). For more information see Almekinders and Eijffinger (1996).

8 The sample excludes other emerging market inflation targeters, such as Chile, Colombia and Turkey, because interventions occurred only for limited periods of time in the case of Chile and Colombia and because of Turkey's comparatively short experience with inflation targeting. Israel, Mexico, and Poland were not included in the analysis, because no interventions took place since the widening of the exchange rate band in Israel in 1997, and the abandonment of the exchange rate crawling peg in Poland in 2000. For Mexico, interventions consist of daily auctions of foreign currency and are considered a reserve management instrument.

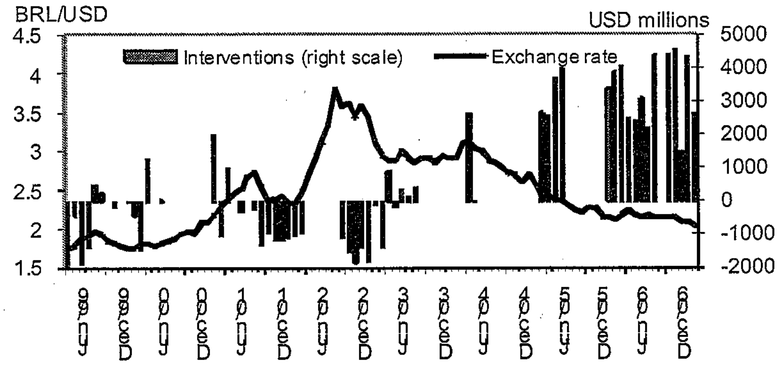
October. Maintenance of a responsible macroeconomic policy mix after the new administration took office in 2003 restored confidence in the policy setting. Robust trade and current account surpluses sustained the appreciating trend (Figure 2).

Spot-market interventions were predominantly against the wind in the form of pre-announced auctions of USD until end-2002. Interventions also took place in the derivatives market through the sale of exchange rate swaps, which resulted in a sharp increase in the public sector's exposure to foreign exchange risk over the period.[9] At the same time, monetary policy was tightened sharply. Since 2003, interventions have been less frequent and predominantly in the form of USD purchases to build up international reserves and to smooth excessive volatility in the spot market. Consistently, the unwinding of foreign exchange swaps has reduced the public sector's exposure to a net creditor position. Sustained disinflation and the restoration of credibility in the policy regime have prompted a gradual relaxation of the monetary stance, despite a tightening in the first half of 2005.

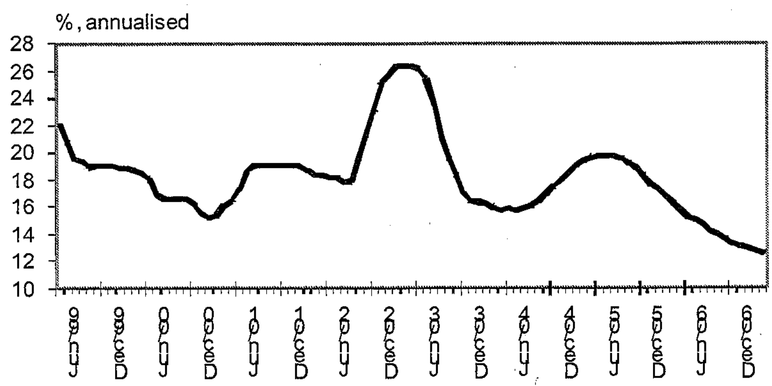
Figure 2

Brazil: Exchange rate, interventions and monetary policy, 1999:7-2007:3

A. Exchange rate and interventions



B. Policy interest rate



Source: Central Bank of Brazil.

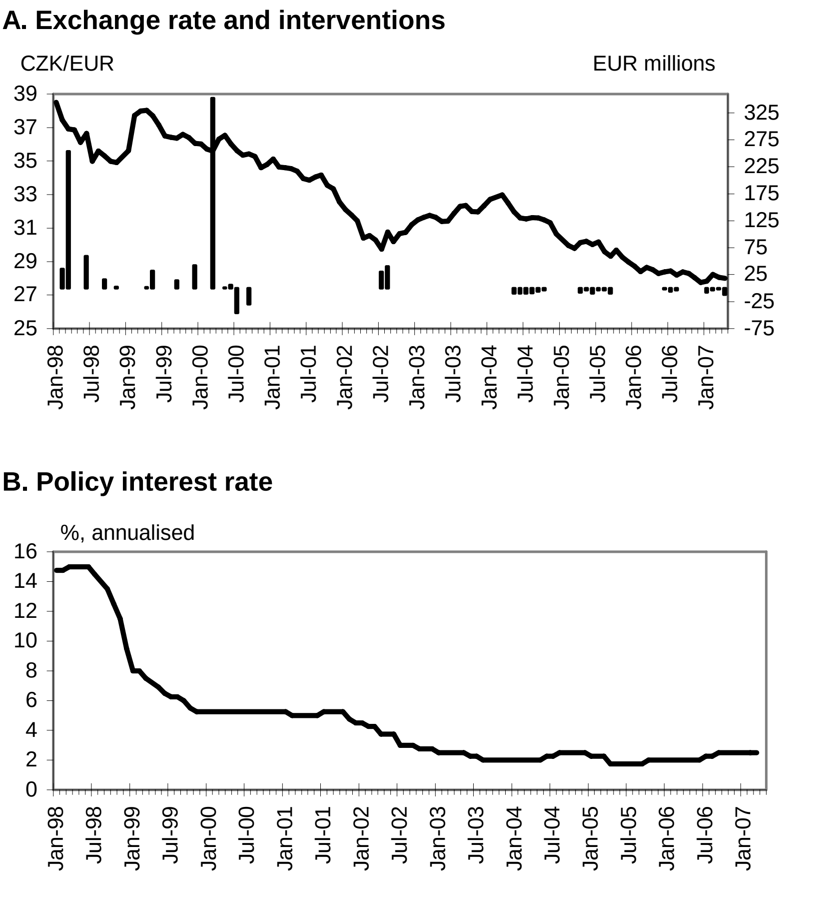
9 Through the exchange rate swaps, the BCB pays contract holders the variation in the USD/BRL exchange rate plus the local onshore USD interest rate, and receives in exchange the cumulative one-day interest rate on interbank certificates of deposit (CDI rate) over the duration of the contract. See Bevilaqua and Azevedo (2005) for more information.

4.2 Czech Republic

The Czech monetary policy framework combines inflation targeting (since January 1998) with a managed exchange rate (since May 1997). A ‘formal commitment’ by the CNB to exchange rate management has been justified on the basis of the economy’s openness to trade and investment and the ensuing potential adverse effects of external shocks on the achievement of the inflation target. The reference currency for the koruna was the Deutschemark until 1999 and subsequently the euro. The CNB reserves the right to intervene in order to smooth ‘major deviations of the exchange rate that are not connected with domestic economic fundamentals and domestic monetary policy’ (CNB 1998), although it does not target any central parity or fluctuation band. Interventions are sterilized through open-market operations.[10]

The koruna appreciated steadily against the euro over the reference period, except for a short period at the beginning of 1999, and between mid-2002 and end-2003 (Figure 3).

Figure 3
Czech Republic: Exchange rate, interventions and monetary policy, 1998:1-2007:3



Source: Czech National Bank.

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10 Open market operations have been used extensively by the CNB since the first half of the 1990s to mop up the excess liquidity associated with the accumulation of foreign reserves. See Holub (2004) for an estimate of sterilization costs in the Czech case.

A sizable interest rate differential, especially during the early period of inflation targeting, as well as inflows of long-term capital linked to improved economic fundamentals and a comprehensive privatization programme after 2001 are the key drivers of the appreciating trend. Spot-market interventions were particularly large at the beginning of 1998, between end-1999 and early 2000, and during 2002, and consisted mainly of purchases of foreign currency to counter the appreciation of the koruna. The CNB has not intervened since 2003, despite a continued appreciation of the domestic currency since early 2004.[11] Although no official statement was made on the reasons for the policy change, a lack of success of previous interventions and the quasi-fiscal costs associated with sterilization operations are likely to have been the main culprits. To prevent monetary conditions from becoming overly restrictive, the CNB gradually relaxed the monetary stance during the period of analysis.

4.3 The effectiveness of exchange rate interventions in Brazil and the Czech Republic

There are very few studies on interventions in the case of Brazil. The existing literature focuses on the effect of spot-market interventions and the issuance of exchange rate derivatives (swaps) and dollar-denominated government securities on the level of the exchange rate. Novaes and Oliveira (2007) show that interventions are ineffective in periods of high exchange rate volatility, such as the transition period between the abandonment of the exchange rate peg and the adoption of inflation targeting in the first semester of 1999, and the run-up to the presidential election in the second semester of 2002. In turn, when the foreign exchange market is calm, the level of the exchange rate seems to be affected more strongly by interventions (in both the spot and derivatives markets), than the stance of monetary policy. The estimation technique is GMM and daily data span the period January 1999-October 2006.

As in the case of Brazil, the literature on foreign exchange interventions in the Czech Republic has focused on testing the effectiveness of such interventions using both event studies and GARCH estimations, rather than on the estimation of intervention reaction functions. By estimating a reaction function using instrumental variables and daily data for the period 2001-02, Disyatat and Galati (2007) find that interventions had a negligible impact on the spot rate and left volatility broadly unchanged. This finding is consistent with the evidence reported by Gersl and Holub (2006) on the basis of GARCH modelling. There also appears to be some asymmetry in interventions, which seem to have taken place predominantly to counter an appreciation of the koruna. Instead, the event study performed by Holub (2004) using monthly data lends some support to the success of intervention policies. On the basis of the event study and GARCH estimations reported by Egert and Komarek (2005) using daily data, interventions appear to have been effective in smoothing exchange rate volatility during from mid-1998 to 2002 when performed in coordination with monetary policy moves.

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11 The CNB has also used off-market operations to convert the proceeds of privatizations into international reserves since 2002. These operations are considered more effective than monetary policy and spot-market interventions in countering appreciation of the koruna (CNB 2001), as well as being less costly to the CNB (Holub 2004).

5 The results

5.1 The determinants of intervention

The results of the estimation of the intervention reaction functions for Brazil and the Czech Republic are reported in Tables 1 and 2, respectively.[12] The regression results confirm the presence of threshold effects in the reaction functions, which lends strong support to the friction model specification. Both thresholds are statistically significant at classical levels, and one of them (Θ_1) is higher in absolute value than the other (Θ_2), suggesting that the central bank intervenes asymmetrically: it appears to react more strongly when aiming to depreciate than to appreciate the domestic currency.[13]

For Brazil, interventions appear to depend strongly on exchange rate deviations from trend, at least over the medium term. A depreciation of the *real* relative to its six-month moving average triggers sales of foreign currency by the monetary authority, which characterizes leaning-against-the-wind interventions. The central bank does not appear

Table 1
The determinants of exchange rate interventions in Brazil[1]

(Dependent variable: Spot-market interventions, in USD billion)

	Model (1)	Model (2)	Model (3)
Threshold 1 (Θ_1)	-2.641*** [0.494]	-2.643** [0.496]	-2.64** [0.495]
Threshold 2 (Θ_2)	0.887* [0.470]	0.887* [0.469]	0.919* [0.471]
FX deviation from trend (short term)	-0.033 [0.097]	-0.032 [0.098]	-0.036 [0.099]
FX deviation from trend (medium term)	-0.123** [0.055]	-0.125* [0.057]	-0.123** [0.058]
FX volatility	0.022* [1.120]	0.022* [0.012]	0.022* [0.012]
Interest rate (one period ahead)	-0.004 [0.107]	-0.017 [0.139]	-0.022 [0.138]
Interest rate (contemporaneous)	– –	0.015 [0.105]	– –
Interest rate (fitted from Taylor rule)[2]	– –	– –	0.097 [0.128]
Interest rate (residuals from Taylor rule)[2]	– –	– –	0.097 [0.129]
FX swaps	-0.066 [0.055]	-0.067 [0.056]	-0.067 [0.057]
Ratio of international reserves to imports	0.185* [0.11]	0.185* [0.109]	0.181* [0.108]
Likelihood function	-155.04	-155.03	-154.87

Notes: 1) The estimation period runs from July 1999 to March 2007. HAC robust standard errors are reported in parentheses. (***), (**) and (*) denote statistical significance at the 1%, 5% and 10% levels, respectvely.

2) The results of the estimation of the Taylor rule are reported in Appendix 3.

Source: Authors' calculations based on data from the Central Bank of Brazil.

12 Unit root tests (not reported) were performed and variables were first differenced when needed.

13 The friction model estimated by Neely (2006) does not allow for asymmetries in the estimation of the threshold.

Table 2
The determinants of exchange rate interventions in the Czech Republic[1]

(Dependent variable: Spot-market interventions, in EUR billions)

	Model (1)	Model (2)	Model (3)
Threshold 1 (Θ_1)	-0.154*** [0.044]	-0.146*** [0.041]	-0.171*** [0.049]
Threshold 2 (Θ_2)	0.111*** [0.04]	0.122*** [0.044]	0.106** [0.025]
FX deviation from trend (short term)	-0.011 [0.025]	-0.014 [0.026]	-0.016 [0.025]
FX deviation from trend (medium term)	0.022 [0.015]	0.022 [0.016]	0.022 [0.014]
FX volatility	0.025*** [0.007]	0.023*** [0.007]	0.024*** [0.007]
Interest rate (one period ahead)	-0.004 [0.002]	-0.003 [0.003]	-0.005 [0.003]
Interest rate (contemporaneous)	– –	-0.009* [0.004]	– –
Interest rate (fitted from Taylor rule) [2]	– –	– –	0.013 [0.012]
Interest rate (residuals from Taylor rule) [2]	– –	– –	-0.01* [0.005]
Ratio of international reserves to imports	0.080 [0.065]	0.082 [0.062]	0.082 [0.058]
Likelihood function	-24.66	-21.85	-20.58

Notes: 1) The estimation period runs from January 1998 to March 2007. HAC robust standard errors are reported in parentheses. (***), (**) and (*) denote statistical significance at the 1%, 5% and 10% levels, respectvely.

2) The results of the estimation of the Taylor rule are reported in Appendix 3.

Source: Authors' calculations based on data from the Central Bank of Brazil.

to react to short-term exchange rate misalignments, at least as defined as changes in the nominal exchange rate from the previous month. The estimation results also show that the central bank reacts to exchange rate volatility, as hypothesized, to calm disorderly markets.[14] These results are robust to different model specifications. Moreover, there does not appear to be a substitution effect between intervention operations in the spot market and in derivatives, given that the coefficient of the variable capturing the public sector's exposure to exchange rate risk associated with the issuance of foreign exchange swaps is not statistically significant. Finally, the regression results are robust to the inclusion of the ratio of foreign reserves to imports to control for the fact the central bank has often stated that interventions have also aimed at accumulating international reserves as a means of reducing the country's external vulnerabilities.

As for the Czech Republic, there is no evidence of a response by the central bank to exchange rate misalignments, unlike the case of Brazil. But exchange rate volatility also triggers a strong response by the monetary authority. These findings are robust to different model specifications. The presence of threshold effects in the reaction function is also validated by the data, as well as the asymmetry in interventions, which appears to

14 A similar result was obtained in the case of Japan using an ordered probit methodology, where the authorities seem to be more prone to intervene following increases in exchange rate volatility (Bernal and Gnabo 2007).

be more prevalent when they are carried out to counter an appreciation of the domestic currency than a depreciation. In addition, unlike Brazil, there does not appear to be a statistically significant effect of changes in foreign reserves on interventions.

5.3 Interdependencies between intervention and monetary policies

With regard to the interdependencies between interventions and monetary policymaking, the regression results highlight important differences between the two countries in the sample. For neither country do the findings suggest that interventions carry strong signals about future moves in monetary policy. The one-period-ahead policy interest rate fails to attract a statistically significant coefficient in both countries. There is nevertheless evidence that the current monetary stance, gauged by the contemporaneous policy interest rate, is negatively correlated with interventions in the Czech Republic. Therefore, a tightening of monetary policy appears to complement spot-market interventions, suggesting that both policies are implemented in a coordinated manner. In the case of Brazil, no evidence was found to indicate that there might be contemporaneous interdependencies between interventions and the conduct of monetary policy. The contemporaneous policy interest rate is not statistically significant at classical levels.

To test this hypothesis further, the contemporaneous interest rate was decomposed into its predicted value on the basis of the estimation of a Taylor rule-type monetary reaction function and the residuals of this reaction function. The regression results (reported in Appendix 3) show that the BCB raises interest rates in response to an increase in inflation expectations and the output gap. The lagged dependent variable is also strongly significant, suggesting some interest rate smoothing when setting monetary policy.[15] The CNB responds to changes in expected inflation, but not to the output gap. There is no evidence of interest smoothing in the CNB's reaction function.

The decomposition of the monetary stance between the fitted Taylor rule and its residuals confirms the finding that interventions are carried out independently of current monetary policy in Brazil. Neither the fitted interest rate nor the residuals of the Taylor rule affect interventions in a statistically significant manner. But this is not the case of the Czech Republic, where the residuals of the Taylor rule—measuring misalignments of the monetary stance in relation to its determinants—enter the intervention reaction function with a negative, statistically significant sign. This suggests that the CNB intervenes to purchase (sell) foreign exchange even when the monetary stance is looser (tighter) than predicted on the basis of the Taylor rule. This result confirms the previous finding that the central bank does try to coordinate intervention and monetary policies, by using spot exchange rate interventions and interest policy movements in a mutually reinforcing manner.

5.4 The marginal effects

Whereas the parameter estimates reported above capture the impact of changes in the explanatory variables on the *desired* level of intervention, the corresponding marginal

15 These findings are in line with those reported by Minella et al. (2003) and de Mello and Moccero (2006, 2007), among others.

effects allow for the analysis of the effects of the explanatory variables on the *observed* level of interventions. We computed the six marginal effects reported in Tables 4-5: Models (1)-(3) refer to specifications reported in Tables 1-2 for easy referencing. Column (1) reports the impact of changes in the explanatory variables on the desired level of intervention based on the parameter estimates reported in Tables 1-2; column (2) reports the impact of changes in the explanatory variables on the observed level of intervention; columns (3) and (4) refer to the same impact, conditional on the sign of intervention (i.e., purchases and sales of foreign currency); and, finally, columns (5) and (6) report the estimated impact of the explanatory variables on the probability, rather than the actual level, of intervention, conditional on the sign of intervention.[16]

As interventions involve costs for the central bank, observed interventions may differ from desired interventions. The empirical evidence presented in columns (1) and (2) for both countries and for all models confirms that observed interventions are lower in magnitude than desired by the central banks. For example, in the case of Brazil, a one-unit increase in exchange rate volatility is associated on average with purchases of foreign currency of almost USD20 million, while the desired level of intervention is about USD2 million higher. Also for Brazil, a one-percentage point appreciation (relative to the medium-term trend), is associated on average with purchases on foreign exchange in the order of USD123-125 million. Similar results are obtained for the Czech Republic.

As implied by the size of the thresholds, the behaviour of the central bank may also depend on the sign of interventions. The results confirm the presence of asymmetries in the intervention reaction functions, as gauged by the higher absolute values of the marginal effects reported in column (4) with respect to those reported in column (3). As such, for equally-sized shocks affecting the explanatory variables, the monetary authorities react more strongly to counter appreciating trends than depreciations. For example, a one-unit increase in exchange rate volatility is associated with interventions of about USD7 million in Brazil and EUR6.7-7.5 millions in the Czech Republic, when the central bank intervenes in support of the domestic currency (i.e., it purchases domestic currency). By contrast, when the central bank intervenes to force a depreciation of the domestic currency (i.e., it sells domestic currency), the amounts increase to USD7.95-7.98 million and EUR8.4-9.2 millions, respectively. In other words, when the central bank is faced with heightened volatility in the foreign exchange market, interventions aimed at a depreciation of the domestic currency are about 25 per cent higher in magnitude in the Czech Republic (15 per cent higher in Brazil) than in the case of interventions in support of the domestic currency. In the same vein, interest rate changes in the Czech Republic are accompanied by stronger interventions when the central bank acts to support the local currency. These asymmetries are also present for the probability of interventions (columns 5-6).

5.5 Robustness checks

The robustness of the estimations was assessed for different model specifications. We first re-estimated the reaction functions for both countries by replacing the ratio of

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16 The marginal effects are evaluated at the respective means of the explanatory variables, conditional on the sign of intervention.

international reserves to imports by changes in reserve money (deflated by CPI inflation) to control for sterilization. The findings (not reported) are robust to this alternative specification. We also controlled for the possibility of a learning process in the intervention reaction function for the Czech Republic. As shown in Figure 3, the CNB was very active in 1998, the first year following the adoption of inflation targeting. The interest rate was sharply cut and numerous interventions were carried out. Therefore, this period can be considered as a transition period from different monetary policy regimes. We therefore re-estimated the model using a sample that starts in January 1999, rather than one year earlier. Again, this alternative specification did not affect our results, although there appears to be slightly stronger evidence in favour of the signalling hypothesis, as the one-period-ahead interest rate becomes significant at the 10 per cent level.

Table 4
Marginal effects: Brazil[1]

(Dependent variable: Spot-market interventions, in USD millions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Model (1)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)	-123.00	-110.00	-38.50	-44.40	2.07	-2.14
FX volatility	22.00	19.80	6.88	7.95	-0.37	0.38
Interest rate (one period ahead)	–	–	–	–	–	–
FX swaps	–	–	–	–	–	–
Ratio of international reserves to imports	185.00	166.00	57.90	66.80	**-3.12**	**3.22**
	Model (2)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)	-125.00	-113.00	-39.30	-45.20	2.11	-2.17
FX volatility	22.00	19.90	6.92	7.96	-0.37	0.38
Interest rate (one period ahead)	–	–	–	–	–	–
Interest rate (contemporaneous)	–	–	–	–	–	–
FX swaps	–	–	–	–	–	–
Ratio of international reserves to imports	185.00	167.00	58.20	67.00	-3.13	3.22
	Model (3)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)	-123.00	-112.00	-39.10	-44.60	2.09	-2.14
FX volatility	22.00	20.00	6.99	7.98	-0.37	0.38
Interest rate (one period ahead)	–	–	–	–	–	–
Interest rate (fitted from Taylor rule)	–	–	–	–	–	–
Interest rate (residuals from Taylor rule)	–	–	–	–	–	–
FX swaps	–	–	–	–	–	–
Ratio of international reserves to imports	181.00	165.00	57.50	65.70	-3.07	3.15

Note: [1] The estimation period runs from July 1999 to March 2007. The marginal effects (for the explanatory variables that were found to be statistically significant) are evaluated at the respective means of explanatory variables, conditional on the sign of intervention. Columns (1) to (5) are measured in USD millions, while columns (5) and (6) report probability changes.

Source: Authors' calculations based on data from the Central Bank of Brazil.

Table 5
Marginal effects: the Czech Republic[1]

(Dependent variable: Spot-market interventions, in EUR millions)

	(1)	(2)	(3)	(4)	(5)	(6)
	Model (1)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)	–	–	–	–	–	–
FX volatility	25.00	22.00	7.45	9.19	-4.80	5.06
Interest rate (one period ahead)	–	–	–	–	–	–
Ratio of international reserves to imports	–	–	–	–	–	–
	Model (2)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)	–	–	–	–	–	–
FX volatility	22.00	20.30	6.71	8.43	-4.48	4.65
Interest rate (one period ahead)	–	–	–	–	–	–
Interest rate (contemporaneous)	-11.00	-10.10	-3.36	-4.21	2.24	-2.33
Ratio of international reserves to imports	–	–	–	–	–	–
	Model (3)					
FX deviation from trend (short run)	–	–	–	–	–	–
FX deviation from trend (medium run)						
FX volatility	23.00	21.20	7.00	8.82	-4.70	4.89
Interest rate (one period ahead)	–	–	–	–	–	–
Interest rate (fitted from Taylor rule)	–	–	–	–	–	–
Interest rate (residuals from Taylor rule)	-6.00	-5.52	-1.83	-2.30	1.23	-1.27
Ratio of international reserves to imports	–	–	–	–	–	-

Note: 1) The estimation period runs from January 1998 to March 2007. The marginal effects (for the explanatory variables that were found to be statistically significant) are evaluated at the respective means of explanatory variables, conditional on the sign of intervention. Columns (1) to (5) are measured in EUR millions, while columns (5) and (6) measure probability changes.

Source: Authors' calculations based on data from the Czech National Bank.

6 Conclusions

The literature on interventions under inflation targeting has neglected the potential interactions that may exist between monetary and exchange rate policies. To bridge this gap, this paper has focused on the experiences of Brazil and the Czech Republic, two countries that have adopted inflation targeting as the framework for the conduct of monetary policy, while occasionally intervening in the foreign exchange market. A friction model was used to estimate intervention reaction functions for both countries, including monetary variables among the regressors to capture these policy interdependencies. It was hypothesized that, if monetary and intervention policies are not interrelated, then the monetary variables should not affect the patterns of intervention at classical levels of statistical significance. We also contribute to the empirical literature by computing the marginal effects associated with the intervention reaction function estimated using a friction model to capture potential asymmetries in the impact of different variables on interventions.

Our findings show that the main reason why the central bank intervenes in the spot foreign exchange market in both Brazil and the Czech Republic appears is to calm disorderly markets, rather than to target a specific level of the exchange rate. Interventions were found to be strongly affected by exchange rate volatility in both countries, and by exchange rate deviations from medium-term trends in Brazil. Moreover, there appears to be strong, asymmetric threshold effects in the intervention reaction function in both countries. The monetary authorities in these countries have intervened predominantly to force a depreciation of the domestic currency, rather than to prop up its value. Finally, interventions seem to take place independently of contemporaneous monetary policy in Brazil, but not in the Czech Republic, where both policies appear to be coordinated.

Appendix 1

Authors	Almekinders and Eijffinger (1996)	Beine, Benassy-Benassy-Quéré & Lecourt (2002)	Dominguez (1998)	Baillie and Osterberg (1997)	Ito (2003)	Ito and Yabu (2007)
Sample period	1987-89	1985-91, 1985-95	1977-94	1995-90	1991-2001	1991-2002
Central banks (CBs)	Bundesbank, Fed	Fed, Bundesbank, BoJ	Fed, Bundesbank, BoJ	Fed, Bundesbank, BoJ	BoJ	BoJ
Theoretical model	Yes: Central bank loss function	No	No	No	No	Yes: Central bank loss function
Econometric model	Friction model	Probit model	Probit model	Two Probit models (one for sales and one for purchases)	GMM	Ordered Probit model
Motivation for the econometric model	Abstaining (band for no action). No intervention is viewed as an investment in the potential effects of future interventions	—	—	—	—	Abstaining (band for no action). There is 'political cost to implement a decision to intervene.
Dependent variable	The amount of intervention	Dummy variable (1 for intervention and 0 otherwise)	Dummy variable (1 for intervention and 0 otherwise)	Dummy variable (1 for intervention and 0 otherwise)	The amount of intervention	Three discrete values (1 for the purchase of domestic currency, -1 for the sale of domestic currency and 0 otherwise)
Explanatory variables						
• Exchange rate level (S_t is the log of exchange rate in time t)	$S_t – S_T$	$\|S_t – S_{t\text{-}1}\|$	$\|S_{t\text{-}1} – S_T\|$	$S_t – S_T$	$S_{t\text{-}1} – S_{t\text{-}2}$' $S_{t\text{-}1} – S_{t\text{-}21}$' $S_{t\text{-}1} – S_{t\text{-}T}$	$S_{t\text{-}1} – S_{t\text{-}2}$' $S_{t\text{-}1} – S_{t\text{-}21}$' $S_{t\text{-}1} – S_{t\text{-}T}$
• Exchange rate target	S_T is a moving average of the exchange rate over past 7 days	—	S_T is a moving average of the exchange rate over the past 10 days	S_T is the Funabashi 125 JPY/USD value	S_T is the Funabashi 125 JPY/USD value	S_T is a moving average of the exchange rate over the previous year
• Exchange rate volatility (σ is a measure of volatility)	σ_t from a daily GARCH	$\sigma_{t\text{-}1}$ from a daily FIGARCH	$\sigma_{t\text{-}1} – \sigma_T$ with $\sigma_{t\text{-}1}$ from a daily GARCH (T is moving average over 10 days) or implied volatility from options	$\sigma_{t\text{-}1} – \sigma$ with $\sigma_{t\text{-}1}$ from a daily GARCH	No	No
Lagged intervention	No	Yes	No	No	Yes	Yes
Main results	CBs react to: • FX deviations • Volatility	CBs react to: • FX deviations Interventions are clustered over time and do not react to: • Volatility	CBs do not react to: • FX deviations • Volatility	CBs react to: • FX deviations • Volatility These results are sensitive to the sign of the operation and the nature of the currency.	CBs react to: • FX deviations Interventions are clustered over time	CBs react to: • FX deviations Interventions are clustered over time

Appendix 2

Computing marginal effects for the friction model

On the basis of Equation (2), the effect of changes in X_t on I_t can be computed from different expectation functions. Once the β's have been estimated, we can compute the effects on the latent variables directly through Equation (10) below. There are, in addition, three other predictions that can be made on the observed amount of interventions, I_t, conditional on the occurrence or not of interventions. These predictions are given by:

$$E[I] = P\left(I^* > \Theta_2\right) * E\left[I \mid I^* > \Theta_2\right] + P\left(\Theta_1 < I^* < \Theta_2\right).E\left[I \mid \Theta_1 < I^* < \Theta_2\right] + P\left(I^* < \Theta_1\right).E\left[I \mid I^* < \Theta_1\right] \tag{3}$$

where,

$$E\left[I \mid I^* > \Theta_2\right] = \sigma\left(z_2 + \frac{\phi(z_2)}{\Phi(z_2)}\right) \tag{4}$$

$$E\left[I \mid \Theta_1 < I^* < \Theta_2\right] = 0, \tag{5}$$

$$E\left[I \mid I^* < \Theta_1\right] = \sigma\left(z_1 - \frac{\phi(z_1)}{1-\Phi(z_1)}\right), \tag{6}$$

$$P\left(I^* > \Theta_2\right) = \Phi(z_2), \text{ and} \tag{7}$$

$$P\left(I^* < \Theta_1\right) = 1 - \Phi(z_1), \tag{8}$$

With $z_1 = \dfrac{X\beta - \Theta_1}{\sigma}$ and $z_2 = \dfrac{X\beta - \Theta_2}{\sigma}$.

Equation (3) can be re-written as:

$$E[I] = \Phi(z_2).\sigma\left(z_2 + \frac{\phi(z_2)}{\Phi(z_2)}\right) + \left(1 - \Phi(z_1)\right).\sigma\left(z_1 - \frac{\phi(z_1)}{1-\Phi(z_1)}\right). \tag{9}$$

Equation (3) refers to the expectations unconditional on the occurrence of interventions, whereas Equations (4-6) refer to the conditional expectations. The expressions $E\left[I \mid I^* > \Theta_2\right]$ and $E\left[I \mid I^* < \Theta_1\right]$ provide the means of (observed) positive and negative interventions. $E[I]$ is the mean of all observed interventions (positive and negative). Finally, $P\left(I^* > \Theta_2\right)$ and $P\left(I^* < \Theta_1\right)$ are the probabilities that an intervention will take place.

The following derivatives can be computed to predict the effects of changes in the exogenous variables using the four expectation functions in Equations (3)-(6) and the two probabilities in Equations (7)-(8). Denote by β_j the j-th component of β. Dropping subscript t, which refers to the t-th observation, for convenience, yields the marginal effects on the latent variable:

$$\frac{\partial E(I^*)}{\partial x_j} = \beta_j \tag{10}$$

The marginal effects on the observed level of intervention are computed as:

$$\frac{\partial E(I)}{\partial x_j} = \beta_j \left[1 + \Phi(z_2) - \Phi(z_1)\right] \tag{11}$$

The marginal effects on the observed level of intervention when the central bank supports the domestic currency are computed as:

$$\frac{\partial E\left[I \mid I^* < \Theta_1\right]}{\partial x_j} = \beta_j \left(1 + z_1 . \frac{\phi(z_1)}{1 - \Phi(z_1)} - \left(\frac{\phi(z_1)}{1 - \Phi(z_1)}\right)^2\right) \tag{12}$$

Finally, the marginal effects on the observed level of intervention when the central bank acts to weaken the domestic currency are computed as:

$$\frac{\partial E\left[I \mid I^* > \Theta_2\right]}{\partial x_j} = \beta_j \left(1 - z_2 . \frac{\phi(z_2)}{\Phi(z_2)} - \left(\frac{\phi(z_2)}{\Phi(z_2)}\right)^2\right) . \tag{13}$$

The marginal effects on the probability of intervening (selling or purchasing foreign currency) are computed as:

$$\frac{\partial P\left[I^* > \Theta_2\right]}{\partial x_j} = \frac{\beta_j}{\sigma} \phi(z_2) \text{, and} \tag{14}$$

$$\frac{\partial P\left[I^* < \Theta_1\right]}{\partial x_j} = -\frac{\beta_j}{\sigma} \phi(z_1) . \tag{15}$$

Appendix 3

Estimation of a Taylor-type monetary policy reaction function for Brazil and the Czech Republic

The Taylor rule is estimated as: $r_t = \rho r_{t-1} + (1-\rho)[\alpha + \beta\pi_t^e + \gamma y_t]_t$, where r_t is the policy interest rate at time t, π_t^e is expected inflation, measured as the one-period-ahead actual inflation, and y_t is the output gap. Data sources and the definition of the variables are reported in the main text.

Table 6
The determinants of monetary policy in Brazil and the Czech Republic

(Dependent variable: the policy interest rate)

	Brazil (1999:7 to 2007:2)	Czech Republic (1998:1 to 2007:2)
Lagged dependent variable	0.725***	0.111
	[0.068]	[0.094]
Constant	-0.396	-1.377**
	[0.758]	[0.587]
Inflation expectation	2.410**	2.395**
	[1.123]	[1.085]
Output gap	0.736*	0.241
	[0.421]	[0.216]
Likelihood function	-188.57	-341.40

Note: 1) The models are estimated by full information maximum likelihood. Standard errors are reported in parentheses. (***), (**), and (*) denote statistical significance at the 1%, 5%, and 10% levels, respectively.

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