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Abstract

Banco de la República's FX intervention policy is described, with a focus on its objectives and main features. Then, based on a survey of the effectiveness of sterilized intervention in Colombia, it is argued that this tool is not useful to cope with the challenges posed by medium term external factors such as quantitative easing in advanced economies, reduced risk premiums in emerging economies or high international commodity prices. The duration of the impact of sterilized intervention on the exchange rate (if any) is much shorter than the effects of those factors. Finally, it is argued that if sterilized FX intervention is effective due to the operation of the portfolio balance channel, it may also have an expansionary effect on credit supply and aggregate demand. In this case, the macroeconomic outcomes of intervention depend on the monetary policy response. This issue is studied with a small open economy DSGE. In general, FX intervention implies a volatility of credit and consumption that is higher than under a more efficient allocation and under alternative monetary regimes without intervention. Furthermore, the more inclined the central bank is to meet an inflation target, the stronger its response to the expansionary effects of the intervention and, consequently, the lower the impact of the intervention on the exchange rate.

Keywords: Monetary Policy, Foreign Exchange Intervention
JEL: F31; F32; F33; E37.

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1 Introduction

This paper first describes current FX intervention policy by Banco de la República, emphasizing its objectives and features, and highlighting some issues that have arisen recently in local policy discussions. Then preliminary answers are provided for the following questions: (i) Is sterilized FX intervention in Colombia effective as an instrument to deal with the challenges posed by quantitative easing policies in advanced economies or high/rising international commodity prices? (ii) Assuming imperfect substitution between different financial assets, sterilized FX intervention may influence the exchange rate (through the portfolio balance channel). What are the macroeconomic consequences of sterilized FX intervention when the effects of the portfolio balance channel on credit supply and the operation of a monetary policy rule are jointly considered?

The first question is relevant because its answer may help define the aim and extent of sterilized FX intervention. The second question is important because the discussions on the effectiveness and desirability of sterilized FX intervention are often framed in a partial equilibrium setting, overlooking the interplay that may exist between sterilized FX intervention, credit supply and monetary policy. The microeconomic basis for sterilized FX intervention effectiveness (portfolio balance channel) also implies the presence of effects of sterilized FX intervention on credit supply, which may prompt monetary policy responses that end up shaping its macroeconomic outcomes. A small open economy DSGE model is used to explore this issue.

2 Current FX Intervention Policy of Banco de la República

2.1 Objectives

FX intervention in Colombia is undertaken with the purposes of (1) maintaining an adequate level of international reserves, (2) fixing short term exchange rate misalignments and (3) occasionally curbing excessive volatility of the exchange rate.

1. Maintaining an adequate level of international reserves

   The maintenance of a stock of international reserves is a must in a small open economy subject to strong external shocks and without the possibility of issuing a reserve currency. This is a key objective of FX intervention by Banco de la República. Hence, the size of the intervention is greatly determined by the criteria used to define a desired or adequate level of international reserves.

   Two aspects must be taken into account when making this decision. First, the international reserves requirements may vary across countries depending not only on their size, trade flows or financial activity, but also on macroeconomic characteristics such as the exchange rate regime, the price formation mechanisms and the structure and regulation of the financial system. In a country with small pass-through from the exchange rate to prices and low currency and FX term mismatches, the scope for exchange rate flexibility as a shock absorber is much greater than in a country with high pass-through, significant liability dollarization or large currency mismatches. Accordingly, the adequate level of international reserves must be lower in the first country, even if both economies are of similar size, face the same (short term) external debt payments, or if they have the same degree of financial deepening or the same current account balance (Edison (2003)).

   In Colombia the credibility of the inflation target is strong, pass-through is low and there is a sound regulation of financial intermediaries' currency and FX term mismatches. Conditions for a high degree of exchange rate flexibility are therefore present. In fact, Banco de la República's FX intervention in the wake of the Lehman crisis was by far the smallest among the large Latin American economies. The volatility resulting from the flexible exchange rate regime contributes

to maintain those conditions, since currency risk is internalized in the private sector funding decisions (thereby limiting mismatches) and pass-through is kept low (Vargas (2011)).

More recently, a new source of external liquidity shocks has emerged in Colombia stemming from the expansion of Colombian banks abroad[1]. Liquidity disturbances in the presence of insufficient regulation or lender of last resort (LOLR) facilities in the host countries may end up causing strong demand pressures in the Colombian FX market. The question remains as to whether this situation justifies holding a much greater stock of international reserves, or if Colombian liquidity regulation must be strengthened to account for this exposure. After all, holding international reserves is generally costly, so forcing the internalization of the risk by banks seems sensible. Besides monitoring the FX liquidity of the conglomerates, imposing additional FX liquidity requirements on banks operating overseas may be necessary to preserve the resilience of the financial system, especially if host countries' regulation or LOLR facilities are deemed subpar, or if the information needed to gauge liquidity risk is not available. At the same time, the cost of the insurance would be borne by the agents originating the risk.

The second aspect to consider when assessing the adequate level of international reserves is that the effectiveness of international reserve accumulation to protect the economy from external liquidity shocks depends on deeper factors such as the contemporaneous behavior of macroeconomic savings and the openness of the financial account. Models of "optimal reserves" are commonly used to judge the appropriateness of the international reserves stock (see for example Jeanne (2007) or Calvo, Izquierdo, and Loo-Kung (2012)). These models posit that international reserves are useful to face "sudden stops" because they help alleviate the consequences of these episodes (decreased consumption), or because they contribute to reduce the probability of such events. At the same time, they recognize that international reserves carry an opportunity cost. The "optimal" level of international reserves solves the trade-off between those benefits and costs at the margin.

Although the rationale behind these models informs international reserves policy, their application in practice has several drawbacks. To begin, they are too simplistic to adequately incorporate the above-mentioned idiosyncratic traits of each economy. Hence, strong, rather coarse assumptions must be made regarding the size, probability and cost of a liquidity shock. The results of these models are extremely dependent on these assumptions, rendering the methods of very limited use for policy purposes[2].

But, perhaps more importantly, these models take the (short term) foreign liabilities as given when calculating "optimal" reserves. This amounts to assuming that the net (short term) foreign asset position of the country increases one on one with the purchases of international reserves. This may not be the case, especially if those purchases are sterilized and there is a high degree of capital mobility in the economy. In the extreme case of perfect capital mobility, as interest rates are kept constant, FX intervention ends up attracting new capital inflows (or reducing the liquid assets of the domestic private sector), thereby leaving the (short term) net asset position of the country unchanged. As a result, the "insurance" against a "sudden stop" is not obtained by the simple accumulation of reserves by the central bank.

When capital mobility is not perfect, reserves purchases do achieve some insurance. However, it is smaller than the one deemed "optimal" initially, since some capital inflows are attracted at any rate. To reach it, larger reserve purchases are required, but they entail greater opportunity

[1] Between 2007 and 2012, 130 Colombian banks subsidiaries were opened or bought abroad. Of those, approximately 67.5% are located in Central America. Moreover, the assets of foreign subsidiaries of Colombian banks rose from 9% to total assets in 2009 to 20% in 2011.

[2] Gerencia Técnica(2012) illustrates this point by applying the method proposed by Jeanne (2007) and showing that the "optimal" level of international reserves in Colombia could vary from nil to more than USD50 billion (14% of GDP), depending on the assumptions on the probability, size and cost of a "sudden stop". The plausibility of the different sets of assumptions made is not clear-cut, since they could refer to episodes or groups of countries whose current relevance is easily debatable.

costs. Thus, the optimal insurance level may now be smaller, and so may be the optimal level of international reserves. A simple variation of the Jeanne (2007) model presented in Gerencia Técnica(2012) shows that "optimal" reserves rapidly decrease with the sensitivity of external short term liabilities to FX intervention.

The broader point here is that international reserves accumulation is not necessarily tantamount to raising the insurance against "sudden stops". It is, as long as the increases in international reserves are coupled by hikes in macroeconomic savings, or at least by rises in the net short term external position of the country. Hence, the effectiveness of reserve accumulation as a tool to protect the economy from external liquidity shocks depends on factors such as the degree of capital mobility or the behavior of domestic savings.

In practice, Banco de la República follows a pragmatic approach in which several international reserves indicators are monitored and reserves purchases are aimed at roughly keeping them stable. These indicators include the ratios of reserves to broad money, short term external debt payments, short term external debt payments plus the current account balance, imports and GDP. To calculate the indicators, trend values of these variables are used in order to filter out cyclical components that may distort the comparisons of reserve coverage through time. Figures 1 through 5 show the evolution of these indicators over the last decade.

2. Fixing short term exchange rate misalignments

   Being the price of an asset, the exchange rate may be subject to sporadic "speculative" behavior, i.e., not totally related to its fundamental determinants. This is especially the case in some EM currency markets, shallower than their advanced economies' counterparts, after periods characterized by a persistent trend and low volatility of the exchange rate. In these circumstances, it is possible that a substantial fraction of market participants share the same "autoregressive" view of the exchange rate and a bubble-like path ensues. This may cause undue damage to tradable sectors (in the case of an appreciation of the currency), inflationary pressures (in the case of a depreciation of the currency) or unwarranted volatility in FX and financial markets.

   Banco de la República closely monitors the evolution of the FX market to detect this kind of behavior. However, it is acknowledged that such episodes are rather infrequent and a procedure is in place to assess their likelihood and take corrective actions when necessary. As explained in Vargas (2011), to conclude a high probability of a misalignment, a thorough examination of the nature and size of capital flows is performed on the basis of FX spot and derivative transactions, the trend of the COP is compared to that of other EM and regional currencies, and the observed real exchange rate is contrasted with several "equilibrium" measures. FX intervention is then undertaken when its benefits (effectiveness) outweigh its costs (quasifiscal and other).

3. Curbing excessive volatility of the exchange rate

   Immediately after the adoption of a flexible exchange rate regime in 1999, the market of currency risk hedging instruments was not well developed. Hence, a mechanism was put in place to intervene in the FX market in order to check episodes of excessive volatility of the exchange rate that could harm financial markets. The Central Bank would auction put/call options to sell/buy US Dollars to/from the Central Bank when the exchange rate in one day exceeds/falls below its 20-day average by a specified percentage. This mechanism has not been active since February 2012, but may be turned on when needed.

2.2 Features

1. Sterilization

   FX intervention in Colombia is sterilized to the extent necessary to keep short term interest rates in line with the policy rate. This means that the expansionary effect reserve purchases needs not be totally offset as long as there are other shifts in money demand and supply that compensate

it. Government deposits at the Central Bank have been the main sterilization mechanism in recent years. They have allowed Banco de la República to remain a net creditor to the financial system.

However, if Government deposits fall short of the amounts required to sterilize additional reserve purchases, there are other offsetting mechanisms in place. The Central Bank still holds a stock of Government securities that can be sold for that purpose. Also, to mop up excess liquidity, Banco de la República can open and has opened remunerated short term (7 and 14 day) deposits that are accessible to a wide array of financial institutions[3]. A drawback of this instrument is that deposits are not negotiable in secondary markets, so they entail liquidity risk for deposit holders. Consequently, sterilization may be difficult and incomplete.

To deal with this problem, in 2009 the Law allowed the Central Bank to issue its own securities and in 2011 the Law authorized the issuance of Monetary Regulation Government Bonds (MRGB) specifically aimed at controlling the money supply (and not for deficit financing). No Central Bank securities have been issued hitherto. In late 2012 an agreement was reached between the Government and Banco de la República to issue MRGB and to deposit the proceeds at the Central Bank. The idea was to coordinate Government debt management policy with sterilization policy. Hence the 1-4 year segment of the Government bond market was reserved for sterilization purposes. The remuneration of the Government deposits at the Central Bank is equivalent to the cost of the MRGB.

Starting in December 2012 the first MRGB were issued with 1.5, 2 and 3 year maturity. The announced amounts of the auctions are still small relative to the monetary base (16%) and international reserves (12%). The relatively long maturities of these bonds have the advantage of introducing some market risk that could discourage capital inflows in response to sterilization. At the same time, they allow the Central Bank to maintain a short term net creditor position with the financial system and, therefore, a tighter grip on short term liquidity.

2. Mode of intervention

   Currently Banco de la República intervenes in the FX market through announced auctions of fixed-amount, daily purchases of USD. After a long and diverse experience with several modes of intervention, the perception at the Central Bank is that this type is the best one for the objectives stated previously, since it minimizes any signal about the defense of a particular level of the exchange rate. This occurs because the amounts of the intervention are the same regardless of the value of the currency.

   Avoidance of strong signals regarding an implicit exchange rate target is crucial for two reasons, inter alia. First, the credibility of the inflation target could be weakened if the market perceives a trade-off between the inflation target and an exchange rate objective. Second, if a perceived exchange rate goal is judged as non-attainable by market participants, additional capital inflows may be attracted, rendering the FX intervention ineffective, possibly introducing unwarranted volatility to the exchange rate and imposing greater costs on the Central Bank, if the latter reacts by increasing intervention.

3 Is Sterilized FX Intervention Useful to Deal with Medium Term Currency Appreciation Forces?

As other EME currencies, the COP has experienced an appreciation in recent years that is related in part to decreasing risk premiums and ample liquidity provision in advanced economies. At the same time, Colombia has benefited from high and increasing terms of trade associated with the behavior

[3] In addition to commercial banks, broker-dealers, investment funds and pension funds are authorized to hold these deposits at the Central Bank.

of international commodity prices (Figure 6). Such trend has not only resulted in a direct increase in national income, but has also sparked large flows of FDI into the mining and oil sectors. As a consequence, output and exports of these goods has substantially expanded. The coincidence of large FDI inflows and increasing prices and volumes of these commodities has been an additional force behind the appreciation of the currency.

A common feature of these factors is that even if they cannot be totally regarded as permanent changes in the external conditions of the Colombian economy, their transitory components are highly persistent. They are medium term sources of currency appreciation. Hence, concerns about "Dutch Disease" have surfaced and there have been calls for Central Bank sterilized FX intervention to cope with this problem. The convenience of the latter in this context must be assessed by measuring its benefits and costs. The benefits are clearly related to its ability to have a significant, long-lasting effect on the exchange rate.

Table 1, taken from Rincón (2012), summarizes the results of several studies on the topic for Colombia. There are mixed outcomes with respect to the impact of sterilized FX intervention on the exchange rate returns or level, depending on the period of analysis, the econometric method used, the frequency of the data, the probability distribution assumed and the measurement of intervention. In some cases no effect is found, while in others intervention depreciates the currency. Results are also diverse with respect to the impact of intervention on exchange rate volatility. However, few studies explore the duration of the effect of FX intervention. As mentioned above, this is a crucial element, given the nature of the shocks being discussed.

In most cases the econometric specification does not allow for dynamic effects of intervention. They are controlled experiments that compare the behavior of the exchange rate in periods with intervention to its behavior in periods without intervention[4]. Only two studies explicitly account for possibly changing effects of intervention through time. Based on a SVAR estimated with monthly data, Echavarría, López, and Misas (2009) found that an intervention shock depreciates the currency for one month. A recent project led by BIS-CCA using intra-day data identified an effect that lasts for some minutes[5].

These results indicate that sterilized FX intervention is not an effective tool to confront the challenges posed by long-lasting phenomena such as quantitative easing in advanced economies, reduced risk premiums associated with relatively poor fundamentals in the advanced world, or high international commodity prices. Thus, a cost-benefit analysis would probably conclude against using this instrument for that purpose, as costs are certain but benefits are small and uncertain. This conforms to the result of Ostry, Ghosh, and Chamon (2012), who show that, even under assumed effectiveness of sterilized FX intervention, optimal reserve accumulation declines with the persistence of capital inflows. It also provides a rationale for the Banco de la República's FX policy presented in the foregoing section, in which sterilized FX intervention is aimed at correcting short-term misalignments.

There may be longer term misalignments related to expenditure or credit excesses derived from the above mentioned phenomena. Nevertheless, sterilized FX intervention does not seem to be a suitable mechanism to fix them[6]. Alternative tools must be evaluated. Capital controls are an option, although their costs and lack of effectiveness (Kamil and Clements (2009)) over the relatively long

[4]In several studies the dependent variable is the return of the exchange rate, i.e. its first difference. In these cases, the level of the exchange rate has a "unit root", so, by construction, any effect of intervention permanently alters the exchange rate. However, those specifications restrict the impact of the intervention to its contemporaneous effect on the exchange rate return, thereby preventing the exploration of lagged responses of the latter.

[5]A third paper by Echavarría, Vásquez, and Villamizar (2010) found significant impacts of intervention on the expected *future returns* of the exchange rate at different horizons. However, with this specification it is difficult to determine the duration of the effects. For example, a permanent effect would show up as a zero coefficient on intervention, but this would be the same outcome of a nil effect. Significant coefficients may indicate a contemporaneous effect of intervention with an indeterminate impact on the expected future exchange rate.

[6]On a different but related track, Lama and Medina (2012) build a DSGE model that explicitly includes a learning by doing externality in the tradable sector and allows monetary policy to lean against the appreciation caused by Dutch Disease. Calibrating the model for Canada, they find that, even if exchange rate stabilization can restore tradable output close to the efficient level, the volatility introduced to macroeconomic aggregates reduces welfare with respect to a scenario in which the exchange rate is allowed to adjust.

periods implied by the duration of the aforementioned shocks may also cast serious doubts about their convenience. Increases in domestic savings through adequate fiscal policy arrangements (especially in the case of the commodity boom cycle), or macro-prudential policies remain as policy choices to consider.

4 Sterilized FX Intervention, the Credit Channel and Monetary Policy: A Deeper Exploration of the Portfolio Balance Approach

Beyond the issue of the empirical relevance of sterilized FX intervention, a case may be made in favor of the use of this instrument when there is a low degree of substitution between different assets in the balance sheets the various agents in the economy. This could be a feature especially in EME with still developing financial markets. Ostry, Ghosh, and Chamon (2012) argue that when the financial account behavior deviates from perfect capital mobility, sterilized FX intervention is a valid tool to manage the exchange rate for a central bank that strictly targets inflation. In this case, there are two instruments (interest rates and FX intervention) to achieve two targets (Inflation and the exchange rate).

Nonetheless, the previous arguments ignore either the microeconomic underpinnings of imperfect capital mobility (as in Ostry, Ghosh, and Chamon (2012)), or the macroeconomic implications of those underpinnings (as in the partial equilibrium analysis of the portfolio balance approach). If sterilized FX intervention influences the exchange rate through the portfolio balance channel, it may have effects beyond those in the FX market that can determine the overall macroeconomic outcomes. More specifically, sterilized FX intervention under imperfect substitution between assets may have an impact on credit supply. Garcia (2011) shows that sterilized FX purchases under inflation targeting in an economy with an active credit channel have expansionary consequences on aggregate demand through their negative impact on lending interest rates.

In sum, sterilized FX intervention may have significant and persistent effects on the exchange rate when the portfolio balance channel is strong. For the same reason, it may also entail substantial shifts in credit supply and aggregate demand. What happens when an inflation-targeting central bank reacts to those shifts? What are the macroeconomic results of the interplay of sterilized FX intervention, credit expansion and inflation targeting? In what follows a small open economy DSGE model with tradable and non-tradable sectors is presented to answer these questions.

4.1 The model

A DSGE model is built for a small open economy that has tradable and non-tradable sectors together with an oil producing sector. The latter does not use domestic resources for production, but generates large foreign income flows. To this otherwise standard model, a financial sector is added that includes both the central bank and commercial banks. The setup for the financial system implies that assets in the balance sheet of the commercial banks are not perfect substitutes. Following Edwards and Vegh (1997) and Benes, Berg, Portillo, and Vavra (2013) this characteristic of the financial system also implies that the central bank has the ability to affect the exchange rate through the sterilized accumulation of international reserves. However, the sterilization entails changes in the holdings of bonds by commercial banks and shifts in the composition of their asset portfolios. These shifts in turn affects loan supply and the rest of the economy. Hence, any sterilized FX intervention undertaken by an IT central bank has complex macroeconomic consequences.

In this section, the main features of the model are discussed. The full set of equations can be found in the Appendix (A). The model economy is populated by households that receive income from labor, profits from firms and banks, and transfers from the government. The budget constraint of a

representative household is

$$y_t^P + w_t h_t + \xi_t^N + \xi_t^B + l_t = \tau_t + \left(\frac{1+i_{t-1}^l}{1+\pi_t^C}\right) l_{t-1} + c_t + \frac{\psi}{2}\left(l_t - \bar{l}\right)^2 \tag{4.1}$$

where w_t is the real wage in terms of the consumption bundle, h_t is the total supply of labor, l_t are loans from commercial banks, ξ_t^N are profits from non-tradable firms and ξ_t^B denotes profits from commercial banks, y_t^P are dividends from the oil sector and τ_t is a lump-sum transfer from the government. The household buys a bundle of consumption c_t at price p_t^C, pays loans from previous periods at a rate i_t^l and it also incurs cost when adjusting its demand for loans[7]. This cost also creates a margin between the loans interest rate and the discount factor:

$$\lambda_t\left(1 - \psi\left(l_t - \bar{l}\right)\right) = \beta \mathbb{E}_t\left[\lambda_{t+1}\left(\frac{1+i_t^l}{1+\pi_{t+1}^C}\right)\right] \tag{4.2}$$

As can be seeing from equation (4.1) this margin is a positive function of total loans and consequently the Euler equation (4.2) becomes a credit demand function. (See Benes, Berg, Portillo, and Vavra (2013) for details).

The consumption bundle is composed by tradable and non-tradable goods. The demand for each type of good is proportional to both its relative price and total consumption. The tradable good is equal across countries and, consequently, the law of one price holds at every moment. It follows that the relative price of the tradable good in domestic currency is:

$$\frac{p_t^T}{p_t^C} = q_t\left(\frac{p_t^{T*}}{p_t^{C*}}\right) \tag{4.3}$$

where q_t is the real exchange rate and p_t^{T*}/p_t^{C*} is the relative price of the tradable good in foreign currency.

The production function in both sectors is characterized by a decreasing returns to scale technology that only uses labor as input. Firms in both sectors determine labor demand by minimizing costs. The equilibrium in the labor market guarantees that $h_t = h_t^N + h_t^T$.

Nominal prices in the non-tradable sector are rigid. In this sector, each firm set prices by maximizing profits under costly price changes as in Rotemberg (1982). That is, the problem of the representative firm in the non-tradable sector is:

$$\max_{p_{j,s}^N} \mathbb{E}_t \sum_{s=t}^{\infty} \beta^{t-s} \frac{\lambda_s}{\lambda_{s-1}} \left\{ \frac{p_{j,s}^N}{p_t^C} y_{j,s}^N - \frac{p_t^N}{p_t^C} CT_{j,s} - \frac{p_t^N}{p_t^C} \frac{\kappa}{2} \left(\frac{p_{j,s}^N}{p_{j,s-1}^N \left(1+\pi_{s-1}^C\right)^{\iota} \left(1+\overline{\pi}\right)^{1-\iota}} - 1 \right)^2 y_{j,s}^N \right\}$$

κ affects the slope of the Phillips curve and ι the degree of price indexation, $CT_{j,s}$ is the total cost of firm j . The above formulation has to take into account the fact that firms in the non-tradable sector have a decreasing returns to scale technology and, consequently, the firm's marginal cost is not equal to the average marginal cost. In fact, following Sbordone (2002) and Gali, Gertler, and Lopez-Salido (2001), the individual firm total cost is:

$$CT_{j,t} = \frac{mc_t^N}{p_t^N} \left(\frac{p_{j,t}^N}{p_t^N} \right)^{\frac{\varepsilon^N(\alpha_N - 1)}{\alpha}} y_{j,t}^N$$

where ε^N is the elasticity of substitution in the non-tradable goods and α_N is the share of labor in the production of non-tradable goods and mc_t^N is the average marginal cost of the non-tradable sector.

The log-linearized first order condition with respect to price yields the Phillips curve of the economy:

[7] Technically, this is a quadratic adjustment cost guarantees existence of a stationary equilibrium for loans.

$$\pi_t^N = \beta \mathbb{E}_t \pi_{t+1}^N + \iota^N \pi_{t-1}^C - \beta \iota^N \pi_t^C + \frac{(\varepsilon^N - 1)}{\kappa} mc_t^N \tag{4.4}$$

where π_t^N is the non-tradable price inflation, π_t^C is the total price inflation, (made up by tradable and non-tradable price inflation).

The financial sector is composed by the central bank and commercial banks. The central bank intervenes in the foreign exchange market by accumulating reserves. The accumulation of reserves is financed by issuing a non-contingent domestic bond that pays an interest rate i_t. Accordingly, the balance sheet of the central bank is given by:

$$q_t ri_t^* = b_t \tag{4.5}$$

where ri_t^* are real international reserves and b_t are central bank bonds. The cash flow of the central bank is given by:

$$\tau_t = b_t - \frac{(1 + i_{t-1})}{\left(1 + \pi_t^C\right)} b_{t-1} + q_t \frac{\left(1 + i_{t-1}^*\right)}{(1 + \pi_t^*)} ri_{t-1}^* - q_t ri_t^* \tag{4.6}$$

and is related to the quasi-fiscal deficit. The central bank receives an interest rate i_t^* on its international reserves and pays an interest rate i_t on domestic bonds. At each point in time the quasi-fiscal deficit of the central bank is an increasing function of the interest rate spread and the amount of foreign reserves.

Each period of time the central bank intervenes in the FX market to maintain the ratio of reserves to the country's foreign liabilities (a proxy of a reserve adequacy indicator) close to a desired steady state level. In addition, it seeks to attain a given operational target for the real exchange rate measured as $RER_t = p_t^T / p_t^N$. It also decides on the interest rate it pays to banks through a policy rule. One possible rule for the FX interventions is[8]:

$$\frac{q_t ri_t^*}{l_t} = \frac{\overline{q\, ri^*}}{l} - \omega \left(RER_t - \overline{RER}\right). \tag{4.7}$$

According to this rule, the central bank buys reserves when RER_t deviates from an operational target, $\overline{RER}$. ω measures the strength of the intervention. When $\omega = 0$, intervention is only aimed at keeping the ratio of foreign reserves to foreign liabilities constant.

Commercial banks' assets comprise loans to households and sterilization bonds from the central bank. In the liability side they hold external debt b_t^*. Therefore, the balance sheet of commercial banks is described through the following equation:

$$b_t + l_t = q_t b_t^* \tag{4.8}$$

As in Edwards and Vegh (1997) and Benes, Berg, Portillo, and Vavra (2013), commercial banks are competitive and set the optimal level of b_t, and l_t by maximizing their cash flow subject to a technology constraint given by:

$$\Omega(b_t, l_t) = \theta_b b_t + \theta_l l_t - 2\theta \sqrt{b_t l_t}$$

This functional form stipulates that loans and sterilization bonds are not perfect substitutes and hence carry different interest rates. After imposing the balance sheet constraint, the first order conditions of the commercial banks are:

$$\mathbb{E}_t \frac{(1 + i_t)}{\left(1 + \pi_{t+1}^C\right)} = \mathbb{E}_t \left(\frac{q_{t+1}}{q_t} \frac{\left(1 + i_t^*\right)}{\left(1 + \pi_{t+1}^*\right)} \right) + \theta_b - \theta \sqrt{\frac{l_t}{b_t}} \tag{4.9}$$

[8] As it will be explained below, the liability side of commercial banks is entirely made up by foreign debt, while their asset side consists of loans to households and sterilization bonds issued by the central bank. Therefore, fixing a ratio of reserves to foreign debt is equivalent to fixing the ratio of reserves to commercial bank loans. From the central bank balance sheet, $q_t\, ri_t^* = b_t$. From commercial banks' balance sheets: $b_t + l_t = q_t\, b_t^*$. Hence, $b_t^* / ri_t^* = 1 + l_t / b_t$.

and

$$\mathbb{E}_t \frac{\left(1+i_t^l\right)}{\left(1+\pi_{t+1}^C\right)} = \mathbb{E}_t \left(\frac{q_{t+1}}{q_t} \frac{\left(1+i_t^*\right)}{\left(1+\pi_{t+1}^*\right)} \right) + \theta_l - \theta \sqrt{\frac{b_t}{l_t}} \tag{4.10}$$

Equation (4.9) is the UIP condition adjusted by a risk premium. As explained in Appendix C of Benes, Berg, Portillo, and Vavra (2013), this risk premium is increasing in the ratio of foreign reserves to foreign liabilities. This is the channel through which foreign exchange interventions work. When the central bank intervenes actively ($\omega \neq 0$ in Equation4.7), it raises the cost to commercial banks because they will hold central bank bonds in excess of its long run value, making external funding less attractive for banks and affecting the exchange rate.

Equation (4.10) is the supply of loans and describes a positive relation between the lending interest rate and loans. As can be seen in equations (4.9) and (4.10) the composition of the asset side of the balance sheet of the commercial bank affects the intermediation spread measured by the difference between the loan rate and the policy rate. In fact, the larger the amount of central bank bonds relative to loans to the households, the lower the loan rate. That is, when the exposure of commercial banks to central bank bonds is larger than its steady state ratio, the commercial banks will try to balance their asset composition by lowering the interest rate on loans.

Summarizing, the fact that central bank bonds and loans to households are not perfect substitutes for the commercial banks implies a mechanism through which FX interventions affect the exchange rate (the UIP condition, Eq (4.9)), but also implies that FX interventions may affect the supply of credit to the domestic economy. In fact, when the central bank "actively" intervenes in the FX market, it will shift the balance sheet of the commercial banks towards central bank bonds and, through Eq (4.10), this will cause a fall in the interest rate on loans.[9]

4.2 Model dynamics

In this section the model is used to illustrate possible effects that sterilized interventions may have on the domestic economy. We do so by simulating two shocks. The first one is a temporary reduction in the external interest rate that induces capital flows into the domestic economy. The second shock is a temporary increase of the oil sector revenue. Results for both active FX intervention (responsive to RER deviations from steady state, $\omega \neq 0$) and passive intervention (non-responsive to RER deviations from steady-state, $\omega = 0$) are discussed. The FX intervention is modeled by means of equation (4.7).

The simulations are carried out using alternative monetary regimes. In particular, we present the results for three monetary policy regimes. In the first one, we assume that the central bank sets the nominal interest rate using the following Taylor rule:

$$i_t = (1-\rho_i)\,\bar{i} + \rho_i i_{t-1} + (1-\rho_i)\psi_\pi \left(\pi_t^C - \bar{\pi}\right) + \epsilon_t^i \tag{4.11}$$

In the second alternative regime, the central bank follows a strict inflation target and sets the nominal interest rate in such a way that $\pi_t^C = \overline{\pi}$. Neither of these alternative rules corrects the distortions created by price rigidities. To fix them, the policy rule must fully stabilize the non-tradable price inflation since this is the only source of nominal rigidities in the economy. That is, we define the "efficient" policy rule as the one that sets the interest rate in such a way that $\pi_t^N = \overline{\pi}$. (See Galí and Monacelli (2005))[10] . This policy rule is used as benchmark in all exercises.

[9]The model is calibrated in order to match the great ratios of the Colombian economy. The price rigidity parameter, $\kappa = 46$ is equivalent to a Calvo´s probability of adjustment every four quarters. The size of the intervention parameter, $\omega = 10$, follows the definition of managed floating in Benes, Berg, Portillo, and Vavra (2013). Based on an estimate of the response of the spread of the lending interest rates to the ratio of loans to public debt in the banks balance sheets θ was set to 0.10.

[10]In an alternative exercise where there are nominal wage rigidities this rule is not optimal any more. However, the main conclusions remain valid.

4.3 Capital inflow shock

The model economy is shocked with a decrease of 100bp in the external interest rate. Results for this shock with the efficient policy rule are displayed in Figure 7. The shock produces an appreciation of the currency that shift demand away from non-tradable goods and into tradable goods. This produces downward pressures on non-tradable inflation, thereby inducing the central bank to reduce domestic bonds interest rates. As a result, lending rate a falls increasing the demand for new loans and decreasing the debt burden of households. These two effects add up and explain the raise in domestic demand for both tradable and non-tradable goods.

The appreciation of the currency increases the marginal cost of the tradable goods relative to the non-tradable goods and shifts the demand for labor towards the non-tradable sector. Consequently, the appreciation of the currency implies a deterioration of the trade balance together with an increase of labor in the non-tradable sector. Finally, given that labor is perfectly substitutable across sectors and it is the only input of production, the increase in the marginal cost of producing the tradable good relative to the non-tradable good, implies a reduction in the relative price of the tradable good. That is, a fall in $RER_t = p_t^T/p_t^N$.

Comparing the efficient policy rule (flexible price equilibrium) with the equilibrium obtained with either the Taylor rule or strict inflation targeting rule gives the extent to which these alternative rules deviate from the efficient equilibrium. Any deviation from this equilibrium is consequently not desirable. Hence the question is whether active FX interventions can close the gap between suboptimal policies and the efficient allocation.

The results with the Taylor rule with and without active intervention are displayed in Figure 7. A central bank that sets the interest rate using a Taylor rule without active intervention in the FX market will reduce the nominal interest rate below its natural level[11] because there is a fall in inflation due to the strengthening of the currency. When the central bank actively intervenes in the FX market, the real appreciation is lower and the real interest rate falls less than in the efficient equilibrium.

However, sterilized active intervention in the FX market by the central bank creates a shift in the asset portfolio of commercial banks towards central bank bonds. Consequently, commercial banks will lower the interest rate on loans and expand credit to households. Notice that the credit expansion is larger than in the efficient equilibrium. In sum, when the central bank follows a Taylor rule to set the nominal interest rate, active FX intervention reduces the volatility of the exchange rate, but it creates a larger credit and consumption expansion in the domestic economy.

Figure 8 contains the results for the interest rate shock for the case in which the central bank follows a strict inflation regime ($\pi_t^C = \overline{\pi}$). In this circumstance, the nominal interest rate is set at a level that avoids the appreciation of the currency, which is the main source of deflation in the economy. In fact, the policy rate follows the external interest rate, implying only a small appreciation. As shown in Figure 8, active FX intervention by the central bank has a minor effect on the exchange rate. However, it affects the loan rate and domestic credit through its impact on commercial banks' portfolio. As a result, the economy becomes more volatile without any significant gain in exchange rate stabilization. This puzzling outcome is explained by the impulse that sterilized FX intervention delivers on domestic demand. With active FX intervention, loans to households increase more, creating an excess demand that the central bank fights back with a smaller reduction in the interest rate. Through the UIP this offsets the effects of FX purchases on the exchange rate.

To recap, there are remarkable differences with respect to the efficient equilibrium with intervention and without acive interventions in the FX market. Active FX interventions imply a larger fall in the loan rate because the sterilization affects the balance sheet of the commercial banks. When the central bank increases its stock of international reserves, it also increases the holdings of central bank bonds by commercial banks, affecting the composition of their portfolio. As explained above, this shift in the portfolio composition has the effect of lowering the loan rate more than in the equilibrium without intervention. Accordingly, loans to households rise by more than their flexible price level and

[11] The natural level of the nominal interest rate is the one that prevails at the flexible price equilibrium.

consumption becomes more volatile (Table 2).[12]

4.4 Oil revenue shock

In oil exporting countries movements in the oil sector revenue can have large impacts on the domestic economy. In this section the model is used to analyze the effects that such shock may have on the economy and how those effects change with different monetary and exchange rate policies. As in the previous section, we use as benchmark the efficient policy rule, ($\pi_t^N = \overline{\pi}$) (Figure 9).

In the efficient allocation, an increase in the oil revenue creates a larger demand for tradable and non-tradable goods together with a decrease in household debt with commercial banks and an appreciation of the currency. The real appreciation is a consequence of the additional demand for non-tradable goods that raises their relative prices and the nominal appreciation induced by the increase of the interest rate by the central bank.

In contrast, under the two alternative monetary policy regimes without active FX intervention, the response of the central bank involves a reduction in the interest rate (Figures 9 and 10). This is a consequence of the fact that the central bank tries to stabilize CPI inflation. That requires smoothing the price changes of both tradable and non-tradable goods. Hence, a strong appreciation is not tolerated. On the other hand, active FX intervention dampens the appreciation, but boosts credit supply and aggregate demand through the reduction of the loan rate. Consequently, the central bank reacts by increasing the policy interest rate. This partially offsets the effectiveness of the FX intervention on the exchange rate. The more the central bank cares about the inflation target, the less effective FX intervention is to curb the appreciation of the currency. This can be noticed by comparing the behavior of the RER in the Taylor and strict inflation targeting regimes with active FX intervention (Figures 9 and 10).

As in Ostry, Ghosh, and Chamon (2012), FX intervention is coupled by increases in the interest rate in response to the income shock. However, unlike Ostry et alters's findings, this is not the result of an optimal policy reaction, but a response to the expansionary effects of intervention. As in the case of the external interest rate shock, FX intervention is associated with higher volatility of most macroeconomic variables but the exchange rate (Table 3).

5 Conclusions

Banco de la República intervenes in the FX market to maintain adequate levels of international reserves, to fix short term exchange rate misalignments and, occasionally, to curb excessive exchange rate volatility. FX intervention is sterilized to the extent required to keep short term interest rates in line with the policy rate. The array of sterilization mechanisms has been expanded in recent years. Currently, an agreement between Banco de la República and the Government is in place to coordinate public debt management policy and Central Bank sterilization policy. Intervention is carried out through announced, daily purchases of fixed amounts of USD. This type of intervention is deemed as convenient because it minimizes any signal of a defense of a particular level of the exchange rate.

A survey of the effectiveness of FX intervention in Colombia do not support its usefulness to cope with the consequences of quantitative easing in advanced economies, reduced risk premiums for EME and high international commodity prices. These phenomena are likely to last for years, while, when effective, FX intervention seems to have a short-lived impact on the exchange rate. Accordingly, perceived medium term exchange rate misalignments must be dealt with other policy instruments.

[12] Unlike Benes, Berg, Portillo, and Vavra (2013), in our model the volatility of consumption and loans increases with FX intervention. The difference in the results might have to do with the specification of the risk premiums in Benes, Berg, Portillo, and Vavra (2013) which depends on the real level of central bank bonds in bank assets, while ours depends on the ratio of bonds to loans. This implies that in Benes, Berg, Portillo, and Vavra (2013) any shock that moves bank's bond holdings will shift the risk premiums, even if the composition of bank assets remains unchanged. Consequently, risk premiums would move in scenarios without active FX intervention and this would trigger interest rate responses that exacerbate consumption and loan volatility in those scenarios.

When sterilized FX intervention is effective due to the operation of the portfolio balance channel, it may also expand credit supply. The macroeconomic outcomes of intervention in this case will depend on the monetary policy rule followed by the Central Bank. A small open economy DSGE is used to explore this issue. In general, FX intervention implies a volatility of credit and consumption that is higher than under the efficient allocation and under alternative monetary regimes without intervention. This is could be a concern for financial stability if intervention reaches a large scale. Furthermore, the more inclined the central bank is to meet the inflation target, the stronger its response to the expansionary effects of the intervention and, consequently, the lower the impact of the intervention on the exchange rate. In effect, monetary policy will (partially) undo the effect of FX policy on the exchange rate. These results cast some doubts on the two instruments - two objectives conclusion of Ostry, Ghosh, and Chamon (2012).

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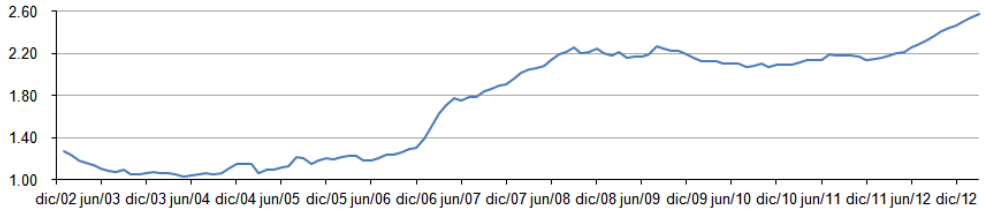
Table 1: Literature Review on the Effectiveness of the Forex Intervention in Colombia*

Authors Period of analysis (mm/yy)	Observed exchange rate Average daily return (%)	 Average daily volatility (%)	Type of intervention being evaluated	Econom tric results Return Mean	 Variance	Data frequency	Data and econometrics Procedure	 Asummed distribution	Intervention indicator
Toro and Julio (2005)									
Sep/04 - Apr/05	-0.12	0.39	Discretionary intervention	Increase Length: Not estimated	Increase	Intra-day	GARCH	GED	Dummy
Kamil (2008)									
Sep/04 - Mar/06	-0.02	0.28	Purchases (options and discretionary)	Increase Length: "short-lived"	Decrease	Daily	2S-IV, TOBIT, GARCH	Normal	Volume (non-weighted)
Jan/07 - Apr/07	-0.07	0.34		No effect	No effect	Daily		Normal	Volume (non-weighted)
Echavarría, Vásquez and Villamizar (2009)									
Apr/99 - Aug/08	0.02	0.43	Purchases (options and discretionary)	Increase Length: 1 to 6 months?	Decrease	Daily	2S-IV, TOBIT, EGARCH	*t*-student	Volume (non-weighted)
Echavarría, López and Misas (2009)**									
Jan/00 - Aug/08	0.04	0.39	Net Purchases (options, volatility and discretionary)	Increase Length: 1 month	---	Monthly	SVAR, Variance decomposition	White noise	Volume (non-weighted)
Rincón and Toro (2010)* **									
Jan/93 - Jul/10	0.02	0.31	Net Purchases (options, volatility and discretionary, preannounced)	No effect Length: Not estimated	Increase	Daily	GARCH	GED	Volume (Weighted by the market turnover)
Jan/93 - Sep/09	0.06	0.15	Net Purchases (discretionary)	No effect Length: Not estimated	No effect	Daily	IGARCH	GED	Volume (Weighted by the market turnover)
Oct/99 - Jul/10	-0.01	0.41	Net Purchases (options, volatility and discretionary, preannounced)	No effect Length: Not estimated	No effect	Daily	IGARCH	GED	Volume (Weighted by the market turnover)
Jan/04 - Jul/10	-0.02	0.58	Net Purchases (options, volatility and discretionary, preannounced)	No effect Length: Not estimated	No effect	Daily	IGARCH	GED	Volume (Weighted by the market turnover)
Jan/08 - Jul/10	-0.001	1.05	Net Purchases (options, preannounced)	No effect Length: Not estimated	No effect	Daily	IGARCH	GED	Volume (Weighted by the market turnover)
Echavarría, Melo, Tellez, and Villamizar (2012)									
Jan/00 - Mar/12	-0.002	0.44	Gross Purchases/Sales (options, volatility and discretionary, preannounced)	Increase Length: Not estimated	----	Daily	GARCH, TOBIT	*i.i.d.*~*N*(0,1)	Volume (non-weighted)
BIS-CCA (2012)									
May/07 - Nov/11	0.00 (7 minutes interval)	0.01	Net Purchases (options, preannounced)	Increase Length: "short-lived" (some minutes)	Decrease Length: "Long-lived" (at least one day)	Intra-day	GMM	----	Dummy, Volume

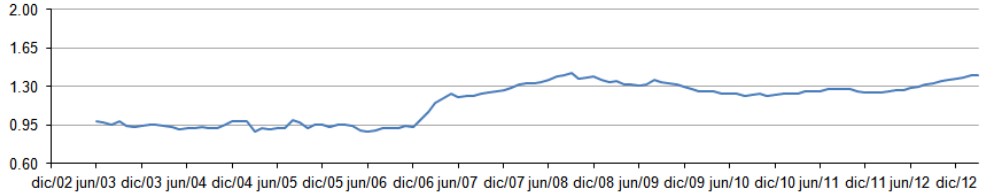
Source: Auhtors' compilation.
* The exchange rate is measured as the amount of COP for USD 1
** The effect of the forex intervenion is evalauted on the level of the exchange rate.
*** When both policies forex intervention and capital controls were used simultaneoulsy (lastest period) their interation increased the return, without increasing its volatility.

Figure 1: International Reserves*/Amortizations**



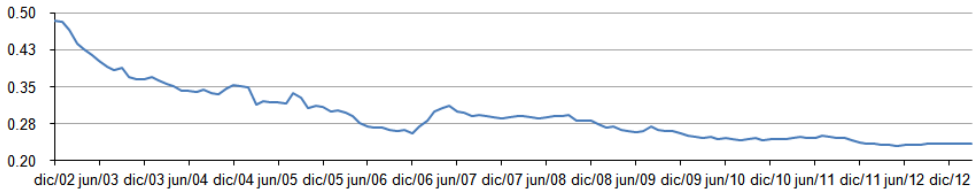
*Projected data from November 28, 2012 to March 2013.
**Projected data from October 2012 to March 2013. Denominator smoothed using Hodrick -Prescott Filter.

Figure 2: International Reserves*/Amortizations + Current Account Deficit**



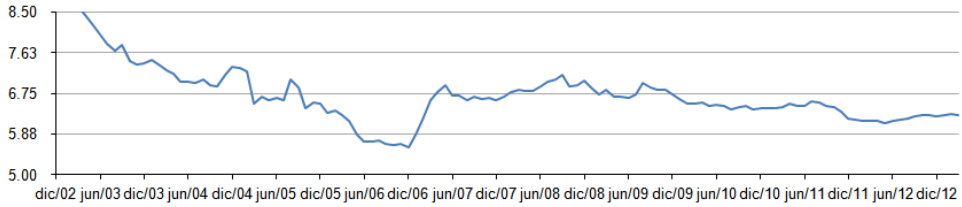
*Projected data from November 28, 2012 to March 2013.
**Projected data from July 2012 to march 2013. Denominator smoothed using Hodrick -Prescott Filter.

Figure 3: International Reserves*/M3**



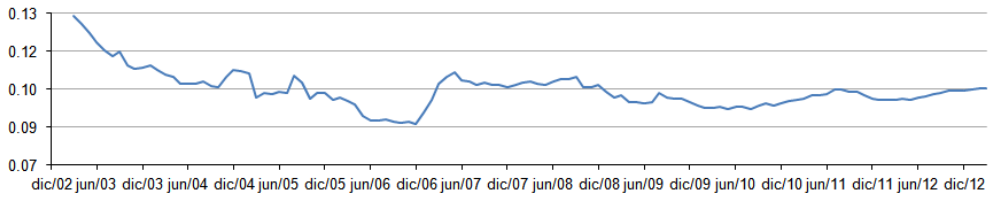
*Projected data from November 28, 2012 to March 2013.
**Projected data from November 2012 to March 2013. Denominator smoothed using Hodrick -Prescott Filter.

Figure 4: International Reserves*/Imports**



*Projected data from November 28, 2012 to March 2013.
**Projected data from July 2012 to March 2013. Denominator smoothed using Hodrick -Prescott Filter.

Figure 5: International Reserves*/GDP**



*Projected data from November 28, 2012 to March 2013.
**Projected data from July 2012 to March 2013. Denominator smoothed using Hodrick -Prescott Filter.

Figure 6: Terms of Trade (Colombia)

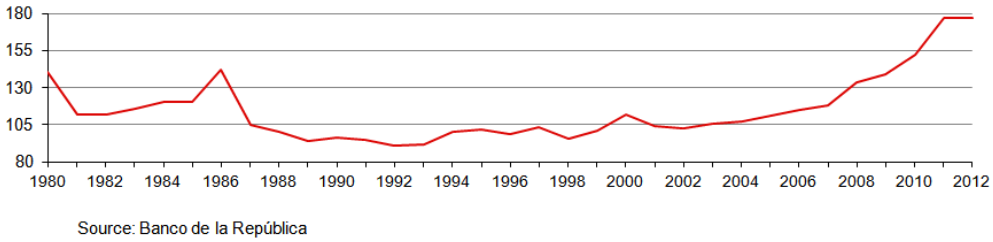


Table 2: Capital inflow shock: Relative variances implied by alternative rules with and without active FX Intervention

	Taylor Rule	Strict Inflation Targeting
Policy Rate	1.03	0.41
Real Interest Rate	16.28	0.43
Loan Rate	3.71	1.49
RER	0.89	0.98
Total Consumption	13.88	1.99
Tradable Consumption	26.37	2.48
Non-Tradable Consumption	4.62	1.36
Total Labor	4.08	0.55
Non-Tradable Labor	4.62	1.36
Tradable Labor	33.39	3.14
Anual Non-Tradable Inflation Rate	0.18	1.09
Anual Tradable Inflation Rate	3.04	1.00
Anual Inflation Rate	1.96	1.00
International Reserves (FX)	3356.18	295.08
Loans to Households	95.53	4.53
Non-Tradable Marginal Cost	3.10	1.23
Real wage	2.61	1.18
Quasi-fiscal Deficit	1.43	0.38
Non-Tradable Output	4.62	1.36
Tradable Output	33.39	3.14
Real Exchange Rate	0.89	0.98

For each variable, the table displays $var(x_t^i)/var(x_t^j)$ where $x_t^i = x_t^{Ri} - x_t^E$. x_t^{Ri} is the value of the variable under each of the alternate rules and x_t^E is the value of the variable under the efficient allocation. i represents active FX intervention and j represents no active FX intervention. If the ratio is greater than one, active FX intervention yields higher volatility.

Figure 7: Capital inflow shock with Taylor rule

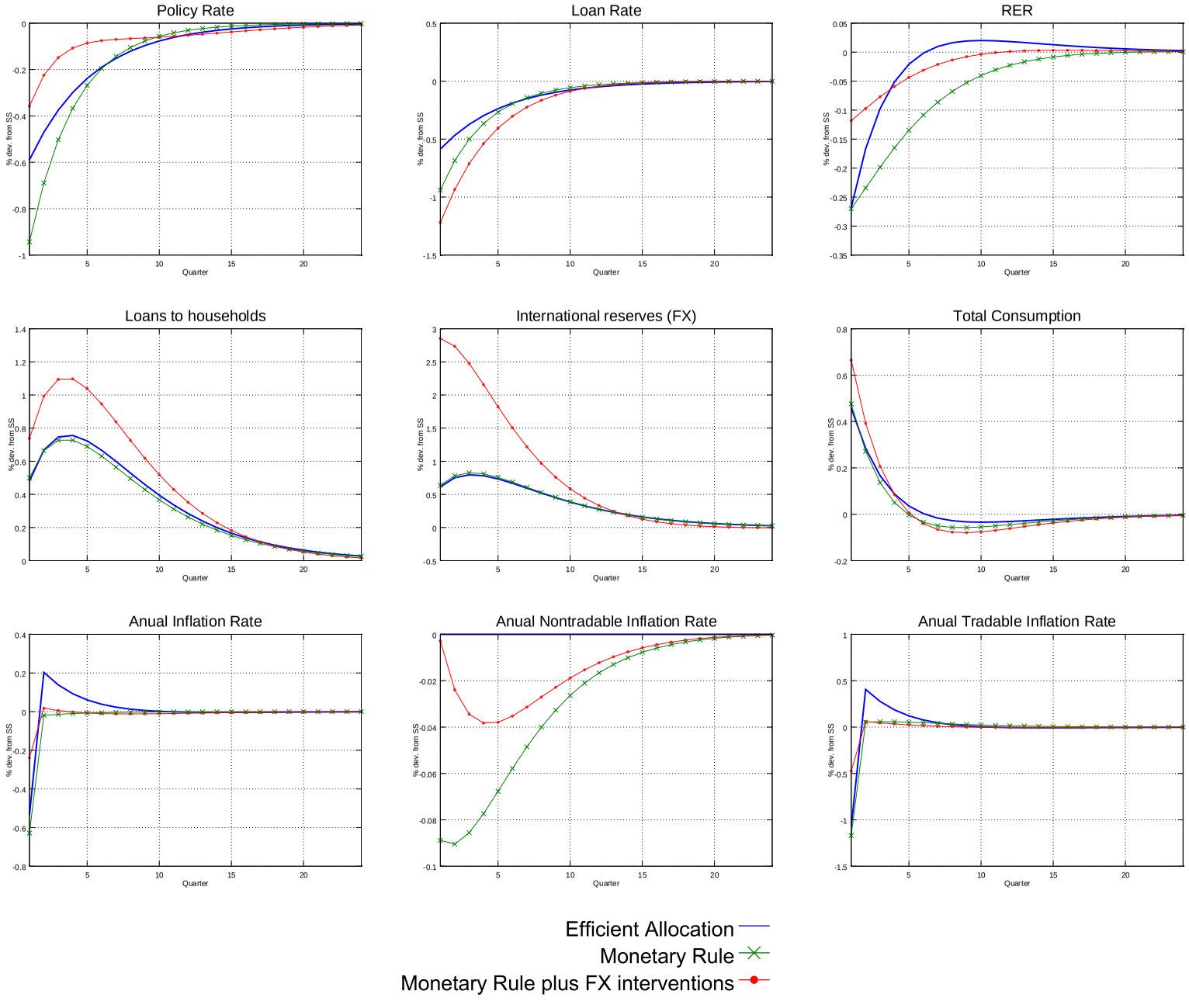
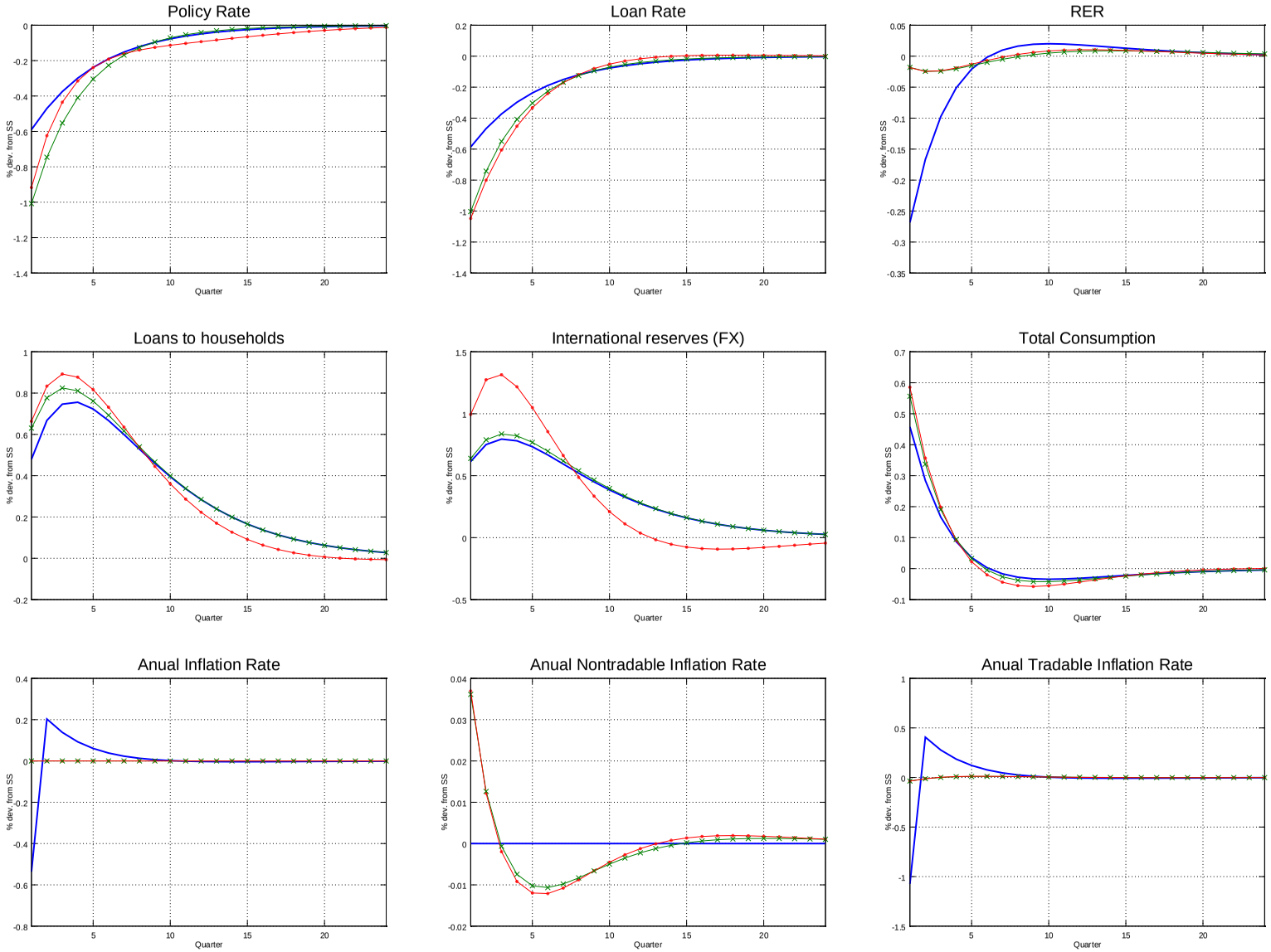


Figure 8: Capital inflow shock with a strict inflation targeting ($\pi_t^c = \bar{\pi}$)



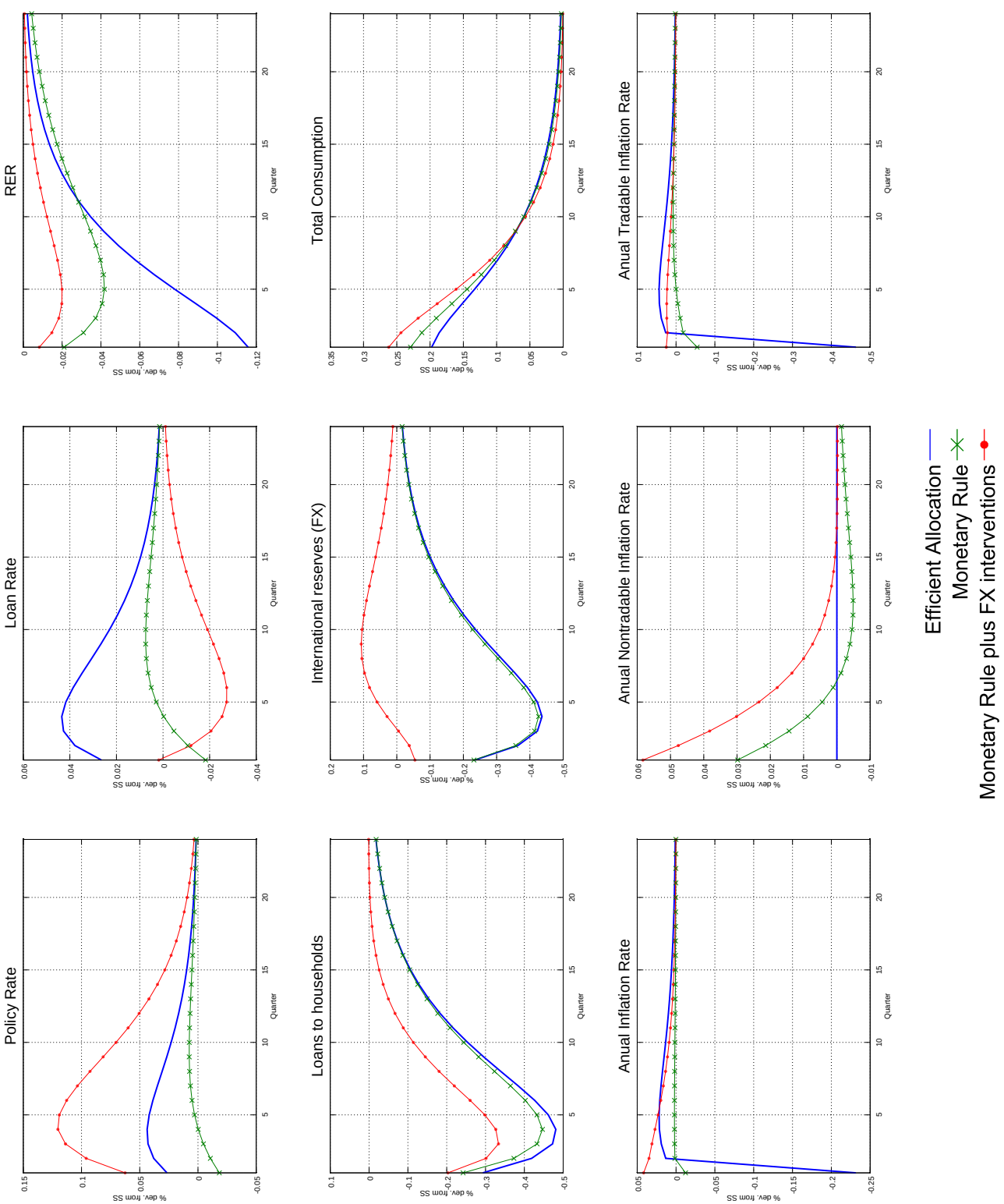


Figure 9: Oil shock with Taylor rule

Figure 10: Oil shock with a strict inflation targeting ($\pi_t^c = \bar{\pi}$)

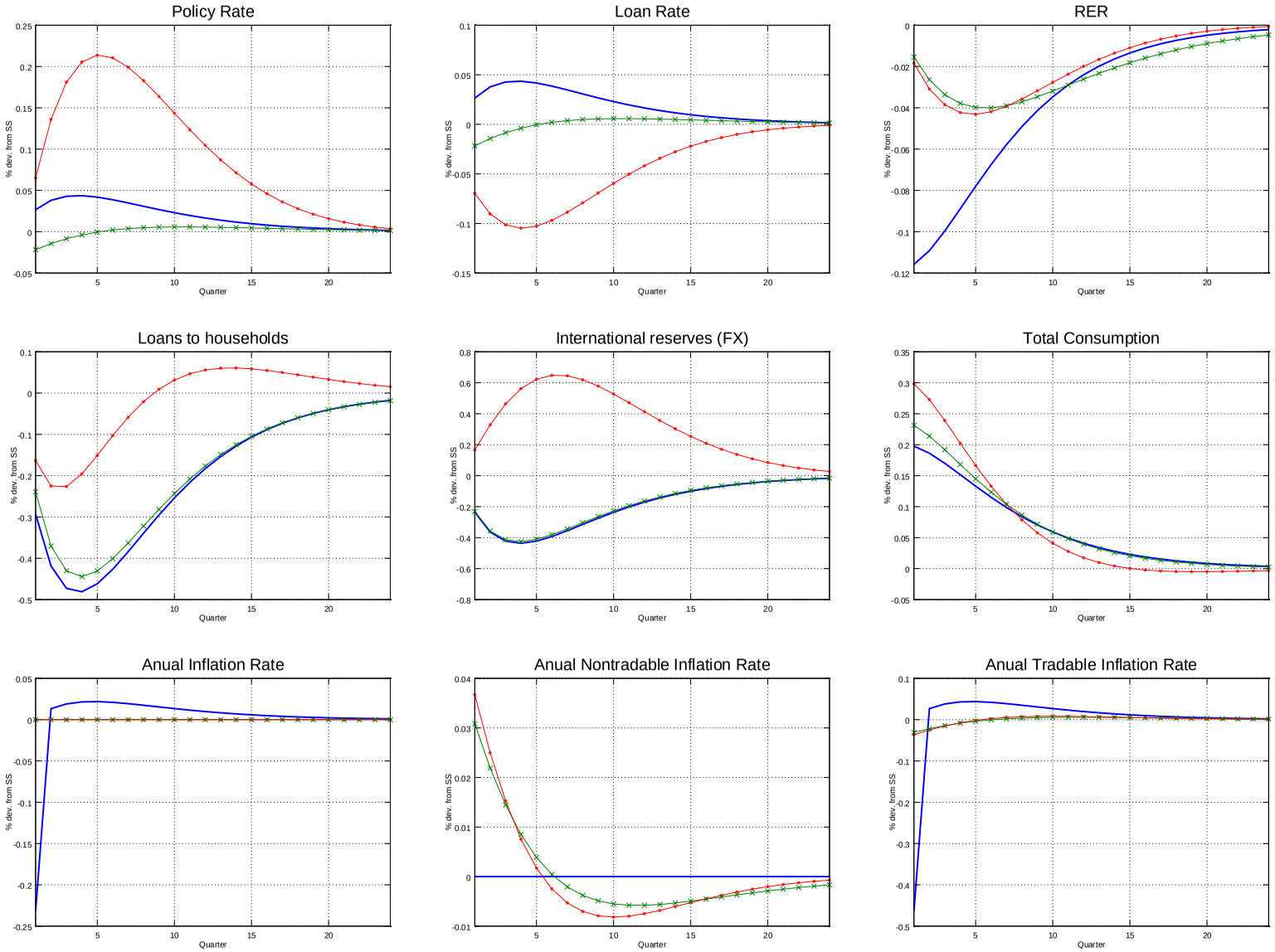


Table 3: Oil revenue shock: Relative variances implied by alternative rules with and without active FX intervention

	Taylor Rule	Strict Inflation Targeting
Policy Rate	2.42	10.62
Real Interest Rate	5.79	32.37
Loan Rate	1.84	7.98
RER	1.23	0.77
Total Consumption	5.29	12.60
Tradable Consumption	2.79	24.44
Non-Tradable Consumption	2.51	3.83
Total Labor	0.19	2.96
Non-Tradable Labor	2.51	3.83
Tradable Labor	12.61	39.68
Anual Non-Tradable Inflation Rate	3.50	1.36
Anual Tradable Inflation Rate	1.32	0.97
Anual Inflation Rate	1.43	1.00
International Reserves (FX)	1896.42	8170.71
Loans to Households	10.13	34.87
Non-Tradable Marginal Cost	2.03	2.56
Real wage	1.87	2.15
Quasi-fiscal Deficit	3.37	14.38
Non-Tradable Output	2.51	3.83
Tradable Output	12.61	39.68
Real Exchange Rate	1.23	0.77

For each variable, the table displays $var(x_t^i)/var(x_t^j)$ where $x_t^i = x_t^{Ri} - x_t^E$. x_t^{Ri} is the value of the variable under each of the alternate rules and x_t^E is the value of the variable under the efficient allocation. i represents active FX intervention and j represents no active FX intervention. If the ratio is greater than one, active FX intervention yields higher volatility.

A The Model

A.1 Households

$$y_t^P + w_t h_t + \xi_t^N + \xi_t^B + l_t = \tau_t + \left(\frac{1+i_{t-1}}{1+\pi_t^C}\right) l_{t-1} + c_t + \frac{\psi}{2}\left(l_t - \bar{l}\right)^2 \tag{A.1}$$

$$\lambda_t = \frac{z_t^U}{c_t} \tag{A.2}$$

$$w_t \lambda_t = \chi h_t^\eta \tag{A.3}$$

$$\lambda_t \left(1 - \psi\left(l_t - \bar{l}\right)\right) = \beta \mathbb{E}_t \left[\lambda_{t+1}\left(\frac{1+i_t^l}{1+\pi_{t+1}^C}\right)\right] \tag{A.4}$$

$$c_t^T = (1-\gamma_c)\left(\frac{p_t^T}{p_t^C}\right)^{-\varepsilon} c_t \tag{A.5}$$

$$c_t^N = \gamma_c \left(\frac{p_t^N}{p_t^C}\right)^{-\varepsilon} c_t \tag{A.6}$$

A.2 Commercial Banks

$$b_t + l_t = q_t b_t^* \tag{A.7}$$

$$\begin{aligned} \xi_t^B = {} & \left(\frac{1+i_{t-1}^l}{1+\pi_t^C}\right) l_{t-1} - l_t + \left(\frac{1+i_{t-1}}{1+\pi_t^C}\right) b_{t-1} - b_t + q_t b_t^* - q_t \left(\frac{1+i_{t-1}^*}{1+\pi_t^{C*}}\right) b_{t-1}^* \\ & - \left(\theta_b b_{t-1} + \theta_l l_{t-1} - 2\theta\sqrt{b_{t-1} l_{t-1}}\right) \end{aligned} \tag{A.8}$$

$$\mathbb{E}_t\left(\frac{1+i_t}{1+\pi_{t+1}^C}\right) = \mathbb{E}_t\left[\left(\frac{q_{t+1}}{q_t}\right)\left(\frac{1+i_t^*}{1+\pi_{t+1}^{C*}}\right)\right] + \theta_b - \theta\sqrt{\frac{l_t}{b_t}} \tag{A.9}$$

$$\mathbb{E}_t\left(\frac{1+i_t^l}{1+\pi_{t+1}^C}\right) = \mathbb{E}_t\left[\left(\frac{q_{t+1}}{q_t}\right)\left(\frac{1+i_t^*}{1+\pi_{t+1}^{C*}}\right)\right] + \theta_l - \theta\sqrt{\frac{b_t}{l_t}} \tag{A.10}$$

A.3 Central Bank

$$q_t r i_t^* = b_t \tag{A.11}$$

$$\tau_t = b_t - \left(\frac{1+i_{t-1}}{1+\pi_t^C}\right) b_{t-1} + q_t \left(\frac{1+i_{t-1}^*}{1+\pi_t^{C*}}\right) r i_{t-1}^* - q_t r i_t^* \tag{A.12}$$

Alternative nominal interest rate rules (A.13)

$$\frac{q_t r i_t^*}{l_t} = \frac{\overline{q\, r i^*}}{l} - \omega\left(RER_t - \overline{RER}\right) \tag{A.14}$$

A.4 Firms

A.4.1 Tradable goods

$$y_t^T = z_t^T \left(h_t^T\right)^{\alpha_T} \tag{A.15}$$

$$\frac{p_t^T}{p_t^C}\left(\alpha_T \frac{y_t^T}{h_t^T}\right) = w_t \tag{A.16}$$

A.4.2 Non-tradable goods

$$y_t^N = z_t^N \left(h_t^N\right)^{\alpha_N} \tag{A.17}$$

$$y_t^N = c_t^N + \frac{\kappa}{2}\left(\frac{1+\pi_t^N}{\left(1+\pi_{t-1}^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}} - 1\right)^2 \tag{A.18}$$

$$mc_t^N\left(\alpha_N \frac{y_t^N}{h_t^N}\right) = w_t \tag{A.19}$$

$$\begin{aligned} 0 = {} & (1-\varepsilon_N)\left(\frac{p_t^N}{p_t^C}\right) y_t^N + \left(\frac{\varepsilon_N}{\alpha_N}\right) mc_t^N y_t^N \\ & - \left(\frac{p_t^N}{p_t^C}\right)\kappa\left(\frac{1+\pi_t^N}{\left(1+\pi_{t-1}^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}} - 1\right)\frac{1+\pi_t^N}{\left(1+\pi_{t-1}^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}} \\ & + \beta\mathbb{E}_t\left[\left(\frac{\lambda_{t+1}}{\lambda_t}\right)\left(\frac{p_{t+1}^N}{p_{t+1}^C}\right)\kappa\left(\frac{1+\pi_{t+1}^N}{\left(1+\pi_t^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}} - 1\right)\frac{1+\pi_{t+1}^N}{\left(1+\pi_t^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}}\right] \end{aligned} \tag{A.20}$$

$$\xi_t^N = \left(\frac{p_t^N}{p_t^C}\right) y_t^N - w_t h_t^N - \left(\frac{p_t^N}{p_t^C}\right)\frac{\kappa}{2}\left(\frac{1+\pi_t^N}{\left(1+\pi_{t-1}^C\right)^{\iota}\left(1+\overline{\pi}\right)^{1-\iota}} - 1\right)^2 \tag{A.21}$$

A.5 Equilibrium

$$\pi_t^C = \left[(1-\gamma_c)\left(\frac{p_{t-1}^T}{p_{t-1}^C}\left(1+\pi_t^T\right)\right)^{1-\varepsilon} + \gamma_c\left(\frac{p_{t-1}^N}{p_{t-1}^C}\left(1+\pi_t^N\right)\right)^{1-\varepsilon}\right]^{\frac{1}{1-\varepsilon}} \tag{A.22}$$

$$\frac{p_t^T}{p_t^C} = q_t\left(\frac{p_t^{T*}}{p_t^{C*}}\right) \tag{A.23}$$

$$\frac{1+\pi_t^T}{1+\pi_t^C} = \frac{p_t^T}{p_t^C}\Big/\frac{p_{t-1}^T}{p_{t-1}^C} \tag{A.24}$$

$$\frac{1+\pi_t^N}{1+\pi_t^C} = \frac{p_t^N}{p_t^C}/\frac{p_{t-1}^N}{p_{t-1}^C} \tag{A.25}$$

$$h_t = h_t^T + h_t^N \tag{A.26}$$

$$\frac{(1+d_t)\left(1+\pi_t^{C*}\right)}{1+\pi_t^C} = \frac{q_t}{q_{t-1}} \tag{A.27}$$

$$RER_t = \frac{p_t^T}{p_t^N} \tag{A.28}$$

$$y_t = y_t^P + \left(\frac{p_t^T}{p_t^C}\right)\alpha_T y_t^T + mc_t^N \alpha_N y_t^N + \xi_t^B + \xi_t^N \tag{A.29}$$

$$(1+i_t^*) = \left(1+\overline{i}^*\right) z_t^{i*} \tag{A.30}$$

A.6 Shocks

$$z_t^{i*} = \rho_{z^{i*}}\left(z_{t-1}^{i*}\right) + (1-\rho_{z^{i*}})\ln\left(\overline{z^{i*}}\right) + \epsilon_t^{i*} \tag{A.31}$$

$$z_t^T = \rho_{z^T}\left(z_{t-1}^T\right) + (1-\rho_{z^T})\ln\left(\overline{z^T}\right) + \epsilon_t^{z^T} \tag{A.32}$$

$$z_t^N = \rho_{z^N}\left(z_{t-1}^N\right) + (1-\rho_{z^N})\ln\left(\overline{z^N}\right) + \epsilon_t^{z^N} \tag{A.33}$$

$$\pi_t^* = \rho_{\pi^*}\left(\pi_{t-1}^*\right) + (1-\rho_{\pi^*})\ln\left(\overline{\pi}^*\right) + \epsilon_t^{\pi^*} \tag{A.34}$$

$$z_t^U = \rho_{z^U}\left(z_{t-1}^U\right) + (1-\rho_{z^U})\ln\left(\overline{z^U}\right) + \epsilon_t^{z^U} \tag{A.35}$$

$$\frac{p_t^{T*}}{p_t^{C*}} = \rho_{p^{T*}}\left(\frac{p_{t-1}^{T*}}{p_{t-1}^{C*}}\right) + \left(1-\rho_{p^{T*}}\right)\ln\left(\frac{\overline{p_{t-1}^{T*}}}{p_{t-1}^{C*}}\right) + \epsilon_t^{p^{T*}} \tag{A.36}$$

$$y_t^P = \rho_{y^P}\left(y_{t-1}^P\right) + \left(1-\rho_{y^P}\right)\ln\left(\overline{y^P}\right) + \epsilon_t^{y^P} \tag{A.37}$$

Table 4: Variables

Symbol	Description
Real quantities	
c	Consumption bundle
c^N	Non-tradable consumption
c^T	Tradable consumption
h	Total labor
h^N	Non-tradable labor
h^T	Tradable labor
l	Loans to households
τ	Quasi-fiscal deficit
b	Sterilization bonds
b^*	External debt
y	Domestic output
y^N	Domestic non-tradable output
y^T	Domestic tradable output
λ	Multiplier for budget constraint
ri^*	International reserves
Interest rates, real exchange rate and relative prices	
i_t	Policy rate
i_t^*	External nominal interest rate
i_t^l	Loan rate
q_t	Real exchange rate
RER	Tradable price / Non-tradable price
$\frac{p_t^T}{p_t^C}$	Tradable price / Consumption bundle price
$\frac{p_t^N}{p_t^C}$	Non-tradable price / Consumption bundle price
Inflation rates and nominal devaluation	
π_t^C	Total inflation rate
π_t^T	Non-tradable inflation rate
π_t^N	Tradable inflation rate
d_t	Nominal devaluation
Profits and marginal cost	
ξ^N	Non-tradable sector's profits
ξ^B	Commercial banks' profits
mc^N	Non-tradable firm's marginal cost
Exogenous variables	
$\frac{p_t^{T*}}{p_t^{C*}}$	External tradable goods relative prices
π_t^{C*}	External inflation rate
z^U	Shock to marginal utility of consumption
z^{i*}	External interest rate shock
z^N	Non-tradable productivity shock
z^T	Tradable productivity shock
y^P	Dividends from the oil sector

Table 5: Parameters

Symbol	Description
$\overline{RER}$	Exchange rate's operational target
$\overline{\pi}^C$	Inflation target
ψ	Quadratic adjustment cost parameter for loans
$\bar{i}$	Long run nominal interest rate
$\bar{i}^*$	Long run external nominal interest rate
χ	Scale parameter in labor supply
η	Inverse of
β	Intertemporal discount factor
γ_c	Non-tradable relative weight in consumption bundle
ε	Elasticity of substitution between tradable and non-tradable goods
ε^N	Elasticity of substitution between varieties of non-tradable goods
θ_b	Exogenous spread between policy and external rate
θ_l	Exogenous spread between loan and external rate
θ	Portfolio channel sensibility
ω	Strength of the Central Bank's FX intervention
α_N	Share of labor in the production of non-tradable goods
α_T	Share of labor in the production of tradable goods
κ	Price changing cost for non-tradable firms
ι	Degree of price indexation for non-tradable firms
$\rho_{z^{i*}}$	Persistence of risk premium shock
ρ_{z^N}	Persistence of non-tradable productivity shock
ρ_{z^T}	Persistence of tradable productivity shock
ρ_{π^*}	Persistence of inflation rate shock
ρ_{z^U}	Persistence of marginal utility of consumption shock
$\rho_{p^{T*}}$	External tradable goods relative prices
ρ_{y^P}	Persistence of dividends from oil sector shock