

Foreign exchange intervention in Colombia¹

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Abstract

This paper describes the Banco de la República's FX intervention policy, with a focus on its objectives and main features. It then argues, based on a review of the literature on the effectiveness of sterilized intervention in Colombia, that this tool is not a useful way of coping 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 impact of sterilized intervention on the exchange rate (if any) is of much shorter duration than are the effects of those external factors. Finally, the paper argues that if sterilized FX intervention is effective through 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 model. In general, FX intervention creates more volatility of credit and consumption than occurs with 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 classification: F31, F32, F33, E37

¹ We are grateful to Ángel Gutiérrez, Franz Hamann, Juan Manuel Julio, Hernán Rincón and Juan Pablo Zárate for helpful comments and input. The views expressed in the paper are those of the authors and do not represent those of the Banco de la República or its Board of Directors.

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1. Introduction

This paper first describes current FX intervention policy by the Banco de la República, emphasizing its objectives and features, and highlighting some issues that have arisen recently in local policy discussions. Preliminary answers are then proposed 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, given that sterilized FX intervention may influence the exchange rate (through the portfolio balance channel), what are the macroeconomic consequences of sterilized FX intervention if one considers both the effects of the portfolio balance channel on credit supply and the operation of a monetary policy rule?

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 discussions on the effectiveness and desirability of sterilized FX intervention are often framed in a partial equilibrium setting, overlooking the possible interplay of sterilized FX intervention, credit supply and monetary policy. The microeconomic basis for the effectiveness of sterilized FX intervention (portfolio balance channel) also implies the presence of effects on credit supply from sterilized FX intervention, which may prompt monetary policy responses that end up shaping the macroeconomic outcomes. A small open economy DSGE model is used to explore this issue here.

2. Current Banco de la República FX intervention policy

2.1 Objectives

FX intervention in Colombia is undertaken (1) to maintain an adequate level of international reserves, (2) to remedy short term exchange rate misalignments and (3) on occasion, to curb excessive exchange rate volatility.

1. Maintaining an adequate level of international reserves

Maintaining a stock of international reserves is a must in a small open economy that is subject to strong external shocks and that cannot issue a reserve currency. This is a key objective of FX intervention by the Banco de la República. Hence, the size of the intervention is determined to a great extent by the criteria used to define a desired or adequate level of international reserves.

Two elements must be taken into account in making this decision. First, the international reserves requirements may vary across countries, depending not only on their size, trade flows and financial activity, but also on macroeconomic characteristics such as the exchange rate regime, 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 appropriate level of international reserves will be lower in the former type of country, even if both economies are of

similar size, face the same (short term) external debt payments, or have the same degree of financial deepening or the same current account balance (Edison (2003)).

In Colombia, the credibility of the inflation target is robust, pass-through is low and there is sound regulation of financial intermediaries' currency and FX term mismatches. The conditions for a high degree of exchange rate flexibility are therefore present. In fact, the Banco de la República 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 helps to maintain the conditions for flexibility, since currency risk is internalized in private sector funding decisions (thereby limiting mismatches), while 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.⁵ 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. A question remains as to whether this situation justifies holding a much greater stock of international reserves, or whether Colombian liquidity regulation must be strengthened to address this exposure. After all, holding international reserves is generally costly, and so forcing banks to internalize the risk seems sensible. Besides monitoring the FX liquidity of the conglomerates, it may be necessary to impose additional FX liquidity requirements on banks operating overseas in order to preserve the resilience of the financial system, especially if host countries' regulations or LOLR facilities are deemed subpar, or if the information needed to gauge liquidity risk is not available. Meanwhile, the cost of the insurance would be borne by the agents originating the risk.

The second element to consider when assessing the adequacy of the international reserves level is that the effectiveness of accumulating international reserves as a way of protecting the economy from external liquidity shocks depends on deeper factors such as the contemporaneous behaviour of macroeconomic savings and the openness of the financial account. Models of "optimal reserves" are commonly used to judge the appropriateness of stocks of international reserves (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 help reduce the probability of such events. At the same time, these models recognize that international reserves entail opportunity costs. The "optimal" level of international reserves provides a solution to 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 with, they are too simplistic to adequately incorporate the above-mentioned idiosyncratic traits of each economy. Hence, strong and rather coarse-grained assumptions must be made regarding the size, probability and cost of a liquidity shock. The results of

⁵ Between 2007 and 2012, 130 Colombian bank subsidiaries were opened or bought abroad. Approximately 67.5% of these are located in Central America. Moreover, the assets of foreign subsidiaries of Colombian banks rose from 9% of total assets in 2009 to 20% in 2011.

these models are extremely dependent on the assumptions, rendering the methods of very limited use for policy purposes.⁶

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 on a one-to-one basis with the purchases of international reserves. This may not be the case, especially if the 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 country’s (short term) net asset position unchanged. As a result, “insurance” against a “sudden stop” is not obtained simply by the central bank’s accumulating reserves.

When capital mobility is imperfect, reserves purchases do achieve some insurance. However, it is less than that initially deemed “optimal,” since some capital inflows are attracted at any rate. To reach the optimal level, larger reserve purchases are required, but they entail greater opportunity costs. Thus, the optimal insurance level may now be lower, as may also be the optimal level of international reserves. A simple variation of the Jeanne (2007) model presented in Gerencia Técnica (2012) shows that “optimal” level of reserves decreases rapidly with the sensitivity of external short term liabilities to FX intervention.

The broader point here is that international reserves accumulation does not necessarily constitute increased insurance against “sudden stops”. It does, as long as the increases in international reserves are coupled with hikes in macroeconomic savings, or at least with rises in the country’s net short term external position. 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 and the behaviour of domestic savings.

In practice, the 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” behaviour, 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 exchange rate volatility. In these circumstances, it is possible that a substantial

⁶ 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 regarding the probability, size and cost of a “sudden stop.” The plausibility of the different sets of assumptions proposed is not clear-cut, since they could relate to episodes or groups of countries whose current relevance is quite open to debate.

fraction of market participants may share the same “autoregressive” view of the exchange rate and that a bubble-like path can ensue. This may cause undue damage to tradable sectors (if the currency appreciates), inflationary pressures (in the case of depreciation) or unwarranted volatility in FX and financial markets.

The Banco de la República closely monitors the evolution of the FX market to detect such behaviour. However, such episodes are recognized to be rather infrequent, and a procedure is in place to assess their likelihood and take corrective action when necessary. As explained in Vargas (2011), the conclusion that there is a high probability of a misalignment depends on various elements: a thorough examination of the nature and size of capital flows performed on the basis of FX spot and derivative transactions; a comparison of the trend of the COP with trends in other EM and regional currencies; and an assessment of the contrast between the observed real exchange rate and several “equilibrium” measures. FX intervention is then undertaken if its benefits (effectiveness) outweigh its costs (quasi-fiscal and other).

3. Curbing excessive exchange rate volatility

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 and check episodes of excessive exchange rate volatility 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 exceeded/fell below its 20-day average by a specified percentage. This mechanism has not been active since February 2012, but can be activated 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 of reserves purchases need not be totally offset as long as there are other shifts in money demand and supply that compensate for it. Government deposits at the Central Bank have been the main sterilization mechanism in recent years. They have allowed the Banco de la República to remain a net creditor to the financial system.

However, in case government deposits fall short of the amounts required to sterilize additional reserves purchases, other offsetting mechanisms are 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 the Banco de la República can open, and has opened, remunerated short term (7-day and 14-day) deposits that are accessible to a wide array of financial institutions.⁷ 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, legislation in 2009 allowed the Central Bank to issue its own securities, and in 2011 the law authorized the issuance of Monetary

⁷ Not only commercial banks, but broker-dealers, investment funds and pension funds are authorized to hold these deposits at the Central Bank.

Regulation Government Bonds (MRGBs) specifically designed for 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 the Banco de la República to issue MRGBs and 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 MRGBs.

The first MRGBs were issued in December 2012, with maturities of 1.5, 2 and 3 years. 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 the Banco de la República intervenes in the FX market through announced auctions of fixed-amount, daily purchases of USD. After long and diverse experience with several modes of intervention, the perception at the Central Bank is that this is the best type for the above-mentioned objectives, since it minimizes any signal about the defense of a particular level of the exchange rate. This is the case 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 should the latter react by increasing intervention.

3. Is sterilized FX intervention useful to deal with medium term currency appreciation forces?

Like other EM currencies, the COP has undergone appreciation in recent years 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 behaviour of international commodity prices (Figure 5). This trend has not only led to 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 have expanded substantially. 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 feature common to 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 appropriateness of such action 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. Findings are mixed with respect to the impact of sterilized FX intervention on exchange rate returns or levels, depending on the period analyzed, 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. Findings are also diverse as regards 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 econometric specifications do not allow for the dynamic effects of intervention. The studies employ controls and compare the behaviour of the exchange rate in periods with intervention to its behaviour in periods without intervention.⁸ Only two studies explicitly account for possibly changing effects of intervention through time. Based on an 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 lasting for some minutes.⁹

These findings 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 militate against using this instrument for that purpose, as costs are certain but benefits are small and uncertain. This is consistent with the findings 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 described in the foregoing section, in which sterilized FX intervention is aimed at correcting short term misalignments.

Longer term misalignments related to expenditure or credit excesses may arise as a result of the above-mentioned phenomena. Nevertheless, sterilized FX

⁸ 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 exploration of its lagging responses.

⁹ 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 as a nil effect. Significant coefficients may indicate a contemporaneous effect of intervention with an indeterminate impact on the expected future exchange rate.

intervention does not seem a suitable remedy.¹⁰ 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 periods implied by the duration of the aforementioned shocks may raise serious doubts about their appropriateness. Increases in domestic savings through adequate fiscal policy arrangements (especially in the case of the commodity boom cycle) or macro-prudential policies remain policy choices meriting consideration.

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 for the use of this instrument when there is a low degree of substitution between different assets in the balance sheets of the various agents in the economy. This could be a feature especially in EMs with still developing financial markets. Ostry, Ghosh and Chamon (2012) argue that when the financial account behaviour 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 exchange rate).

Nonetheless, the foregoing arguments ignore either the microeconomic underpinnings of imperfect capital mobility (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 – effects that can determine overall macroeconomic outcomes. More specifically, sterilized FX intervention under imperfect substitution between assets may impact the supply of credit. García (2011) shows that sterilized FX purchases in a context of 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.

¹⁰ 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 work against the appreciation caused by Dutch Disease. Calibrating the model for Canada, they find that even if exchange rate stabilization can restore tradable output to near the efficient level, the volatility introduced to macroeconomic aggregates reduces welfare in comparison with a scenario in which the exchange rate is allowed to adjust.

4.1 The model

Here, we construct a DSGE model for a small open economy that has tradable and non-tradable sectors as well as an oil producing sector (which does not use domestic resources for production, but generates large foreign income flows). Added to this otherwise standard model is a financial sector 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 (2012), 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 as well as shifts in the composition of their asset portfolios. These shifts in turn affect loan supply and the rest of the economy. Hence, any sterilized FX intervention undertaken by an IT central bank has complex macroeconomic consequences.

This section describes the main features of the model. The full set of equations can be found in the Appendix (sections A1-A5, setting forth the model). The model economy comprises households that receive income from labor, profits from firms and banks, and transfers from the government. The budget constraint of a representative household is:

$$y_t^p + w_t h_t + \xi_t^N + \xi_t^B + l_t = \tau_t + \left(\frac{1 + i_t^l}{1 + \pi_t^c} \right) l_{t-1} + c_t + \frac{\psi}{2} (l_t - \bar{l})^2 \quad (4.1)$$

where w_t is the real wage in terms of the consumption bundle, h_t is the total supply of labor, l_t is loans from commercial banks, ξ_t^N is profits from non-tradable firms and ξ_t^B 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 consumption bundle c_t at price p_t^c , pays loans from previous periods at a rate i_t^l and also incurs cost when adjusting its demand for loans.¹¹ This cost also creates a margin between the loan interest rate and the discount factor:

$$\lambda_t (1 - \psi (l_t - \bar{l})) = \beta E_t \left[\lambda_{t+1} \left(\frac{1 + i_t^l}{1 + \pi_{t+1}^c} \right) \right] \quad (4.2)$$

As can be seen 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 (2012) for details).

The consumption bundle is composed of 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:

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

¹¹ Technically, this quadratic adjustment cost guarantees a stationary equilibrium for loans.

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 decreasing returns to scale technology that uses only 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 sets prices by maximizing profits under costly price changes as in Rotemberg (1982). The problem of the representative firm in the non-tradable sector, in other words, is:

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

where 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 decreasing returns to scale technology, and consequently the firm's marginal cost is not equal to the average marginal cost. In fact, following [19] and [9], the individual firm's 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 non-tradable goods, α_N is the share of labor in the production of non-tradable goods and mc_t^N is the average marginal cost in the non-tradable sector.

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

$$\pi_t^N = \beta E_t \pi_{t+1}^N + \iota^N \pi_{t-1}^C - \beta \iota^N \pi_t^C + \frac{(\varepsilon^N - 1)}{\kappa} mc_t^N \quad (4.4)$$

where π_t^N is the non-tradables price inflation, and π_t^C is the total price inflation (composed of tradable and non-tradable price inflation).

The financial sector comprises 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:

$$q_t r_t^* = b_t \quad (4.5)$$

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

$$\tau_t = b_t - \frac{(1 + i_{t-1})}{(1 + \pi_t^C)} b_{t-1} + q_t \frac{(1 + i_{t-1}^*)}{(1 + \pi_t^*)} r_{t-1}^* - q_t r_t^* \quad (4.6)$$

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.

During each period, the central bank intervenes in the FX market to keep the ratio of reserves to the country's foreign liabilities (a proxy reserve-adequacy indicator) close to a desired steady-state level. In addition, it seeks to reach a given operational target for the real exchange rate measured as $RER_t = p_t^T / p_t^N$. It also determines the interest rate it pays to banks by using a policy rule. One possible rule for the FX interventions is.¹²

$$\frac{q_t r_t^*}{i_t} = \frac{\overline{q r i^*}}{i} - \omega (RER_t - \overline{RER}). \quad (4.7)$$

Under 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 aims only to keep the ratio of foreign reserves to foreign liabilities constant.

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

$$b_t + l_t = q_t b_t^* \quad (4.8)$$

As in Edwards and Vegh (1997), and Benes, Berg, Portillo, and Vavra (2012), 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:

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

and

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

Equation (4.9) is the UIP condition adjusted by a risk premium. As explained in Appendix C of Benes, Berg Portillo and Vavra (2012), this risk premium is increasing

¹² As will be explained below, commercial banks' liability side consists entirely of foreign debt, while their asset side consists of loans to households plus 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, $q_t r_t^* = b_t$. From commercial banks' balance sheets: $b_t + l_t = q_t b_t^*$. Hence, $b_t^* / r_t^* = 1 + l_t / b_t$.

as a function of 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 Equation 4.7), it raises the cost to commercial banks because they will hold central bank bonds in excess of their long term 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 commercial bank balance sheet 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 household loans, 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.

To summarize, 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 it 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 commercial bank balance sheet towards central bank bonds, and through Eq. (4.10) this will cause a drop in the interest rate on loans.¹³

4.2 Dynamics of the model

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

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

$$i_t = (1 - \rho_i) \bar{i} + \rho_i i_{t-1} + (1 - \rho_i) \psi_\pi (\pi_t^C - \bar{\pi}) + \varepsilon_t^i \quad (4.11)$$

In the second alternative, the central bank follows a strict inflation target and sets the nominal interest rate in such a way that $\pi_t^C = \bar{\pi}$. Neither of these alternative rules corrects the distortions created by price rigidities. To fix them, the policy rule must fully stabilize 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

¹³ The model is calibrated in order to match the high ratios of the Colombian economy. The price rigidity parameter $\kappa = 46$ is equivalent to a Calvo’s probability of adjustment every four quarters. The magnitude of the intervention parameter $\omega = 10$ follows the definition of managed floating in Benes, Berg Portillo and Vavra (2012). Based on an estimate of how the lending interest rate spread responds to the loans-to-public-debt ratio in the banks’ balance sheets, θ was set to 0.10.

one that sets the interest rate in such a way that $\pi_t^N = \bar{\pi}$. (See Galí and Monacelli (2005)).¹⁴ This policy rule is used as a benchmark in all the exercises.

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 shifts demand away from non-tradable goods and into tradable goods. This produces downward pressure on non-tradable inflation, thereby inducing the central bank to reduce domestic bond interest rates. As a result, lending rates fall, increasing the demand for new loans, and decreasing households' debt burden. These two effects add up to explain the rise in domestic demand for both tradable and non-tradable goods.

The appreciation of the currency increases the marginal cost of tradable goods relative to non-tradables, and shifts the demand for labor towards the non-tradable sector. Consequently, the appreciation of the currency implies a deterioration of the trade balance along with an increase of labor in the non-tradable sector. Finally, given that labor is perfectly substitutable across sectors and that it is the only production input, the increase in the marginal cost of producing a tradable, as opposed to a 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 either with the Taylor rule or with a strict inflation targeting rule reveals 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 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,¹⁵ because there is a decline 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 case.

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. Note that the credit expansion here is greater than in the efficient equilibrium. In short, 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 creates greater expansion of credit and consumption in the domestic economy.

¹⁴ In an alternative exercise where there are nominal wage rigidities this rule is not optimal any more. However, the main conclusions remain valid.

¹⁵ The natural level of the nominal interest rate is the one that prevails at the flexible price equilibrium.

Figure 8 shows the results of the interest rate shock for the case in which the central bank follows a strict inflation regime ($\pi_t^C = \bar{\pi}$). In this circumstance, the nominal interest rate is set at a level that prevents 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 the 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 gives to domestic demand. With active FX intervention, loans to households increase more, creating an excess demand that the central bank combats via 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 notable differences as regards efficient equilibrium with, versus without, active intervention in the FX market. Active FX interventions imply a larger drop 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 portfolio composition has the effect of lowering the loan rate more than occurs in the case of equilibrium without intervention. Accordingly, loans to households rise by more than their flexible price level, and consumption becomes more volatile (Table 2).¹⁶

4.4 Oil revenue shock

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

In the efficient allocation, an increase in oil revenue creates a larger demand for tradable and non-tradable goods along with a decrease in household debt to 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 of the nominal appreciation induced by the central bank's interest rate hike.

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

¹⁶ In contrast to Benes, Berg, Portillo and Vavra (2012), in our model the volatility of consumption and loans increases with FX intervention. The difference in the findings could have to do with the specification of the risk premiums in the Benes et al. model, which depends on the real level of central bank bonds in bank assets, while our specification depends on the ratio of bonds to loans. This implies that in Benes, Berg, Portillo and Vavra (2012), any shock that moves banks' bond holdings will shift 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.

to stabilize CPI inflation. That requires smoothing the price changes of both tradable and non-tradable goods. Hence, sharp appreciation is not tolerated. On the other hand, active FX intervention dampens appreciation, but boosts credit supply and aggregate demand through 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 effect FX intervention has in curbing appreciation of the currency. This can be seen by comparing the behaviour 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 with increases in the interest rate in response to the income shock. However, in contrast to the findings of Ostry et al., 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 in most macroeconomic variables but not in the exchange rate (Table 3).

5. Conclusions

The Banco de la República intervenes in the FX market to maintain adequate levels of international reserves, to remedy 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 the 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 appropriate because it minimizes any signal of a defense of a particular level of the exchange rate.

A survey on the effectiveness of FX intervention in Colombia does not support the notion that it is helpful in coping with the consequences of quantitative easing in advanced economies, reduced risk premiums for EMEs and high international commodity prices. These phenomena are likely to last for years, while FX intervention, when effective, seems to have but a short-lived impact on the exchange rate. Accordingly, perceived medium term exchange rate misalignments must be dealt with by other policy instruments.

When sterilized FX intervention is effective through 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 efficient allocation and under alternative monetary regimes without intervention. This 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 doubt on the “two targets, two instruments” conclusions of Ostry, Ghosh and Chamon (2012).

Literature Review on the Effectiveness of the Forex Intervention in Colombia*

Table 1

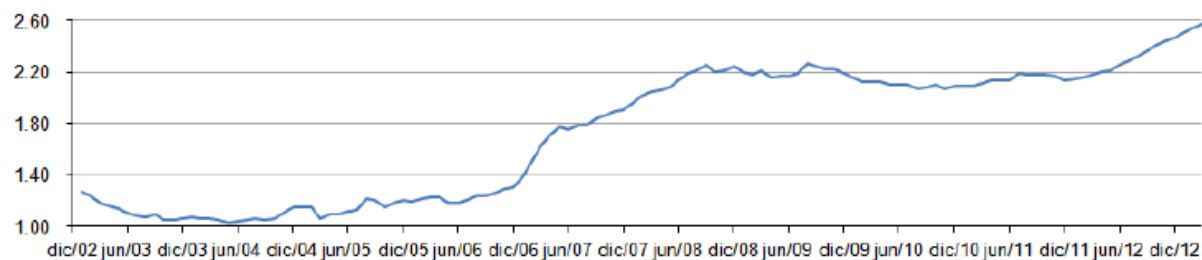
Authors Period of analysis (mm/yy)	Observed exchange rate		Type of intervention being evaluated	Econometric results Return		Data and econometrics			
	Average daily return (%)	Average daily volatility (%)		Mean	Variance	Data frequency	Procedure	Assumed distribution	Intervention indicator
Toro and Julio (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) 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.i.d. ~ N(0,1)</i>	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

* The exchange rate is measured as the amount of COP per USD 1 ** The effect of the forex intervention on the level of the exchange rate is evaluated. *** When both policies, forex intervention and capital controls, were used simultaneously (latest period), their interaction increased the return without increasing its volatility.

Source: Authors' compilation.

International Reserves*/Amortizations**

Figure 1

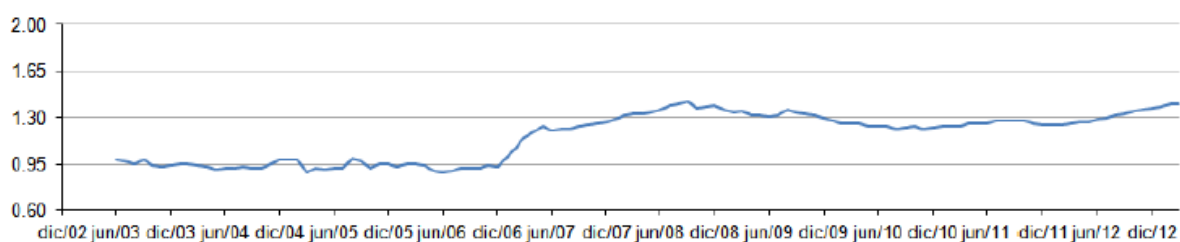


*Projected data from November 28, 2012 to March 2013.

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

International Reserves*/Amortizations + Current Account Deficit**

Figure 2

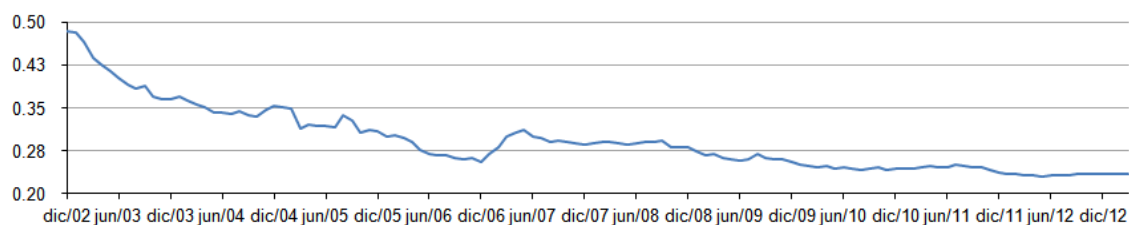


*Projected data from November 28, 2012 to March 2013.

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

International Reserves*/M3**

Figure 3

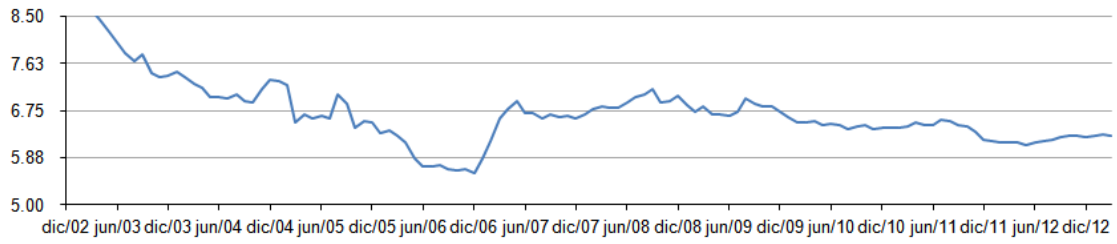


*Projected data from November 28, 2012 to March 2013.

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

International Reserves*/Imports**

Figure 4

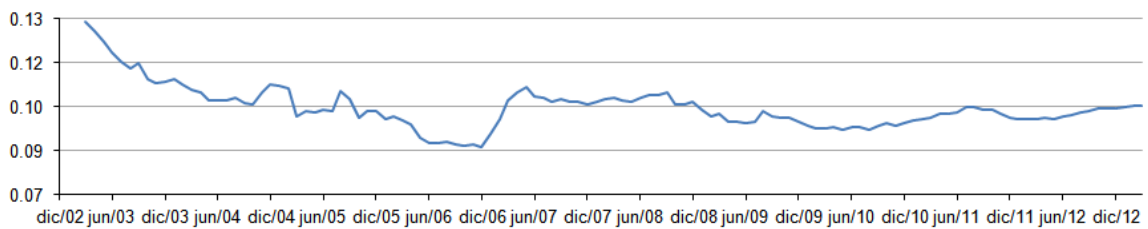


*Projected data from November 28, 2012 to March 2013.

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

International Reserves*/GDP**

Figure 5

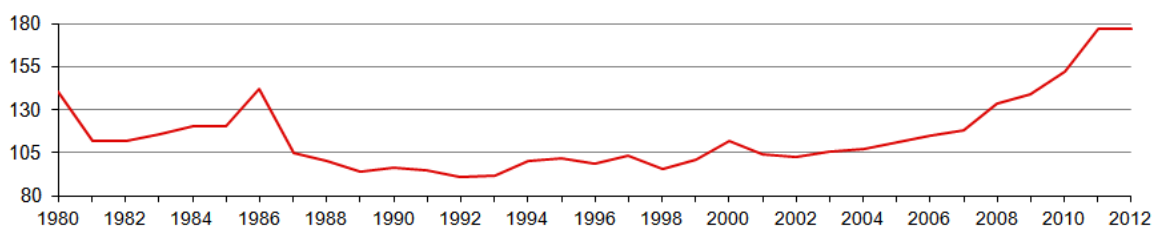


*Projected data from November 28, 2012 to March 2013.

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

Terms of Trade (Colombia)

Figure 6



Source: Banco de la República

Capital inflow shock: Relative variances implied by alternative rules with and without active FX intervention

Table 2

	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
Annual Non-Tradable Inflation Rate	0.18	1.09
Annual Tradable Inflation Rate	3.04	1.00
Annual 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.

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

Table 3

	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
Annual Non-Tradable Inflation Rate	3.50	1.36
Annual Tradable Inflation Rate	1.32	0.97
Annual 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.

Figure 7: Capital inflow shock with Taylor rule

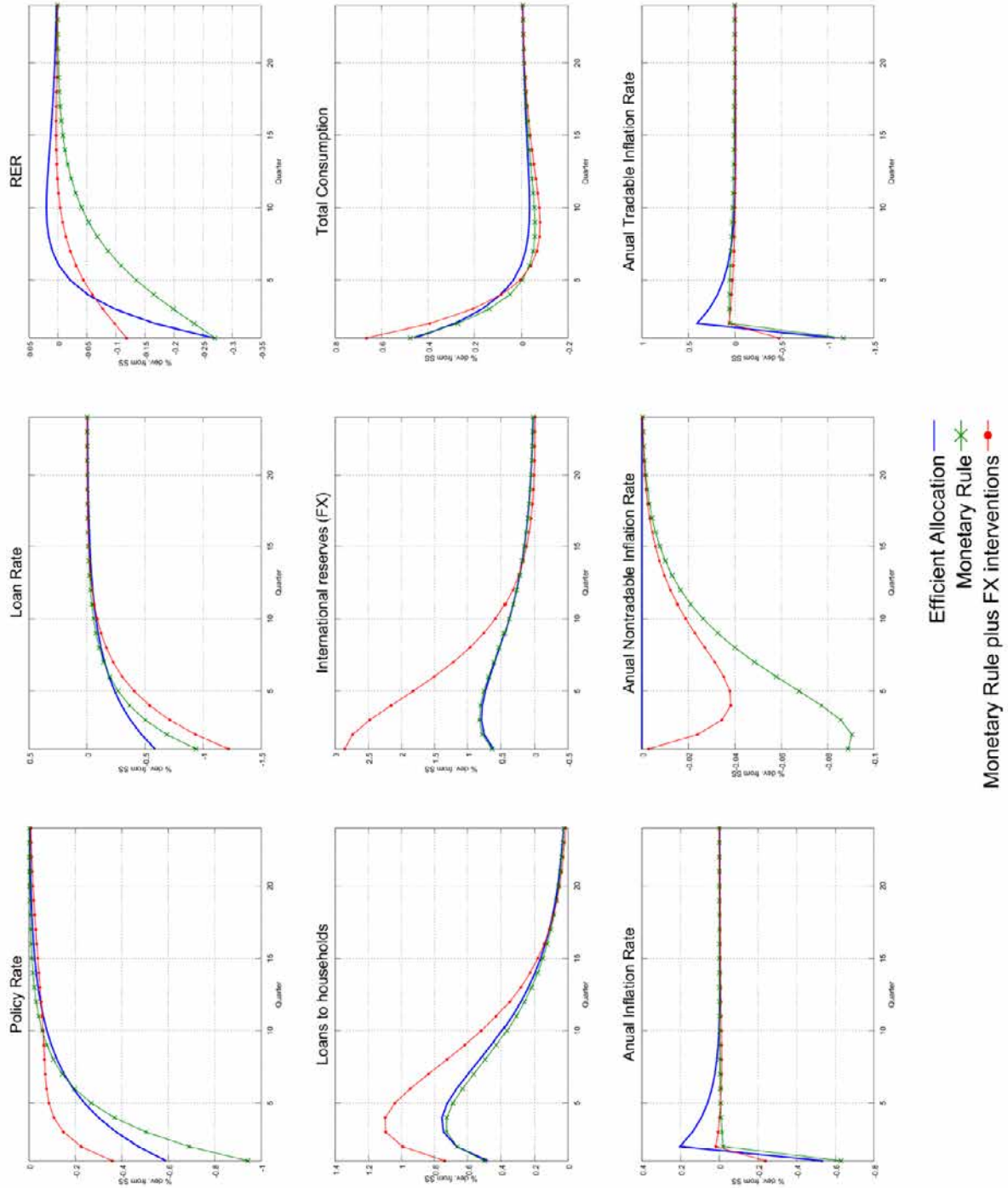


Figure 8: Capital inflow shock with strict inflation targeting ($\pi_t^c = \bar{\pi}$)

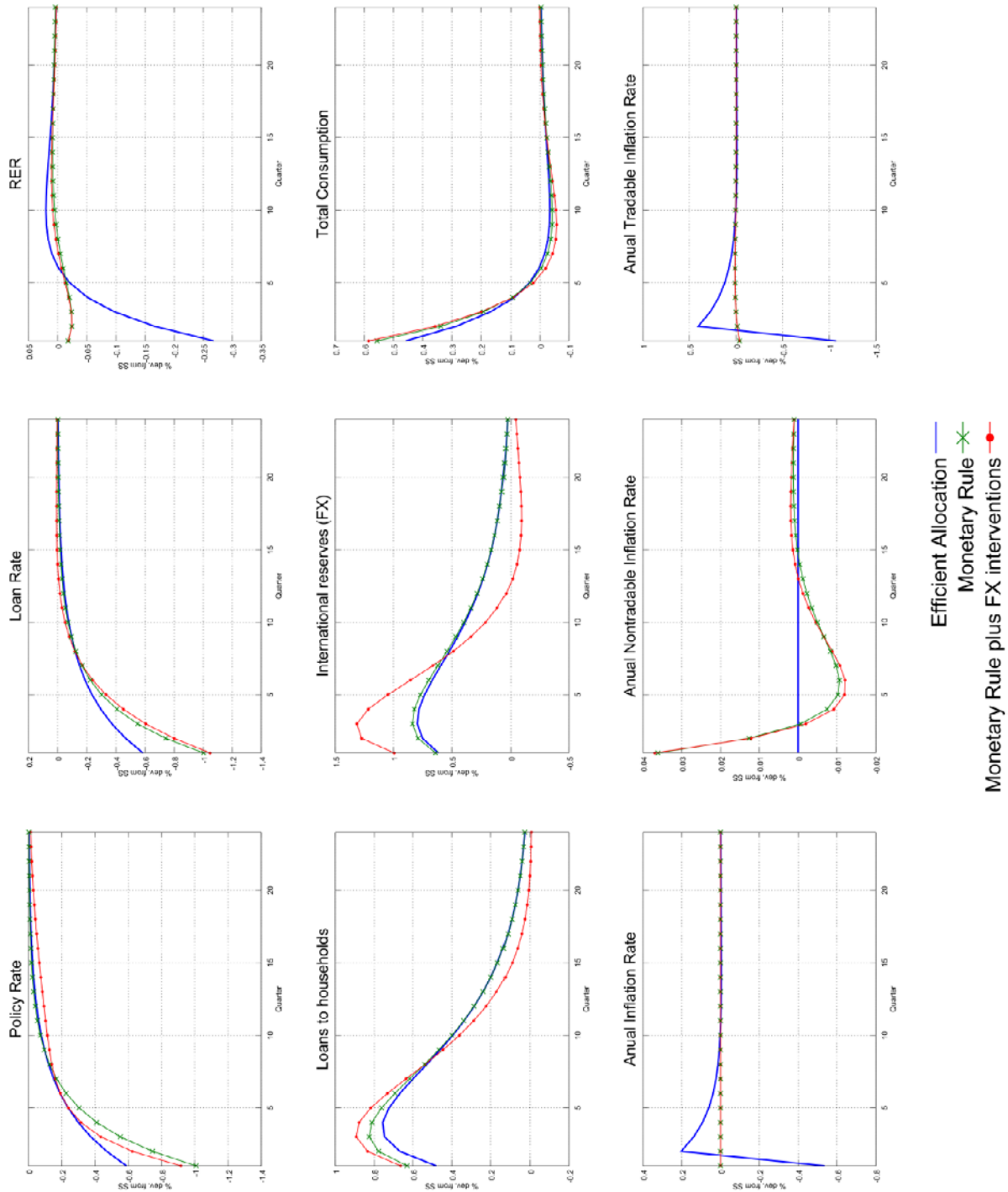


Figure 9: Oil shock with Taylor rule

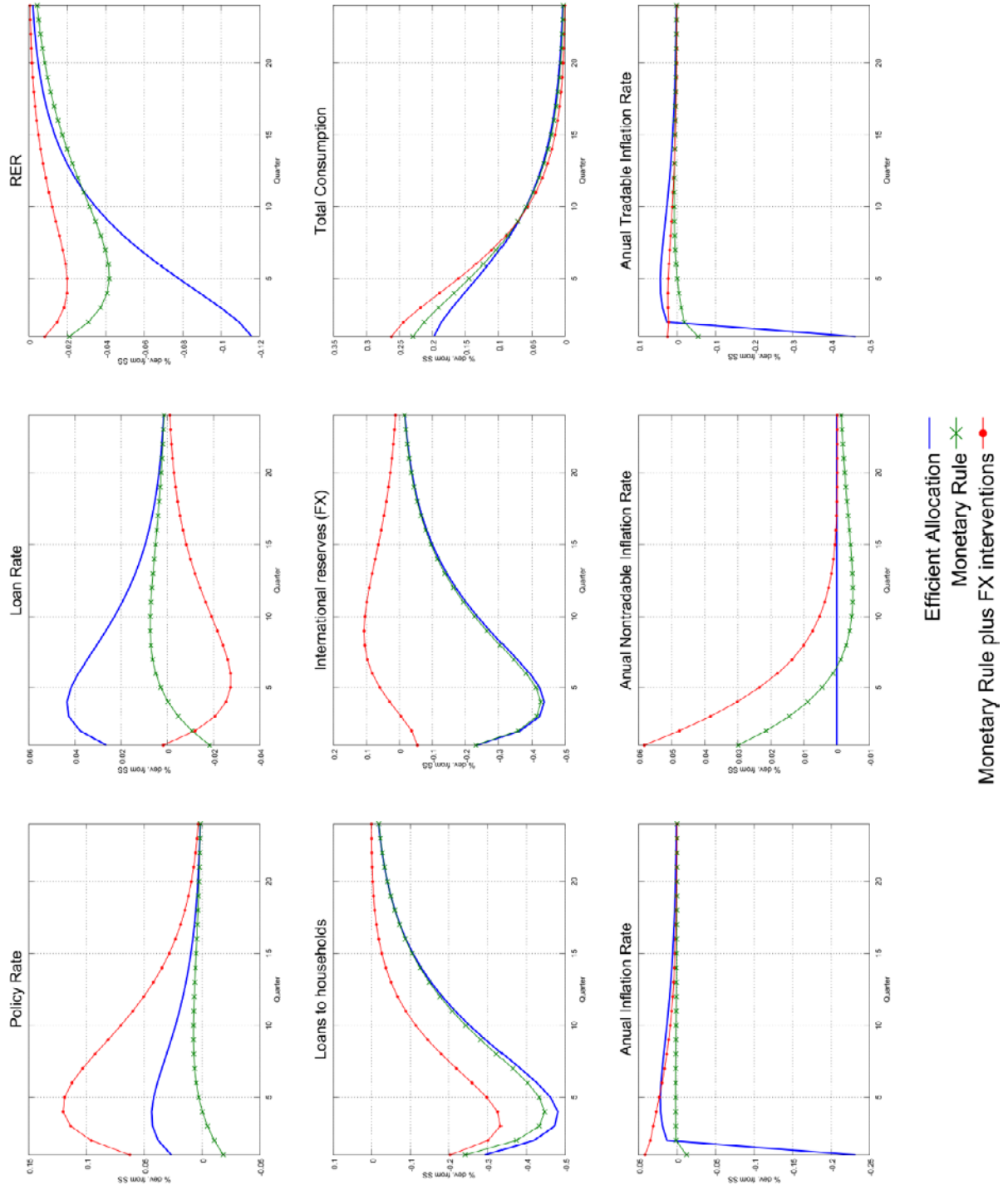
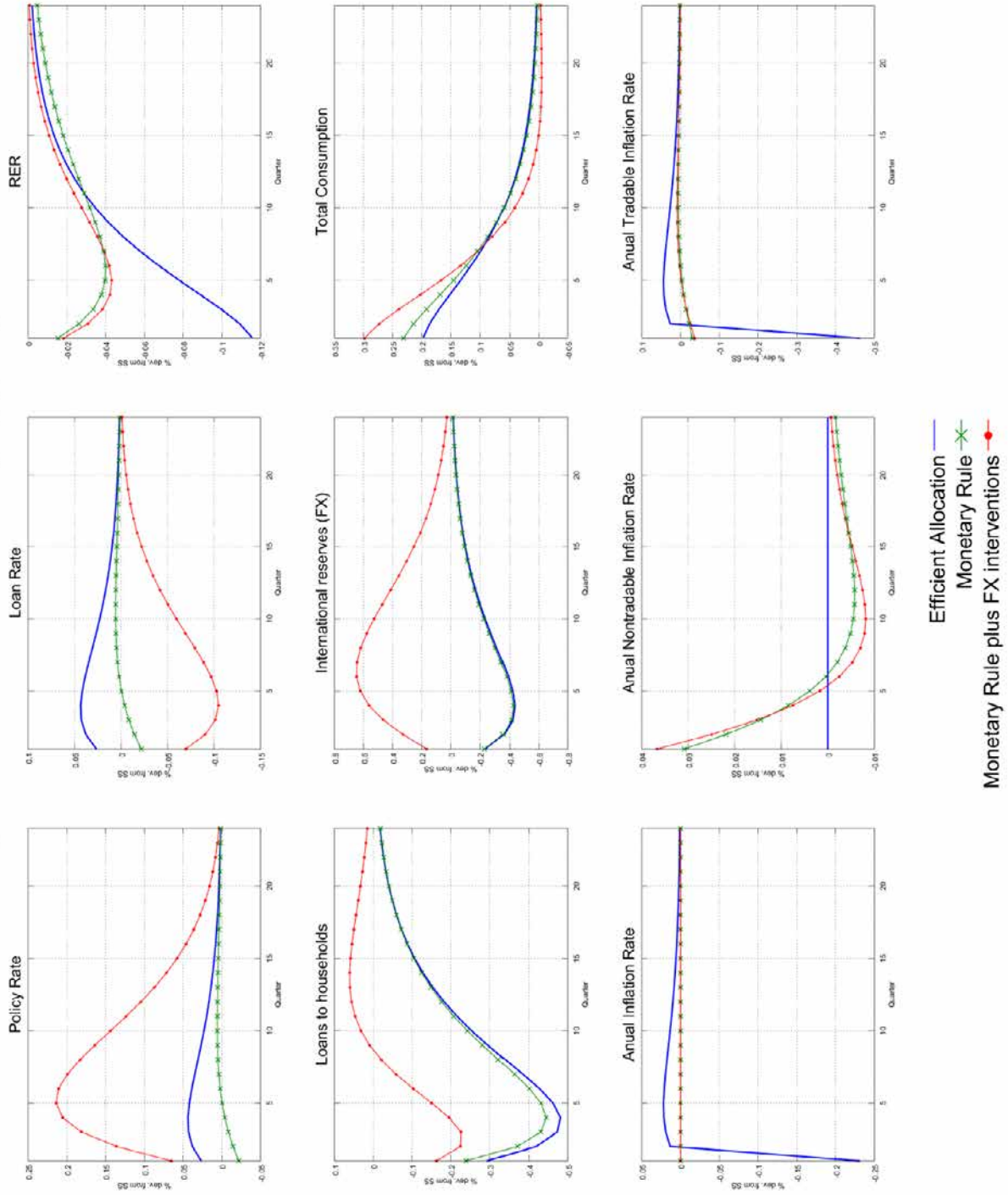


Figure 10: Oil shock with strict inflation targeting ($\pi_t^e = \bar{\pi}$)



A. The Model

A.1 Households

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

$$\lambda_t = \frac{z_t^U}{c_t} \quad (\text{A.2})$$

$$w_t \lambda_t = \chi h_t^\eta \quad (\text{A.3})$$

$$\lambda_t (1 - \psi (l_t - \bar{l})) = \beta E_t \left[\lambda_{t+1} \left(\frac{1 + i_{t+1}'}{1 + \pi_{t+1}^C} \right) \right] \quad (\text{A.4})$$

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

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

A.2 Commercial Banks

$$b_t + l_t = q_t b_t^* \quad (\text{A.7})$$

$$\xi_t^B = \left(\frac{1 + i_{t-1}'}{1 + \pi_t^C} \right) l_{t-1} - l_t + \left(\frac{1 + i_{t-1}}{1 + \pi_t^C} \right) b_{t-1} - b_t + q_t b_t^* - q_t \left(\frac{1 + i_{t-1}^*}{1 + \pi_t^{C^*}} \right) b_{t-1}^* \quad (\text{A.8})$$

$$- (\theta_b b_{t-1} + \theta_l l_{t-1} - 2\theta \sqrt{b_{t-1} l_{t-1}}) \quad (\text{A.9})$$

$$E_t \left(\frac{1 + i_t}{1 + \pi_{t+1}^C} \right) = E_t \left[\left(\frac{q_{t+1}}{q_t} \right) \left(\frac{1 + i_{t+1}^*}{1 + \pi_{t+1}^{C^*}} \right) \right] + \theta_b - \theta \sqrt{\frac{l_t}{b_t}}$$

$$E_t \left(\frac{1 + i_t'}{1 + \pi_{t+1}^C} \right) = E_t \left[\left(\frac{q_{t+1}}{q_t} \right) \left(\frac{1 + i_{t+1}^*}{1 + \pi_{t+1}^{C^*}} \right) \right] + \theta_l - \theta \sqrt{\frac{b_t}{l_t}} \quad (\text{A.10})$$

A.3 Central Bank

$$q_t r_t^* = b_t \quad (\text{A.11})$$

$$\tau_t = b_t - \left(\frac{1 + i_{t-1}}{1 + \pi_t^C} \right) b_{t-1} + q_t \left(\frac{1 + i_{t-1}^*}{1 + \pi_t^{C^*}} \right) r_{t-1}^* - q_t r_t^* \quad (\text{A.12})$$

$$\text{Alternative Nominal Interest Rules} \quad (\text{A.13})$$

$$\frac{q_t r_t^*}{l_t} = \frac{\overline{q r}}{\bar{l}} - \omega (RER_t - \overline{RER}) \quad (\text{A.14})$$

A.4 Firms

A.4.1 Tradable goods

$$y_t^T = z_t^T (h_t^T)^{\alpha_T} \quad (\text{A.15})$$

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

A.4.2 Non-tradable goods

$$y_t^N = z_t^N (h_t^N)^{\alpha_N} \quad (\text{A.17})$$

$$y_t^N = c_t^N + \frac{\kappa}{2} \left(\frac{1 + \pi_t^N}{(1 + \pi_{t-1}^C)' (1 + \bar{\pi})^{1-t}} - 1 \right)^2 \quad (\text{A.18})$$

$$m c_t^N \left(\alpha_N \frac{y_t^N}{h_t^N} \right) = w_t \quad (\text{A.19})$$

$$0 = (1 - \varepsilon_N) \left(\frac{p_t^N}{p_t^C} \right) y_t^N + \left(\frac{\varepsilon_N}{\alpha_N} \right) m c_t^N y_t^N \quad (\text{A.20})$$

$$\begin{aligned} & - \left(\frac{p_t^N}{p_t^C} \right) \kappa \left(\frac{1 + \pi_t^N}{(1 + \pi_{t-1}^C)' (1 + \bar{\pi})^{1-t}} - 1 \right) \frac{1 + \pi_t^N}{(1 + \pi_{t-1}^C)' (1 + \bar{\pi})^{1-t}} \\ & + \beta E_t \left[\left(\frac{\lambda_{t+1}}{\lambda_t} \right) \left(\frac{p_{t+1}^N}{p_{t+1}^C} \right) \kappa \left(\frac{1 + \pi_{t+1}^N}{(1 + \pi_t^C)' (1 + \bar{\pi})^{1-t}} - 1 \right) \frac{1 + \pi_{t+1}^N}{(1 + \pi_t^C)' (1 + \bar{\pi})^{1-t}} \right] \end{aligned}$$

$$\xi_t^N = \left(\frac{p_t^N}{p_t^C} \right) y_t^N - w_t h_t^N - \left(\frac{p_t^N}{p_t^C} \right) \frac{\kappa}{2} \left(\frac{1 + \pi_t^N}{(1 + \pi_{t-1}^C)' (1 + \bar{\pi})^{1-t}} - 1 \right)^2 \quad (\text{A.21})$$

A.5 Equilibrium

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

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

$$\frac{1 + \pi_t^T}{1 + \pi_t^C} = \frac{p_t^T}{p_t^C} / \frac{p_{t-1}^T}{p_{t-1}^C} \quad (\text{A.24})$$

$$\frac{1 + \pi_t^N}{1 + \pi_t^C} = \frac{\rho_t^N}{\rho_t^C} / \frac{\rho_{t-1}^N}{\rho_{t-1}^C} \quad (\text{A.25})$$

$$h_t = h_t^T + h_t^N \quad (\text{A.26})$$

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

$$RER_t = \frac{\rho_t^T}{\rho_t^N} \quad (\text{A.28})$$

$$y_t = y_t^P + \left(\frac{\rho_t^T}{\rho_t^C} \right) \alpha_T y_t^T + m c_t^N \alpha_N y_t^N + \xi_t^B + \xi_t^N \quad (\text{A.29})$$

$$(1 + i_t^*) = \left(1 + \bar{i}^* \right) z_t^{i^*} \quad (\text{A.30})$$

A.6 Shocks

$$z_t^{i^*} = \rho_{z^{i^*}} (z_{t-1}^{i^*}) + (1 - \rho_{z^{i^*}}) \ln(\bar{z}^{i^*}) + \varepsilon_t^{i^*} \quad (\text{A.31})$$

$$z_t^T = \rho_{z^T} (z_{t-1}^T) + (1 - \rho_{z^T}) \ln(\bar{z}^T) + \varepsilon_t^T \quad (\text{A.32})$$

$$z_t^N = \rho_{z^N} (z_{t-1}^N) + (1 - \rho_{z^N}) \ln(\bar{z}^N) + \varepsilon_t^{z^N} \quad (\text{A.33})$$

$$\pi_t^* = \rho_{\pi^*} (\pi_{t-1}^*) + (1 - \rho_{\pi^*}) \ln(\bar{\pi}^*) + \varepsilon_t^{\pi^*} \quad (\text{A.34})$$

$$z_t^U = \rho_{z^U} (z_{t-1}^U) + (1 - \rho_{z^U}) \ln(\bar{z}^U) + \varepsilon_t^{z^U} \quad (\text{A.35})$$

$$\frac{\rho_t^{T^*}}{\rho_t^{C^*}} = \rho_{\rho^{T^*}} \left(\frac{\rho_{t-1}^{T^*}}{\rho_{t-1}^{C^*}} \right) + (1 - \rho_{\rho^{T^*}}) \ln \left(\frac{\rho_{t-1}^{T^*}}{\rho_{t-1}^{C^*}} \right) + \varepsilon_t^{\rho^{T^*}} \quad (\text{A.36})$$

$$y_t^P = \rho_{y^P} (y_{t-1}^P) + (1 - \rho_{y^P}) \ln(\bar{y}^P) + \varepsilon_t^{y^P} \quad (\text{A.37})$$

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
$REER$	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

Symbol	Description
\overline{RER}	Exchange rate's operational target
$\overline{\pi}^C$	Inflation target
ψ	Quadratic adjustment cost parameter for loans
\overline{i}	Long run nominal interest rate
\overline{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
ρ_{z^*}	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

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