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FOREIGN EXCHANGE AND MONETARY POLICY: ESSAYS FROM A DEVELOPING COUNTRY PERSPECTIVE

A dissertation submitted in partial satisfaction of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

ECONOMICS

by

Juan C. Catalán-Herrera

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Abstract

FOREIGN EXCHANGE AND MONETARY POLICY: ESSAYS FROM A DEVELOPING COUNTRY PERSPECTIVE

by

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DOCTOR OF PHILOSOPHY in ECONOMICS

University of California, Santa Cruz

Professor Carl Walsh, Chair

The first essay investigates the participation of an IT-central bank in the exchange rate market, as a supplemental tool for monetary policy. It presents a way of modeling a hybrid IT-regime with a managed float for a small open economy. The strategy followed, differs from most approaches that combine IT with partial control over the exchange rate, in that it uses the exchange rate as an operational target and interventions as instrument. The analysis is done in a general equilibrium setting, considering a financial system dominated by commercial banks, who solve an optimization problem giving rise to a premium in the UIP condition; Central bank’s behavior is described by two rules: a policy rate in a Taylor-type rule and another one describing the accumulation of international reserves. The model suggests that, when shocks affecting the economy are supply shocks, intervention in forex market can render better results than just re-setting the policy rate, in the sense that it reduces volatility of inflation, keeping it closer to its long run-level. For other type of shocks, intervention exacerbates inflation volatility.

The second essay explores the effectiveness of forex interventions within an IT-context using Guatemalan daily data from 2008 to 2012, as a case study. In a first stage, I estimate the central bank reaction function, using a friction model à la Rosett. In a second stage, I use the conditional expectation of intervention, generated with estimates of the reaction function, as an instrument for actual interventions in a reduced form model of the exchange rate daily-returns, allowing for GARCH effects in the conditional variance. Results show statistical evidence of the existence of threshold effects in the reaction function, and indicate that intervention operations during the sample
period, influenced the variance, but not the level of exchange rate. The central bank reacted systematically to previous-day exchange rate changes, when deciding the amount of intervention, and also to deviations from a short-term trend. Despite intervention had a dampening effect over the daily exchange rate return’s volatility, they do not appear to be the main cause of the remarkable stability of the nominal exchange rate in Guatemala.

The final essay deals with the fact that emigrant remittances have been growing around the world since 1970, but in the past few years, their growth rate has enlarged significantly. In Guatemala, remittances have increased their nominal value in about 142 percent over the last decade and there is concern with the idea that large and sustained remittance inflows can provoke an appreciation of the real exchange rate, making the production of tradable goods less profitable; a Dutch-Disease-like phenomenon. This essay explores how remittance flows affect the real exchange rate in the Guatemalan economy using a stochastic, dynamic general equilibrium model. The model generates a real exchange rate appreciation, a tradable sector contraction, and a non-tradable expansion, similar to those that are observed in national accounts data; within the model, capital adjustment costs and heterogeneous labor play a predominant role in mimicking the dynamics of the observed real exchange rate appreciation. In addition, the results suggest that, in Guatemala, economic agents perceive the observed shift in the remittances flow as permanent.
To my parents, wife, daughter and son,
for their unbounded and inexhaustible support.
Chapter 1

Introduction

As theoretical physicists strive for a theory of everything—a comprehensive and coherent theoretical framework of physics that fully explains all physical aspects of the cosmos—economists hanker for a high enough level of abstraction. One in which a single theory applies for all, from small decision makers at the household level to the macroeconomics of industrialized and developing countries alike. Although substantial progress has been made in the last thirty years, with increased micro foundations in the field of macroeconomics and models based on basic axioms, we are still far from building our own economic theory of everything. Had we achieved that level of abstraction, exploring economic issues from a developing country perspective would be futile. But unfortunately, economics is not there yet, and developing countries and emerging markets have structural characteristics that tend to differentiate these economies from their industrialized counterparts. Therefore, accounting for these differences and studying economic issues from particular perspectives, remains a subject of pragmatic preponderance.

This assertion is evident when we observe the growth in the literature on developing countries—at least for those denominated emerging markets—which now constitutes a large share of the field of international finance and macroeconomics. The goal of the present dissertation is to make a contribution to this expanding literature, by exploring two deeply intertwined topics: monetary policy and exchange rates, from the standpoint
of developing countries. The subject is approached from three different angles; the first essay develops a theoretical model which considers the participation of an inflation targeting –IT– central bank in foreign exchange rate markets. The second one, studies empirically the effectiveness of foreign exchange interventions within an IT-framework, using Guatemalan data as a case study. Finally, the third essay touches on the real side of the economy, exploring the consequences of an increased influx of worker’s remittances over the real exchange rate.

The motivation for the first essay, stems from the observation that standard modeling approaches are ill-equipped to analyze intervention practices. Monetary policy and concerns of central banks regarding the exchange rate are usually studied in the context of the New Keynesian model, which features only one instrument—a short term interest rate—used to target inflation and exchange rate behavior. This modeling approach is unfit for the practices of central banks in developing countries, where often, intervention in foreign exchange markets is seen as another instrument in achieving central bank’s objectives; frequently understood as a supplemental instrument, supporting the transmission role of the interest rate, but there are also cases where interventions are used independently from the main instrument, aimed to different objectives, and thus, making the standard modeling approach too stylized to model these interactions.

Therefore, one important contribution of the model presented in the first essay, is that it differs from most approaches that combine IT with partial control over the exchange rate, in that this model uses the exchange rate as an operational target (and interventions as instrument), instead of studying concerns for the exchange rate in the context of a standard New Keynesian inflation targeting model with only one instrument. Most of this literature, by ignoring the exchange rate management and its channels, it is not suitable for modeling the central bank behavior in developing countries and emerging markets. The model proposed here, takes into account the conditions under which monetary policy is conducted in developing countries, displaying two salient features: first, it considers a financial system dominated by commercial banks, who face limitations in their borrowing capacity from abroad. Banks (who play a predominant role in the financial system) solve an optimization problem where they get to choose how much to borrow from abroad, and select how to divide its assets between loans and government securities. Their optimization problem is subject to an incentive compati-
bility constraint, that addresses the possibility of default and gives rise to a premium in the UIP condition, allowing domestic interest rates to deviate from the international interest rate; it also introduces a wedge between the policy rate and the rate charged for loans. Results suggest that, when shocks affecting the economy are supply shocks, intervening in the forex market can render better results than just re-setting the policy rate, in the sense that it reduces the volatility of inflation, keeping it closer to its long run-level.

The second essay begins with the presumption that, in the case of emerging markets and developing countries with limited integration to global financial markets and limited stocks of outstanding assets, the scope of intervention might be broader (than in developed economies) and it may be possible to have an effective intervention policy; one that limits exchange rate volatility and does not precludes an active monetary policy. Consequently, the second essay explores this two-objectives, two-instruments world empirically, by assessing the effectiveness of forex interventions within an inflation-targeting framework, using Guatemalan daily data from 2008 to 2012.

There are two key elements in the empirical strategy employed: first, a reaction function for monetary authorities is estimated using Rosett’s generalization of the Tobit model, allowing for nonlinearities in the reaction function of the central bank, to match the observed insensitiveness to some realization of the state of the world. Second, in order to minimize the ubiquitous problems caused by the simultaneous determination of exchange rates and central bank intervention, the exchange rate used in the first stage of the analysis, is that quoted at the beginning of the trading day, while intervention data is reported at the close of the day in which it was performed. Since intervention at time \( t \) cannot influence the opening quote, this timing in data collection helps to attenuate simultaneity problems. The results can be summarized in five main findings, valid for the sample period:  
i) There is statistical evidence of the existence of threshold effects in the reaction function, as expected for a managed float regime.  
ii) Evidence suggest that monetary policy is conducted independently from the exchange rate policy.  
iii) The central bank attempted to counteract short term trends of the nominal exchange rate.  
iv) Intervention has not influenced the exchange rate level.  
v) But it did have a dampening effect over daily exchange rate return’s volatility.

Finally, in the third essay I develop a general equilibrium model intended to
characterize the short run equilibrium real exchange rate, and establish a theoretical relationship between the real exchange rate and workers’ remittances flow. Remittances have become an important inflow of financial resources to the developing world, as they have grown considerably during the last decade, and have prove themselves more resilient to the global financial crisis, than other types of financial flows. Parallel to the surge in remittances, a real exchange rate appreciation has also been observed, generating concerns about a Dutch-Disease-like phenomenon. After calibrating the model, I compare its predictions with actual data from Guatemalan national accounts. The results are very suggestive that the real exchange rate appreciation observed in the last decade, was strongly influenced by demand factors. The model presented in this essay, generates an appreciation path for the real exchange rate, a tradable sector contraction, and a non tradable sector expansion, similar to those observed in national accounts data.
Chapter 2

Monetary Policy in Developing Economies: A Hybrid Model with Interventions in Forex Markets

2.1 Introduction

Developing economies are different from their developed counterparts, however, are they different enough to require a different way to conduct monetary policy? There are some structural differences that, in principle, could restrict the available channels for transmission of monetary policy in developing economies. Differences like having less developed institutions, uncompetitive banking systems, being more exposed to international influences and having large informal sectors, may quite possibly require a different policy formulation and thus, call for separate models that allow policy makers to discern between competing policies.

An important question that arises when taking these differences into account is, what would be the optimal degree of exchange-rate flexibility for developing countries? In general, the recommendation for open economies is that optimal policy requires a flexible exchange rate. As Devereux and Engel [2003] report, the argument supporting this recommendation can be traced back to Friedman [1953], and it is based on the
idea that the degree of flexibility between nominal prices and the exchange rate is different. Friedman argued that country-specific real shocks or demand shocks, require an adjustment in the relative price level between countries. This needed adjustment can be brought by a change either in the internal nominal prices or in the exchange rate, and since there is some evidence pointing to rigid nominal prices, the usual policy recommendation is to let the exchange rate move freely.

Despite the rooted acceptance of this policy recommendation, it relies on assumptions that are not necessarily observed in developing economies. For example, it assumes perfect capital mobility (to ensure an immediate adjustment of the exchange rate), but in developing economies with underdeveloped financial systems and limited supply of financial assets, this assumption might not be satisfied, at least in the short run. If the exchange rate is not subject to the same arbitrage pressures, the benefits attributed to a fully flexible exchange rate might be overstated, giving room for a better policy configuration; perhaps one that includes an active participation of the central bank in the exchange rate market.

Central banks in developing countries, have all along put more emphasis on the exchange rate than they have officially admitted, as documented by Calvo and Reinhart [2000]. According to these authors, the fact that many emerging markets (and some developed) appear to be reluctant to let their currencies fluctuate stems from a common cause – lack of credibility, that hinders the anchorage of expectations. Nevertheless, since there is evidence of a positive correlation between the volatility of the nominal and the real exchange rate, avoiding large fluctuations in the nominal exchange rate, more than a “fear to float” due to a lack of credibility, it could be the optimal response for a central bank that implements its monetary policy in an environment plagued with internal and external distortions. For example, capital flows that are assumed to help smooth consumption in face of external shocks, could be exacerbating those shocks in developing countries, where boom-bust cycles are common; capital inflows and the associated currency appreciation had been followed by busts, featuring sudden stops, sharp depreciations and recessions. Intervention in the foreign exchange rate market in this context, could be a well justified policy measure, if intended to hamper down these vicious cycles.

\[^1\]As documented by Mussa [1986], and many others afterwards.
Intervention in foreign exchange markets and the interest of central bankers on the exchange rate, has long been debated. Monetary policy evolved from targeting money aggregates in the 1980’s towards targeting the exchange rate and using it as the nominal anchor. According to Batini [2006], in 1985 more than half of developed countries and 75% of developing countries, were engaged in some sort of fixed exchange rate regime, twenty years later, these proportions decreased to 5% and 55% respectively. Even today, some emerging countries seem to be targeting an undervalued real exchange rate level, as part of a development strategy, based on channeling investment to export industries, as proposed by Dooley et al. [2003]. But in general, countries (developed and developing alike) have shifted towards a new preferred nominal anchor, i.e. inflation, under the so called Inflation Targeting -IT- regime. If we consider a small economy, open to international capital flows which is operating its monetary policy under this regime, the usual recommendation for the exchange rate policy, is again to adopt a flexible exchange rate regime and, there are two related arguments to support this recommendation: First, according to the Mundell-Fleming framework, countries that are integrated to the global capital markets cannot use the exchange rate as an additional tool for monetary policy, since these open economies are subject to the impossible trinity, i.e. they can achieve simultaneously, only two out of the following three policy goals: an independent monetary policy, financial integration and exchange rate stability, and second, since monetary policy represents only one instrument, according to Tinbergen [1952] it can only pursue one objective, therefore, if the central bank of a financially integrated economy chooses to control inflation, the exchange rate cannot be targeted simply because the lack of independent instruments.

Nevertheless, Aizenman et al. [2011a] show that even IT-central banks follow a mixed strategy, where both inflation and the real exchange rate are important determinants of the policy interest rate. The question is why? are these central banks just wasting resources, acting like a dog chasing its own tail? or is it possible, on the one hand, that the particularities of developing economies allows them to escape from the policy trilemma and, on the other hand, that the recent hoarding of international reserves provides some countries with an additional policy instrument to pursue simultaneously two objectives? At least we know that emerging countries indeed display a different configuration of the policy trilemma; according to Aizenman et al. [2010] emerging
market countries had move to a middle ground, where none of the three delimiting policy objectives of the trilemma dominates, contrasting with industrialized countries that had move markedly towards financial integration, and non-emerging market developing economies, that appear to be bias towards exchange rate stability.

For emerging economies, the more balanced configuration of the trilemma has been observed jointly with an increase in the reserves to GDP ratio, suggesting that it might be possible to target a desired combination of the three policies by accumulating international reserves. If reserves accumulation gives some slackness to the restrictions imposed by the trilemma, a bigger spectrum of feasible policies could be at the disposal of central banks. If so, we should ask again, what would be the best contribution of monetary policy in such economies? Should these countries devote monetary policy solely to restrain an internal distortion (i.e. the internal nominal price rigidity) and assume a passive role with respect to the exchange rate? or is it possible to use intervention in the foreign exchange rate market as an additional tool of monetary policy? Answering this question is especially important for developing countries who are implementing monetary policy under inflation targeting, since this policy regime can be destabilizing for a country subject to terms of trade volatility.

However, the analysis of such intervention practices are beyond the reach of standard modeling approaches. Monetary policy and concerns of central banks regarding the exchange rate are usually studied in the context of the New Keynesian -NK- model, which features only one instrument —a short term interest rate— used to target inflation and exchange rate behavior. This modeling approach is unfit for the practices of central banks in developing countries, where often, intervention in the forex market it is seen as another instrument in achieving central bank’s objectives; frequently understood as a supplemental instrument, supporting the transmission role of the interest rate —the main instrument-, but also there are cases where interventions are used independently from the main instrument aimed to different objectives, and therefore, making the standard modeling approach (i.e. one featuring only a Taylor-type rule) too stylized to model these interactions.

Therefore, the aim of this paper is not to engage in the fixed vs. flexible exchange rates debate, but rather to consider the participation of an IT-central bank in the
exchange rate market, as a supplemental tool for monetary policy. It presents a way of modeling a hybrid IT-regime with a managed float for a small open economy—SOE—. The strategy followed here, differs from most approaches that combine IT with partial control over the exchange rate, in that it uses the exchange rate as an operational target (and interventions as instrument), instead of studying concerns for the exchange rate in the context of a standard New Keynesian inflation targeting model with only one instrument—where interest rates that are used to target both, inflation and the exchange rate—. The main disadvantage of using this standard NK approach, is that it necessarily leaves the determination of interest rates to exogenous elements (usually the UIP condition) and fails to account for other possible transmission channels associated with achieving the exchange rate operational target through interventions in the foreign exchange market. Most of this literature, by ignoring the exchange rate management and its channels, it is not suitable for modeling the central bank behavior in developing countries and/or emerging markets.

The analysis is done in a general equilibrium setting, which allows the study of the financial stocks needed for capturing balance sheet effects of intervention. The model takes into account conditions under which monetary policy is conducted in developing countries, displaying two salient features. First, it considers a financial system dominated by commercial banks, who face limitations in their borrowing capacity from abroad. Banks are supposed to solve an optimization problem where they get to choose how much to borrow from abroad, and select how to divide its assets between loans and government securities. Their optimization problem is subject to an incentive compatibility constraint, that addresses the possibility of default and gives rise to a premium in the UIP condition that allows domestic interest rates to deviate from the international interest rate; it also introduces a wedge between the policy rate and the rate charged for loans. Second, Central bank’s behavior is described by two rules: a policy rate in a Taylor rule and another one describing the accumulation of international reserves. In this first model, both rules will be used to target inflation, but in principle, both can pursue multiple targets. The rest of the paper is organized as follows. Section 2 describes the model. Section 3 describes the calibration of the model and the algorithm used to solve it. Section 4 describe model dynamics and Section 5 concludes.
2.2 The Model

The model takes into account the conditions under which monetary policy is conducted in developing countries, particularly, it includes a financial friction limiting the borrowing capacity of domestic banks from abroad, a preponderant role of banks within the financial system and, as in Ravenna and Walsh [2006], it introduces the cost of working capital into the production side of the model, by assuming that firms need to pay for labor before the proceeds from the sale of output are received. Considering these two frictions, is relevant since the dynamic and static interactions between frictions in both, the international and domestic financial markets, have important consequences for emerging market’s performance as Caballero and Krishnamurthy [2001] -CK- have shown. Although the frictions that are considered here are different from the collateral constraints discussed in CK, it will be argued that these same interactions (between international and domestic financial frictions) might be relevant for the conduct of monetary policy in developing economies.

2.2.1 Banking Sector

The banking sector consists of a commercial bank and a central bank. The commercial bank seeks to maximize its cash flow and has access to a credit line from abroad. It will make loans to firms and will hold securities issued by the central bank. Therefore, its balance sheet has loans and central bank’s securities on the assets side, and the credit line from abroad will be its sole liability (and source of funding). The balance sheet of the Central Bank will show international reserves in the assets side and self-issued securities on the liabilities side, these securities will be issued in order to finance the accumulation of reserves; as the commercial bank, the Central Bank will transfer its cash flow to households. A detail description of the two financial agents follow.

²From the point of view of a consolidated public sector, the distinction between government and central bank securities is unimportant since both represent official liabilities, monetary policy implemented with central bank issued securities will generate a quasi-fiscal deficit (or surplus), which will end up as a burden to tax-payers at some point. Since the central bank’s cash flow will be transferred to households, this is a simple way of bypassing fiscal considerations, which are out of the scope of the present paper.
2.2.1.1 Central Bank

The central bank will be allowed to hold a stock of foreign assets (international reserves) -$IR_t$- for which it collects a return -$i_{t}^{f}$- by investing them abroad. In order to finance the acquisition of those reserves, it will issue securities -$B_t^s$- in the domestic market paying an interest rate -$i_{t}$.-³ For the moment, fiat money will be ignored, implying that the accumulation of international reserves is done by sterilized interventions. The central bank will interact with commercial banks (in the local market) selling or buying securities when ever it wants to modify the stock of reserves; which is the usual way for central banks to acquire reserves in developing and emerging economies.

In this setting, the central bank will have two instruments at disposition: the interest rate to control inflation, and the level of reserves to influence the exchange rate. Therefore, its behavior will be characterized by two policy rules: a standard Taylor rule for the policy interest rate —as a function of inflation ($\pi_t$) and a random disturbance with zero mean ($\epsilon_{\pi,t}$)- which can be introduced without further explanation:

$$i_t = \omega\pi_t + \epsilon_{\pi,t}$$  \hspace{1cm} (2.1)

and another rule describing the accumulation of international reserves, which deserves a short digression. In order to formulate a rule describing the accumulation of reserves, we should first clarify what are the motives for intervention. The objectives for intervention are particularly varied, according to the Bank of International Settlements (BIS), the reasons for intervention cited by central banks (that do not use the nominal exchange rate as the nominal anchor) include: to control inflation or maintain internal balance, to maintain external balance and prevent resource misallocation or preserve competitiveness and boost growth, and to prevent or deal with disorderly markets or crisis, among others. Since policies regarding intervention (ergo, the foreign exchange rate) can potentially target a wide range of objectives, in what follows, we will assume that the primary objective of monetary policy is to ensure low inflation as a sound basis for sustained economic growth, hence, the central bank will use both instruments to keep inflation close to its long run level.

Consequently, we assume that the central bank will have an operational target

³Variables in capital letters denote nominal values.
for the exchange rate $-\tilde{S}_t-$, that is based on the state of the economy,\textsuperscript{4} and will adjust this target in order to stabilize inflation, according to:

$$\tilde{S}_t = S_T - \gamma_s(\pi_t - \pi)$$ (2.2)

After setting a particular value for the operational target of the exchange rate, the central bank will accommodate the real value of its stock of international reserves, in order to move the exchange rate towards that particular target, according to:

$$\frac{S_t \cdot IR_t}{P_t} = IR - \omega_s \left( e^{(S_t - \tilde{S}_t)} - 1 \right)$$ (2.3)

where $-IR-$ is a long run value for the international reserves and $S_t$ is the nominal exchange rate.\textsuperscript{5} With this structure, the central bank will affect the exchange rate through systematic interventions, by varying the stock of international reserves and not through a re-setting of the interest rate.

Therefore, in every period the central bank will set the interest rate according to eq.(2.1) and will adjust the stock of reserves as specified by eq. (2.3). By issuing securities that pay an interest rate $i_t$, potentially different from the compensation $-i^{rf}_t-$ coming from investing the international reserves at the international risk free interest rate, the central bank will generate a quasi-fiscal deficit (or surplus), which will be transferred to households; the transfer in domestic currency and nominal terms is given by,

$$CB^{NT}_t = \left(1 + i^{rf}_{t-1}\right)S_tIR_{t-1} - S_tIR_t + B^o_t - (1 + i_{t-1}) B^o_{t-1}$$

after imposing the budget identity $S_tIR_t = B_t$, this transfer can be expressed in real terms as follow:\textsuperscript{6}

\textsuperscript{4}Many central banks will argue that their interventions aim to dampen exchange rate volatility rather than to meet a specific target for the level of the exchange rate, in this case we could introduce a rule for the stock of reserves as a function of the volatility of the exchange rate and define the operational target for the exchange rate in terms of its volatility.

\textsuperscript{5}Defined as the amount of domestic currency needed to buy one unit of foreign currency, ergo, an increase in $S_t$ implies a nominal depreciation; in the same way, an increase in $\tilde{S}_t$ implies a depreciation of the central bank’s exchange rate target.

\textsuperscript{6}Lower case letters denote variables in real terms e.g. $x_t = x_t/P_t$, where $P_t$ is the aggregate price level.
\[ CB_t^T = \frac{b_{t-1}^s}{(1 + \pi_t)} \left[ (1 + i^{tf}_{t-1}) \frac{S_t}{S_{t-1}} - (1 + i_{t-1}) \right] \] (2.4)

### 2.2.1.2 Commercial banks

A representative bank, operating in a competitive industry, is assumed to determine optimal balance sheet quantities by taking all interest rates as predetermined. For simplicity, the liabilities side of the commercial bank’s balance sheet, will only consist of credit lines coming from abroad \(-F_t-\); the assets side will be comprised of the sum of loans \(-L_t^s-\) supplied to firms, and securities \(-B_t^d-\) purchased from the central bank in open market operations -OMO’s-. Then, the commercial bank will seek to maximize its next period cash flow, at period \(t\) is given by,

\[ \Pi_t^{NB} = (1 + j_{t-1})L_{t-1}^s - L_t^s + (1 + i_{t-1})B_{t-1}^d - B_t^d + S_tF_t - (1 + i^*_{t-1})S_tF_{t-1} \] (2.5)

after imposing the balance sheet identity: \(S_tF_t = L_t^s + B_t^d\), the cash flow can be expressed in real terms:

\[ \Pi_t^B = \frac{(1 + j_{t-1})}{(1 + \pi_t)} l_{t-1}^s + \frac{(1 + i_{t-1})}{(1 + \pi_t)} b_{t-1}^d - \frac{(1 + i^*_{t-1})}{(1 + \pi_t)} (b_{t-1}^d + l_{t-1}^s) \frac{S_t}{S_{t-1}} \] (2.6)

where \(i_t\) is the return on securities, \(i^*_{t}\) is the interest rate paid over loans coming from abroad, and \(j_t\) is the interest rate paid by firms over granted loans. Banks face an agency problem between them and the foreign creditors, since the commercial bank is simultaneously a lender and a borrower—it will borrow abroad in order to lend domestically-. We assume that commercial banks can default on their foreign debt and abscond with a fraction \(\theta_t\) of repayments made by firms.\(^7\) As in Céspedes et al. [2012], banks maximization problem will be subject to the following incentive compatibility constraint (in order to prevent absconding):

\(^7\)Throughout most of the paper, we shall take this fraction as constant, \(i.e., \theta_t = \theta\). This assumption can be relaxed and allow the fraction to depend upon the composition of the level of credit in the economy or the ratio between loans and securities hold by the banking system as a whole.
\[ (1 + i_{t-1}) B_{t-1}^d + (1 + j_{t-1}) L_{t-1}^s - (1 + i_{t-1}^*) S_t F_{t-1} \geq \theta_t (1 + j_{t-1}) L_{t-1}^s \quad \forall t \]

This constraint simply states that profits made by the bank (given the current interest rates) should be higher or equal than the fraction of repayments that they can abscond in case of default, it also implies that banks cannot steal the amount invested in central bank securities, since those funds can be reimbursed to the foreign lender by the central bank in case of default. We assume that this constraint always binds and, as in Geanakoplos [2010] and Bruno and Shin [2012], it addresses the possibility of default in a way that the actual probability of default is zero in the resulting contract.

In order to solve the maximization problem of commercial banks, we set eq. (2.6) one period forward, and solve:

\[
\max_{\{l_t, b_t\}} \Pi_{t+1}^B = \frac{(1 + j_t)}{(1 + \pi_{t+1})} l_t^s + \frac{(1 + i_t)}{(1 + \pi_{t+1})} b_t^d - \frac{(1 + i_t^*)}{(1 + \pi_{t+1})} (b_t^d + l_t^s) \frac{S_{t+1}^c}{S_t}
\]

s.t.

\[
\frac{(1 + i_t)}{1 + \pi_{t+1}} b_t^d + \frac{(1 + j_t)}{1 + \pi_{t+1}} (1 - \theta_t) l_t^s = (1 + i_t^*) S_{t+1}^c f_t
\]

and the balance sheet identity,

\[ S_t f_t = b_t^d + l_t^s \]

From were we get the following first order conditions,

\[ l_t^s : \quad (1 + j_t) = (1 + i_t^*) \frac{S_{t+1}^c}{S_t} \left[ \frac{1 + \eta_t}{1 + \eta_t (1 - \theta_t)} \right] \quad \text{(2.7)} \]

\[ b_t^d : \quad (1 + i_t) = (1 + i_t^*) \frac{S_{t+1}^c}{S_t} \quad \text{(2.8)} \]

Where \( \eta_t \) is the Lagrangian multiplier associated to the incentive compatibility constraint. The first equation represents a modified UIP condition, which includes a premium that differentiates domestic and foreign interest rates, a premium related to how stringent the contract with the foreign lender is (measured by \( \theta \)). Also notice that,
if $\eta_t$ was equal to zero (i.e. access to international capital markets was frictionless), we would have the conventional uncovered parity for both interest rates (the policy and the market rate), where foreign and domestic interest rates are equated to each other, once you take into account the corresponding expected variation of the exchange rate ($S_{t+1}/S_t$).

### 2.2.2 Households

Households solve a standard problem, they decide how to divide their time between work and leisure and how much to consume. In order to smooth consumption intertemporally, households only have access to a one-period bond $-D_t$ that pays the domestic market rate $-j_t$; this implies they do not have access to the foreign source of funding nor to central bank securities (only through commercial banks which they own).\(^8\)

The economy is inhabited by infinitely lived households, who obtain utility from consumption of a composite good $-C_t$ and disutility from time spent working $-N_t^s$. Households seek to maximize the expected value of their lifetime utility function:

$$\beta \sum_{t=0}^{\infty} U(C_t, N_t^s),$$

where $\beta \in (0, 1)$ is the usual subjective discount factor and $U(C_t, N_t^s)$ is utility in period $t$, given by:

$$U(C_t, N_t) = \frac{\mu_t C_t^{1-\sigma}}{1-\sigma} - \frac{N_t^{s(1+\varphi)}}{1+\varphi}$$

(2.9)

where $\mu_t$ is a preference shock, and the composite consumption good is defined as,

$$C_t = \left[ \int_0^1 c_{it}^{(\varepsilon-1)/\varepsilon} \, dt \right]^{\varepsilon/(\varepsilon-1)}$$

(2.10)

The budget constraint in nominal terms takes the form:

$$\int_0^1 p_{it} c_{it} \, dt + (1 + j_{t-1}) D_{t-1} = W_t N_t^s + D_t + \Pi_t^N$$

(2.11)

where $p_{it}$ is the price of good $i$, $W_t$ is the nominal wage, $D_t$ are bonds purchased at time $t$, and $\Pi_t^N$ are transfers coming from the central bank $-CB^{NT}$, commercial banks.

---

\(^8\)The net supply of this one-period bonds is assumed to be zero in equilibrium, and households are subject to the usual no-ponzi scheme restriction i.e. $\lim_{k \to \infty} \prod_{i=0}^{D_{t+k}} \left(1 + j_{t+i} \right) \leq 0$. 

\( \Pi^N_{t} \) and firms \( \Pi^F_{t} \), all of which are not internalized by the household, thus taken as given. By maximizing the the composite good for any given level of expenditure, we get the following set of demand equations,

\[
e_{it} = \left( \frac{p_{it}}{P_t} \right)^{-\varepsilon} C_t
\]  

(2.12)

\( \forall i \in [0,1] \), where \( P_t \equiv \left[ \int_0^1 p_{it}^{(1-\varepsilon)} \right]^{\frac{1}{1-\varepsilon}} \) is the aggregate price index. Conditional on eq. (2.12), it can be shown that \( \int_0^1 p_{it} e_{it} di = P_tC_t \), substituting this result into the budget constraint eq. (2.11) and solving household’s maximization problem, we get the usual equilibrium conditions:

\[
U_{C_t} (C_t, N^s_t) = \beta U_{C_{t+1}} (C_t, N^s_t) \frac{1 + j_t}{(1 + \pi_{t+1})} \\
-U_{N^s_t} (C_t, N^s_t) = \frac{W_t}{P_t}
\]  

(2.13)

\[
C_t + \frac{(1 + j_{t-1})}{(1 + \pi_t)} d_{t-1} = \frac{W_t}{P_t} N^s_t + d_t + CB^T + \Pi^B_t + \Pi^f_t 
\]  

(2.15)

### 2.2.3 Firms

Assume a continuum of firms indexed by \( i \in [0,1] \). Each firm will produce a differentiated good using the same technology:

\[
y_{it} = Z_t \left( N^d_{it} \right)^{1-\alpha}
\]  

(2.16)

where \( Z_t \) is a productivity factor, common across firms that evolves exogenously over time. All firms will face the same demand schedule, given by eq. (2.12) and all of them will take as given the aggregate price level \( P_t \) and the composite consumption good \( C_t \). It is also assumed that the firm must borrow an amount \( W_t N^d_t \) from commercial banks to pay for labor services, making the nominal cost of labor equal to: \( (1 + j_t)W_t N^d_{it} \). Therefore, the standard cost minimization problem (given the production function eq. 2.16) will render the following first order condition, which determines firm’s real marginal cost,
\[
\varphi_{it} = \frac{(1 + j_i)w_i/p_t}{(1 - \alpha) Z_t (N_{it})^{-\alpha}}
\]  
(2.17)

assuming a small price dispersion, the average real marginal cost will be,

\[
\varphi_t = \frac{(1 + j_t)w_t/p_t}{(1 - \alpha) Z_t (N^d_t)^{-\alpha}}
\]  
(2.18)

Following Calvo [1983], we assume that each firm can reset its price only with probability \((1 - \omega)\), in any given period, therefore, firm’s pricing decision becomes a dynamic one, that involves choosing \(p_{it}\) to maximize,

\[
E_t \sum_{j=0}^{\infty} (1 - \omega) \omega^j \Delta_{t+j} \left[ \left( \frac{p_{it}}{P_{t+j}} \right) c_{it+j} - \varphi_{t+j} c_{it+j} \right]
\]

were \(\Delta_{t+j} = \frac{\beta U_{C_{it+j}}(C_{it+j}, h_{it+j})}{U_{C_t}(C_t, h_t)}\) is the appropriate discount factor and \(c_{it+j}\) is given by eq. (2.12). Let \(p_{t}^*\) be the optimal price chosen by all firms adjusting at time \(t\). The first-order condition for this optimal price is given by,

\[
p_{t}^* = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{\infty} \omega^j \Delta_{t+j} \cdot C_{t+j} \cdot \varphi_{t+j} \cdot P_{t+j}^\varepsilon}{E_t \sum_{j=0}^{\infty} \omega^j \Delta_{t+j} \cdot C_{t+j} \cdot P_{t+j}^{\varepsilon-1}}
\]

dividing both sides by \(1/P_t\),

\[
\frac{p_{t}^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} \frac{E_t \sum_{j=0}^{\infty} \omega^j \Delta_{t+j} \cdot C_{t+j} \cdot \varphi_{t+j} \left( \frac{P_{t+j}}{P_t} \right)^\varepsilon}{E_t \sum_{j=0}^{\infty} \omega^j \Delta_{t+j} \cdot C_{t+j} \left( \frac{P_{t+j}}{P_t} \right)^{\varepsilon-1}}
\]

which can be rewritten as,

\[
\frac{p_{t}^*}{P_t} = \frac{\varepsilon}{\varepsilon - 1} E_t \left( \frac{\Theta_t}{\Psi_t} \right)
\]  
(2.19)

where,

\[
\Theta_t = \Delta_t \varphi_t C_t + \omega E_t \left[ (1 + \pi_{t+1})^\varepsilon \Theta_{t+1} \right],
\]  
(2.20)

\[
\Psi_t = \Delta_t C_t + \omega E_t \left[ (1 + \pi_{t+1})^{\varepsilon-1} \Psi_{t+1} \right]
\]  
(2.21)

The remaining fraction \(-\omega\) of firms that do not get the signal to re-optimize, will
set their price according to the rule,

\[ P_t^{\text{rule}} = P_{t-1}(1 + \pi_{t-1}) \]

where prices are set taking into account the average price level of the previous period and last period inflation. With this indexation rule, the appropriate price average in period \( t \) satisfies:

\[ P_t^{1-\varepsilon} = (1 - \omega)P_t^* (1-\varepsilon) + \omega P_t^{\text{rule} (1-\varepsilon)} \]

implying the aggregate price dynamics:

\[
(1 + \pi_t)^{1-\varepsilon} = (1 - \omega) \left( \frac{\varepsilon}{\varepsilon - 1} \cdot E_t \frac{\Theta_t}{\Psi_t} \cdot (1 + \pi_t) \right)^{1-\varepsilon} + \omega (1 + \pi_{t-1})^{1-\varepsilon}
\]

(2.22)

Firm profits in real terms are,

\[ \Pi_t^f = C_t (1 - \varphi_t) \]

### 2.2.4 Closing the small open economy

In order to close the model, it is necessary to impose an exogenous steady state level for foreign indebtedness \( f_t \), without it, foreign liabilities may not be stationary, complicating the analysis of local dynamics. Given the structure of the model, imposing this steady state level is enough to ensure a unique solution, without resorting to other common ways of closing a small open economy.\(^9\)

Additionally, a country borrowing premium is introduced, defining the interest rate at which commercial banks can borrow from abroad \( i_t^* \), as a function of foreign indebtedness:

\[ i_t^* = (1 + i_t)\epsilon_t^f + \psi(e^{(f_t - f)} - 1) + \chi_t \]

where \( \chi_t \) is an AR(1) process with zero mean.

\(^9\)See Schmitt-Grohé and Uribe [2003].
It is usual to assume that sovereign borrowers face, up to a certain limit, an upward sloping supply curve of foreign funds. This upward-sloping portion of the supply curve reflects the fact that, as the level of the debt increases, the perceived probability of default also rises. In this model, the country risk premium is not included because it is needed to make foreign indebtedness revert to trend (as aforementioned, a long run value for \( f \)- suffices and the incentive compatibility constraint deals with default), but rather it is included for two important reasons: First, it makes possible to take into account the social cost of holding reserves, captured by the last term of eq. (2.28), which depends on the spread between the private sector’s cost of borrowing abroad \(-i^r_-\) and the yield that the Central Bank earns on its liquid foreign assets \(-i^r_-\), the appropriate social cost, as suggested by Rodrik [2006]. Second, introducing a country borrowing premium is a simple way to model sudden capital outflows or changes in the external cost of funding, represented by shocks to \(-\chi_-\) in eq. (2.23).

### 2.2.5 Exogenous processes

The model includes three sources of uncertainty: a productivity shock, a demand (or taste) shock and a shock to the cost of foreign funding. All three shocks are assumed to follow an autoregressive process of order one:

\[
Z_{t+1} = \rho_Z Z_t + (1 - \rho_Z) \bar{Z} + \nu^Z_{t+1}; \quad \nu^Z_t \sim N \left(0, \sigma^2_Z\right) \tag{2.24}
\]

\[
\mu_{t+1} = \rho_\mu \mu_t + (1 - \rho_\mu) \bar{\mu} + \nu^\mu_{t+1}; \quad \nu^\mu_t \sim N \left(0, \sigma^2_\mu\right) \tag{2.25}
\]

\[
\chi_{t+1} = \rho_\chi \chi_t + (1 - \rho_\chi) \bar{\chi} + \nu^\chi_{t+1}; \quad \nu^\chi_t \sim N \left(0, \sigma^2_\chi\right) \tag{2.26}
\]

where \( \rho_j \in (0, 1) \) for \( j = Z; \mu; \chi \).

---

10 This cost differs from perhaps the most commonly found in the literature, *i.e.* the fiscal one, accounting for the difference between the interest rate of domestic government bonds and the yield on reserves, however, this is looking at the cost solely from the perspective of the public sector, but in a general equilibrium setting “...any difference between the interest costs of domestic government bonds and short-term foreign borrowing is tantamount to a transfer from the public to the private sector in the domestic economy (or vice versa), and needs to be netted out when calculating the cost from a national standpoint.” D. Rodrik [2006]. That is exactly what is happening in the model, the fiscal cost is netted out, remaining only the difference between \( i^r \) and \( i^r' \).
2.2.6 Market Clearing

Market clearing requires that demand equals supply in all markets, i.e. clearing in the goods market requires,

\[ y_{it} = c_{it} \quad \forall i \in [0, 1]; \forall t \]

From the labor supply equation we can obtain,

\[ \int_0^1 N_{it}^d \, di = N_t^d = N_t^s = N_t \]

defining \( N_t^d = \int_0^1 N_{it}^d \, di \), with the arrangements below,

\[ N_t^d = \int_0^1 \left( \frac{y_{it}}{Z_t} \right)^{\frac{1}{\alpha}} \, di = \int_0^1 \left( \frac{c_{it}}{Z_t} \right)^{\frac{1}{\alpha}} \, di \]

\[ N_t^d = \left( \frac{C_t}{Z_t} \right)^{\frac{1}{\alpha}} \int_0^1 \left( \frac{P_{it}}{P_t} \right)^{-\frac{\varepsilon}{\alpha}} \, di \]

Using Calvo insight,

\[ \frac{Z_t N_t^d(1-\alpha)}{C_t} = \left[ (1 - \omega) \left( \frac{p_t^e}{P_t} \right)^{-\frac{\varepsilon}{1-\alpha}} + \omega \left( \frac{P_{rule}}{P_t} \right)^{-\frac{\varepsilon}{1-\alpha}} \right]^{1-\alpha} \]

\[ \frac{Z_t N_t^d(1-\alpha)}{C_t} = \left[ (1 - \omega) \left( \frac{\varepsilon}{\varepsilon - 1} \cdot \frac{E_t \Theta_t}{\Psi_t} \right)^{-\frac{\varepsilon}{\alpha}} + \omega \left( \frac{1 + \pi_{t-1}}{1 + \pi_t} \right)^{-\frac{\varepsilon}{\alpha}} \right]^{1-\alpha} \]

after imposing equilibrium in the labor market, we get the goods market equilibrium condition,

\[ C_t = Z_t N_t^d(1-\alpha) \left[ (1 - \omega) \left( \frac{\varepsilon}{\varepsilon - 1} \cdot \frac{E_t \Theta_t}{\Psi_t} \right)^{-\frac{\varepsilon}{1-\alpha}} + \omega \left( \frac{1 + \pi_{t-1}}{1 + \pi_t} \right)^{-\frac{\varepsilon}{\alpha}} \right]^{\alpha-1} \] (2.27)

Clearing Central Bank’s securities market requires,
$b_t^* = b_t^d = b_t \ \forall t$

The loan market equilibrium requires,

$l_t^d = \frac{W_t}{P_t} N_t = l_t^* = l_t \ \forall t$

The real transfer to households is given by,

$$\Pi_t = CB_t^T + \Pi_t^f + \Pi^B_t$$

which after imposing equilibrium, can be written as:

$$\Pi_t = \frac{b_{t-1}S_t}{(1 + \pi_t)S_{t-1}} \left[ r_{t-1}^f - i_{t-1}^* \right] + C_t (1 - \varphi_t) + \frac{l_{t-1}}{(1 + \pi_t)} \left[ (1 + j_{t-1}) - (1 + i_{t-1}^*) \cdot S_t \right]$$

by substituting this real transfer into the households budget constraint eq. (2.15), we get the economy wide resource constraint:

$$C_t \varphi_t = l_t + \frac{l_{t-1}}{(1 + \pi_t)} \left[ (1 + j_{t-1}) - (1 + i_{t-1}^*) \cdot \frac{S_t}{S_{t-1}} \right] + \frac{b_{t-1}S_t}{(1 + \pi_t)S_{t-1}} \left[ r_{t-1}^f - i_{t-1}^* \right]$$

This concludes the specification of the model. Appendix B contains the complete system of equations to solve.

2.3 Model parametrization and solution algorithm

2.3.1 Parametrization

The values assumed for the different parameters in the baseline calibration, are summarized in Table 2.1. Most of them are common in the literature (for a quarterly frequencies), and some are specific to this model and deserve some explanation.

Those parameters that are fairly standard, e.g. the discount rate $\beta = 0.93$, the inverse of the elasticity of labour supply $\varphi^{-1} = 1$ and the labor share in the production
function \((1 - \alpha) = \frac{2}{3}\) were set in accordance with much of the recent business cycle literature. The relative utility weight on labour \(\chi = 12.5\) was set to get a steady state share of working hours of roughly \(\frac{1}{3}\). The parameter \(\varepsilon\) that determines the degree of competition in the differentiated goods market, is set to 6 in order to obtain a markup of 20%. The parameter that determines the degree of price stickiness \(-\omega-\) is set to 0.75 in order to have prices changing every one year.

Now consider the the less common parameters, which are: the inflation coefficient \(-\gamma_s-\) on eq. (2.2) and the adjustment coefficient for international reserves \(-\omega_s-\) in the intervention rule eq. (2.3). These are policy parameters, and thus, the monetary authority will choose a value for them according to its intentions; a central bank inclined to a more flexible exchange rate will choose a small value for \(\omega_s\), on the contrary, a central bank that views intervention as an effective policy instrument and who is willing to intervene heavily in the forex market, will choose a higher value for this parameter. In the same way, the policy makers will choose a high value for \(\gamma_s\), when they believe intervention is an effective tool to achieve the central bank objective (defined in this model as to keep inflation close to its steady state value), and a low value otherwise. Therefore, for any particular set of believes or any particular information set, over which policy decision making is based on, there will be a different combination of these policy parameters. In order to assess what are the implications for model’s dynamics, some sensitivity analysis is conducted on Appendix A.3, where a range of values of these parameters are considered in addition to their baseline settings, \(i.e. \gamma_s = 1.2\) and \(\omega_s = 1.7\).

2.3.2 Solution

In order to solve the model, the complete system of equations is transformed to express it in terms of logarithmic deviations from the steady state, \(i.e.\) I used transformed variables: \(\hat{j}_t = log(\frac{j_t}{j_{ss}})\) for every variable \(j\). Then, a first-order approximation is made using Taylor’s expansion and the model is solved using the method of Klein [2000]. By using this method, matrices \(P\) and \(F\) are obtained, which generate the dynamic solution by iterating on the following two linear equations:

\[x_t = Px_{t-1} + B\omega_t\]
Table 2.1: Model Parameters

<table>
<thead>
<tr>
<th>SYMBOL</th>
<th>VALUE</th>
<th>DESCRIPTION:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varphi^{-1}$</td>
<td>1</td>
<td>Elasticity of labor supply</td>
</tr>
<tr>
<td>$\sigma^{-1}$</td>
<td>0.2</td>
<td>Elasticity of inter-temporal substitution</td>
</tr>
<tr>
<td>$\varepsilon$</td>
<td>6</td>
<td>Degree of competition in the differentiated goods market</td>
</tr>
<tr>
<td>$\theta$</td>
<td>0.22</td>
<td>Fraction of repayments banks can abscond</td>
</tr>
<tr>
<td>$\omega_{\pi}$</td>
<td>1.8</td>
<td>Inflation coefficient, Taylor rule</td>
</tr>
<tr>
<td>$\gamma_{1}$</td>
<td>1.2</td>
<td>Inflation coefficient, operational exchange rate target</td>
</tr>
<tr>
<td>$S_{T}$</td>
<td>1.2</td>
<td>Exchange rate consistent with fundamentals</td>
</tr>
<tr>
<td>$\omega_{S}$</td>
<td>1.7</td>
<td>International reserves adjustment coefficient</td>
</tr>
<tr>
<td>$i^{rf}$</td>
<td>0.0073</td>
<td>Risk free interest rate</td>
</tr>
<tr>
<td>$\chi$</td>
<td>12.5</td>
<td>Relative utility weight on labor</td>
</tr>
<tr>
<td>$1 - \alpha$</td>
<td>2/3</td>
<td>Labor share in production function</td>
</tr>
<tr>
<td>$\omega$</td>
<td>0.75</td>
<td>Probability of not adjusting prices</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.93</td>
<td>Subjective discount factor</td>
</tr>
<tr>
<td>$f$</td>
<td>0.56</td>
<td>Steady state foreign debt</td>
</tr>
<tr>
<td>$\rho_{Z}$</td>
<td>0.8</td>
<td>Autoregressive coefficient productivity process</td>
</tr>
<tr>
<td>$\rho_{\nu}$</td>
<td>0.8</td>
<td>Autoregressive coefficient demand</td>
</tr>
<tr>
<td>$\iota$</td>
<td>0.1</td>
<td>Coeff. determining steady state wedge between $i^{rf}$ rate and $i^{*}$</td>
</tr>
<tr>
<td>$\rho_{\chi}$</td>
<td>0.71</td>
<td>Autoregressive coefficient of country premium process</td>
</tr>
</tbody>
</table>

$k_t = F x_t$

where $k$ is a vector composed by controls and co-state variables, $x$ is a vector of endogenous and exogenous states, $F$ characterizes the policy function (including the optimal dynamics of co-state variables) and $P$ is a transition matrix for the states. $B$ is a matrix that determines which variables can experience an exogenous shock and in what magnitude. $\omega_t$ is an innovation vector.

### 2.4 Intervention as a distinct form of monetary policy

It is common to define ‘intervention’ as official purchases or sales of foreign exchange undertaken with the objective of influencing the exchange rate. This definition is obscure with respect to whether the exchange rate is an intermediate target, an operational target or a policy goal in itself. An understanding of the motive for buying or
selling foreign exchange is a necessary component of the definition of intervention. In the present model, sterilized intervention is the instrument used by the Central Bank to alter the supply of securities available in the domestic economy (held by commercial banks) in order to influence the exchange rate, with the final objective of keeping inflation close to its long run level.

Under this narrower definition for intervention, the current section analyzes the response of an IT-Central Bank to three basic shocks (productivity, demand, and the cost of foreign funding). A comparison is made between two central banks, both of which follow a Taylor-rule -eq.(2.1)– and have the same steady state level of international reserves -IR-, but they differ in the way they manage the exchange rate. The first central bank, despite it has a stock of international reserves, it will allow the exchange rate to move freely i.e. it will set $\omega_s = 0$ in eq.(2.3) and on eq.(2.2) it will set: $S_T = S_t$ and $\gamma_s = 0$; this means that it will not use its reserves for policy purposes and it will not target any particular value for the exchange rate -S_t-, I will refer to this case as: No-Intervention. The other central bank will follow a hybrid regime, in which in addition to the conventional Taylor-rule, it will use international reserves to influence the exchange rate, trying to move it closer to the operational target -$S_T$-, a target that will be aligned with the ultimate goal of keeping inflation close to its long run level, thus, in this case $\omega_s, \gamma_s > 0$ and $S_T$ will be set by the monetary authority, I will refer to this case as: Intervention.

2.4.1 Model Dynamics

In order to examine the dynamics of the artificial economy, this section shows the impulse-response functions for three types of transitory shocks, and for both types of central banks. In all figures the solid line depicts the system dynamics when the Central Bank decide to intervene and the discontinuous line depicts the responses of the system when the Central Bank allows the exchange rate to move freely.\footnote{Bear in mind that even when the central bank is not intervening, the economy is still subject to the incentive compatibility constraint and firms still need to borrow from banks to pay for labor, therefore the economy will not necessarily behave as the standard NK model.}
2.4.1.1 Shock to the country borrowing premium

We analyze an unanticipated increase in the country borrowing premium $\chi_t$ (see Figure 2.1). As foreign cost of funding rises, also does the market interest rate in the economy $j_t$ (around 15%). As the interest rate increases, firms will take less loans, therefore labor and output will decrease ($-3\%$ and $-2\%$ respectively). Lower output implies lower consumption, and a lower demand implies that prices will go down (inflation decreases), to which the central bank reacts by lowering the policy rate. These results are aligned with conventional wisdom or other conventional models. What is noteworthy or specific to the present model is the following.

As foreign funding cost increases and resources fly away from the domestic economy, the exchange rate depreciates on impact ($-1.1\%$) in both cases, No-Intervention and Intervention. In the case of Intervention, the central bank tries to counteract the depreciation by decreasing its holdings of foreign reserves ($-1\%$ in real value), being mildly successful in affecting the exchange rate (only between the 5th and the 10th quarter). What results interesting is that, by reducing its holdings of international reserves, the Central Bank is not only unable to affect substantially the exchange rate, but also the foreign resources that it is liberating are not been used to ease the contraction of the economy, they are flying away, increasing the loss of foreign resources in the domestic economy. The contraction in the supply of loans is greater in the case of Intervention because, as the Central Bank increases the policy rate and reduces the supply of securities by its sterilized intervention, it makes even more stringent the compatibility constraint that limits the ability of commercial banks to access foreign resources, therefore, the reduction in the supply of loans to firms and the loss of foreign resources are both worse under Intervention. Additionally, these results suggest that pursuing a hybrid-policy with this type of shock, is also detrimental for the ultimate goal of the central bank. By intervening in the forex market, the central bank is exacerbating the reduction in prices and apparently increasing inflation volatility, with respect to inflation dynamics observed under the No-Intervention policy.\footnote{Some selected variables are shown in Figure 2.1, for the complete set of variables see Appendix A.1. The one assumed for this model: to keep inflation close to its long run value. On Appendix A.3, it can be observed how sensitive are inflation dynamics to different values of the inflation coefficient $-\gamma_s$ in the exchange rate rule.}
2.4.1.2 Demand shock

Figure 2.2 shows the impulse-response functions for a demand shock $-\mu_t$. After a shift in preferences, households decide to consume more ($\sim 3\%$), nothing else has changed in the economy and therefore, in order to meet the higher demand, firms need to borrow more from banks, so demand for loans increases as well as the interest rate over those loans. In order to provide incentives to households to supply more labor, the real wage also increases ($\sim 2\%$) and as consequence (together with the increase in the interest rate), the real marginal cost also rises ($\sim 5\%$). Again, the model specific findings follow.

Commercial banks increase foreign borrowing in order to satisfy the higher domestic demand for loans. As foreign resources come into the economy, the exchange rate appreciates on impact ($\sim 1.2\%$). The Central Bank reacts by buying some of those resources, increasing both: its holdings of international reserves and the supply of securities when sterilizing. But again for this type of shock, Intervention seems to be pernicious. When the Central Bank increases the supply of securities it relaxes the
constraint on foreign borrowing for commercial banks, and that is why foreign debt increases even more in the case of Intervention, which allows commercial banks to grant even more loans and again, worsening the outcome for inflation, which reaches higher levels under Intervention (again, with respect to No-Intervention).

2.4.1.3 Productivity shock

An unanticipated increase in the total factor productivity $Z_t$ is depicted in Figure 2.3. With this shock, the economy becomes essentially richer. The higher productivity allows a higher consumption of goods ($-1.5\%$) and leisure (labor decreases $-15\%$). Since the economy can produce more efficiently, the real marginal cost decreases, firms use less labor and therefore demand for loans diminishes, as well as the market interest rate $j_t$. The higher productivity induces a depreciation of the exchange rate on impact, to allow for a gradual appreciation as long as total factor productivity remains above its steady state level. In order to counteract the initial depreciation, the Central Bank operating under the hybrid-regime will decrease its holdings of international reserves,
which implies a reduction of securities’ supply, and again, by reducing the supply of securities, the Central Bank is making tighter the collateral constraint, reducing the amount of resources that commercial banks can obtain abroad, therefore reducing further the amount of domestic loans granted to firms. The difference in this case, is that the effect of intervention over aggregate demand and prices, is one that helps to achieve Central Bank’s objective.

It can be observed in Figure 2.3, that inflation for the Central Bank pursuing the hybrid-regime is almost half of that one resulting from the No-Intervention case, and thus the needed increase in the policy rate is also consequently higher for the No-Intervention case. This result suggest that when shocks affecting the economy are coming from the supply side, following a hybrid-regime can render better results than simply relying on the policy interest rate.
Figure 2.4: Responses to all three shocks. –– No Intervention –– Intervention.

2.5 Concluding remarks

The model proposed in this paper, is related to the continuing efforts to integrate financial frictions into macroeconomic models, emphasizing the links between these financial frictions and relative prices, leverage, and aggregate outcomes. It is similar to Bernanke and Gertler [1989], Kiyotaki and Moore [1995a], and many others, in the sense that it includes a borrowing constraint (the incentive compatibility constraint in this case). The innovation here is that the borrowing constraint is related to international financial markets and it can be relaxed or tighten by actions of the central bank, specifically by interventions in the foreign exchange market. Modeling interventions explicitly is also an intended contribution of this paper, since most of the literature that explores policy concerns with respect to the exchange rate, does it through a re-setting of the interest rate, rather than through interventions as such.

An interesting result, is that the model can discern between situations in which intervention can be regarded as a beneficial supplemental policy, in the sense that it reduces the volatility of inflation, keeping it closer to its long run-level. Results suggest that, when shocks affecting the economy are supply shocks, intervening in the forex market can render better results than just re-setting the policy rate (see Figure 2.4).
Although we cannot formally address welfare implications of the model, since we are evaluating dynamics of the linearized version, it is still encouraging to find a combination of policies that can render a lower inflation volatility and also identify the type of shocks for which this hybrid-policy is effective in achieving the objective of an IT central bank. These results might be relevant for developing economies, which are subject to several supply shocks.\footnote{These results come from the dynamic responses of the model to a single realization of each exogenous shock. In order to see if the results hold for any realization of the random disturbance, a simulation of 2000 periods was conducted for each type of shock, reaching to the same conclusions. See Appendix A.2.}

The down side of accumulating reserves is that they are not free. According to Rodrik [2006], the costs “... amount to around 1 percentage point of GDP annually for developing nations taken as a whole”. If reserves are able to reduces the probability of suffering a financial crisis, and all these nations are already paying this ‘insurance premium’, it is worthwhile to explore further whether these reserves can serve a better purpose than just being an expensive insurance.
Chapter 3

Foreign Exchange Market
Interventions Under Inflation Targeting: The case of Guatemala

3.1 Introduction

In a pure inflation-targeting –IT- regime, the central bank is expected to adopt a completely flexible exchange rate, mainly because countries integrated to global capital markets, are believed to be constrained by the impossible trinity.\(^1\) Consequently, if the central bank of a financially integrated economy chooses to control inflation, for example, the exchange rate cannot be targeted, simply because the lack of independent instruments.\(^2\) Moreover, it is typically assumed that yield differentials will be arbitraged out through highly elastic short-term capital flows, and therefore, any attempt of the central bank to influence the supply of foreign exchange, will be futile, since interventions would be neutralized by private capital reallocations.

\(^1\) *a.k.a.* Macroeconomic trilemma, which states that financially integrated countries, can only achieve simultaneously two out of the following three policy goals: an independent monetary policy, financial integration and exchange rate stability. Typically all three objectives are desirable, yet only two are mutually consistent, thus policymakers must decide which one to give up, and this is the *trilemma*.

\(^2\) Since monetary policy represents one policy instrument, according to Tinbergen [1952] it can only pursue one objective.
Despite the clarity of the *trilemma* and the difficulties of empirical literature to show that central bank intervention has reduced exchange rate volatility (or moved the exchange rate in the desired direction), intervention in foreign exchange—forex—markets remains an active policy tool, especially in developing and emerging market countries. Even IT-central banks often reserve explicitly the right to intervene in foreign exchange markets, alleging concerns about the exchange rates ‘deviating from fundamentals’ or showing ‘excessive volatility’ (see Neely [2005a], Gnabo et al. [2010a] and Aizenman et al. [2011b]). In this context, it is only fair to ask how much intervention an IT-regime can withstand? And remain effective in terms of maintaining a low and stable inflation, without limiting monetary policy actions, and without ending up using tacitly the exchange rate as a nominal anchor. In other words, is the grip of the constraint imposed by the *trilemma*, loose enough to allow foreign exchange rate intervention to be effective?

In the case of emerging markets and developing countries, with limited integration to global financial markets and limited stocks of outstanding assets, the scope of intervention might be broader, and it may be possible to have an effective intervention policy; one that limits exchange rate volatility and does not precludes an active monetary policy (meaning the ability to drive local interest rates away from the world interest rate). For these countries, intervention in forex markets might be well justified when there is a high pass-through of the exchange rate into domestic prices, or where significant currency mismatches exist between financial assets and liabilities. Nonetheless, even assuming blindly that large deviations of the real exchange rate (away from medium-run equilibrium) are costly, one can not conclude *a priori* that central bank interventions can potentially render better outcomes, unless forex intervention is in fact effective.

Therefore, this paper’s attempts to explore this two-objectives, two-instruments world empirically, by studying the effectiveness of forex interventions within an inflation-targeting framework, without ignoring the potential interdependencies between monetary and exchange rate policies. I will focus on Guatemalan daily data from 2008 to 2012, which can provide an interesting case study to the growing literature on managed floating regimes within the IT-framework, for several reasons. First, Guatemalan central bank has been implementing its monetary policy under an IT-regime since 2006, but it
Inflation targeters in Latin-America. A total of 2159 observations from January 03, 2003 to April 09, 2013.

Figure 3.1: Daily returns of bilateral nominal exchange rate

kept participating in the forex exchange market, intervening 148 days in a span of about four years. Second, the daily returns of the exchange rate between the Guatemalan domestic currency vis-à-vis the US dollar, have shown an astounding stability, compared with the daily returns observed in the other five Latin-American countries that have adopted an IT-regime (see Figure 3.1). The remarkable stability is not only evident from the graph, but also the coefficient of variation\(^3\) of the nominal exchange rate, is about five times larger in Brazil, about four times larger in Colombia and almost three times larger in any other country listed (see Table 3.1).

Another distinctive characteristic of Guatemalan data (shared with other developing or emerging market economies), is that the central bank does not only conducts

\(^3\)A normalized measure of dispersion, also known as the Relative Standard Deviation -RSD-.
monetary policy, but it is also in charge of interventions, which it is at odds with several more mature economies, where the central bank is in charge of monetary policy, but the exchange rate policy is conducted by the ministry of finance, Humpage [2003]. This distinction in the institutional framework is important as pointed out by Gnabo et al. [2010a], because it may increase the scope for interdependencies between interventions and monetary policy. Therefore the empirical approach that I will follow, starts with an estimation of the central bank reaction function, using a friction model à la Rosett [1959] in which monetary policy variables are included.\textsuperscript{4} Results from this first stage, suggest that the Guatemalan central bank reacted systematically to previous-day exchange rate changes when deciding the amount of intervention, and to deviations from a short-term trend. Interdependencies between monetary and exchange rate policies seem to be weak, since the contemporaneous policy rate is not statistically significant (as an explanatory variable for intervention), nor its lags. This result is reinforced by the fact that it was not possible to find evidence that current forex intervention conveys a signal of future monetary policy actions, as the leads of the policy rate also failed to attract a statistically significant coefficient. Both results suggest that there is certain independence between monetary and exchange rate policies in Guatemala, and that the central bank might be attempting to use the policy interest rate and interventions in forex markets, as two independent policy instruments.

One particular objective of this investigation is to explore whether the remarkable

\textsuperscript{4}Rosett’s friction model is a generalization of the popular Tobit model (Tobin [1958]). From Rosett’s original paper: “The Tobin model deals with relationships in which it is known that the conditional cumulative distribution function of the dependent variable has a mass point at some lower or upper limiting value of the dependent variable. The more general model [Rosett’s] includes cases in which the mass point is anywhere in the conditional cumulative distribution function”.

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Table 3.1: Nominal Exchange Rate: IT Countries in Latin-America

<table>
<thead>
<tr>
<th>Descriptive Statistics (2003.1 - 2013.4)</th>
<th>Guatemala</th>
<th>Colombia</th>
<th>Chile</th>
<th>Mexico</th>
<th>Peru</th>
<th>Brazil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coefficient of variation</td>
<td>2.8%</td>
<td>11.4%</td>
<td>8.2%</td>
<td>9.8%</td>
<td>8.2%</td>
<td>13.8%</td>
</tr>
<tr>
<td>Mean</td>
<td>7.79</td>
<td>2044.06</td>
<td>520.18</td>
<td>11.97</td>
<td>2.97</td>
<td>1.97</td>
</tr>
<tr>
<td>Standard Dev.</td>
<td>0.22</td>
<td>233.49</td>
<td>42.81</td>
<td>1.17</td>
<td>0.24</td>
<td>0.27</td>
</tr>
<tr>
<td>Min.</td>
<td>7.38</td>
<td>1652.41</td>
<td>431.22</td>
<td>9.92</td>
<td>2.54</td>
<td>1.54</td>
</tr>
<tr>
<td>Max.</td>
<td>8.40</td>
<td>2634.06</td>
<td>676.75</td>
<td>15.37</td>
<td>3.45</td>
<td>2.78</td>
</tr>
<tr>
<td>Kurtosis</td>
<td>8.49</td>
<td>11.57</td>
<td>9.59</td>
<td>18.44</td>
<td>16.42</td>
<td>15.98</td>
</tr>
<tr>
<td>Skewness</td>
<td>0.570</td>
<td>0.027</td>
<td>0.706</td>
<td>0.828</td>
<td>0.394</td>
<td>-0.005</td>
</tr>
</tbody>
</table>
stability of the exchange rate in Guatemala can be explained by interventions of the central bank in the forex market. Therefore, in a second stage, I use the conditional expectation of intervention, generated with estimates of the reaction function (from the first stage), as an instrument for actual interventions in a reduced form model of the exchange rate daily returns, allowing for GARCH effects in the conditional variance. From this exercise, I found that central bank’s intervention was not able to affect the level of the exchange rate during the sample period. On the contrary, there is statistical evidence that interventions did have a dampening effect over daily exchange rate return’s volatility. However, they do not appear to be the main determinant of the remarkable stability of the nominal exchange rate in Guatemala.

### 3.1.1 Related literature

The literature regarding central bank interventions in forex markets has been growing for almost thirty years, and now it can be considered extensive. However, identifying the effectiveness of intervention remains a valid research question, since the existing empirical research has failed to find reliable connections between official transactions and fundamental determinants of exchange rates Humpage [2003], and studies about the effectiveness of intervention have rendered mixed results. Most of the empirical literature comprises studies carried out using data from developed countries, and conclusions depend on the methods employed, samples and frequencies used. Despite the mixed results, there is some sense that intervention systematically moves the exchange rate when it is publicly announced, coordinated across countries and when it is consistent with the stance of monetary policy. Sarno and Taylor [2001], Humpage [2003] and Neely [2005a] offer surveys of the literature on foreign exchange intervention, including sections on the theoretical channels through which intervention might affect exchange rates and summaries of the empirical findings.

Despite the presumption that the scope of intervention could be broader in developing countries and emerging market economies, the empirical literature on the effects of intervention over the exchange rate using data from these countries is still scare, most likely because of the lack of reliable data. Nevertheless, the few available studies help to provide a sense of the effectiveness of central bank interventions in these countries. The

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[^5]: Literature on interventions became relevant soon after the collapse of Bretton-Woods and after the Jurgensen [1983] report was published by G-10 central banks.
effectiveness of intervention, as in the case of more developed economies, it appears to be dependent on the monetary policy framework within which interventions take place, the sample used and whether intervention was publicly announced or not, but in general results are mixed as well. See Hutchison [2003], Disyatat and Galati [2005, 2007] for reviews of the existing literature on intervention in emerging countries.

In a more recent study, Berganza and Broto [2012] find that forex interventions in some IT countries, have been more effective to lower volatility of exchange rates than in non-IT countries, using panel data from for 37 emerging economies. For Chile, Pincheira [2013] finds that interventions in 2008 had a significant, but relatively short lived, impact on the distribution of inflation expectations at long horizons, but for interventions carried out in 2011, no relevant impact was found. Kohlscheen [2013] presents indirect evidence of the effectiveness of sterilized interventions in Brazil, based on records of daily customer order flow data reported by Brazilian dealers as well as foreign exchange intervention data during 2002-2011. He finds that the effect of US$ sales by end-users on the exchange rate was much stronger on days in which the central bank did not intervene in the spot foreign exchange market. For Colombia, Echavarría et al. [2013] argues that the impact of pre-announced and transparent US$ 20 million daily interventions in 2008, were much larger than the impact of dirty interventions adopted in 2004-2007.

Among the large body of research, this paper lays between two strands of the empirical literature, one studying the motives of central bank to intervene (or the determinants of intervention) through the estimation of a reaction function and another one trying to identify the effects of intervention over the volatility of exchange rates using Garch models. The estimation of a reaction function for the central bank has been attempted using linear models, e.g. OLS (as in Ito [2002] and Galati et al. [2005]), using limited dependent variable models, e.g. probit models (as in Dominguez [1998], Kim and Sheen [2002], Guimaraes and Karacadag [2004], Ito and Yabu [2007]) and using censored regressions, e.g. tobit models (as in Almekinders and Eijffinger [1994] and Kamil [2008]). However, porbit or logit models deal with the probability of intervention but they discard information contained in the amount of intervention, tobit models take into account the amount, but they may take either buying or selling intervention as the dependent variable but not both. Therefore the friction model appears to be the
most appropriate approach for studying intervention. The friction model was brought
back by Almekinders and Eijffinger [1996] to estimate the reaction functions of U.S. and
German central banks, and it has been also adopted more recently by Kim and Sheen
[2006], Neely [2005b, 2008], Jun [2008] and Gnabo et al. [2010a].

This study is closer to Disyatat and Galati [2007] and Kamil [2008]. Both papers
first estimate a reaction function of the central bank and then use the fitted values
as instruments in regressions that estimate the effect of intervention. Kamil [2008] for
example, uses a censored tobit model to estimate the central bank reaction function.
Then uses projections from the reaction function to assess the effectiveness of interven-
tion using a Garch (1,1) model with Colombian daily data. Disyatat and Galati [2007]
employ a similar approach to evaluate the effects of intervention over daily returns of
the spot rate, the implied volatility and risk reversals, using OLS and data from the
Czech Republic. I attempt to improve over this strategy, by estimating a friction model
for the reaction function instead of using OLS or a tobit model, and then use the con-
ditional expectation of intervention (generated with estimates of the reaction function)
as the instrument for actual intervention in a Garch model. This can prove to be a
better approach, since interventions usually are carried out only for a few days during
any sample period, thus for the most part, obvious zeros of interventions are not well
predicted by a linear model. Regarding the tobit model, it could potentially take care
of the nonlinearity, allowing the dependent variable to be insensitive to its determi-
nants over a range of values, but it has the drawback that it could only take either
buying or selling intervention as the dependent variable, but not both. On the contrary,
the friction model has the advantage that it can consider both types of intervention
simultaneously in a single reaction function.

The rest of the paper is organized as follows. After the introduction, Section 2
briefly describes the exchange rate policy in Guatemala and the data used in this study.
Then, Section 3 describes the empirical strategy to be followed, including a detailed
description of the friction and GARCH models. Section 4 presents the estimation results.
Finally, Section 5 concludes.
3.2 Exchange rate policy in Guatemala

The exchange rate between Guatemala’s domestic currency -Quetzal- and the US dollar has been remarkably stable. Maintaining parity since its creation in 1924 until 1982, when a system of multiple exchange rates was established due to pressures stemming from the oil shocks of the 70’s, and the subsequent global recession in the early 80’s. This scheme of multiple exchange rates, eroded the reserves of the central bank and gradually induced devaluations of the domestic currency during the second half of the 1980’s decade. In 1989, the central bank introduced several reforms initiating the transition towards a floating regime. From 1989 to 1995 the exchange rate was allowed to fluctuate within a band; auctions and direct interventions in forex markets were implemented to enforce those bands. An electronic system of foreign currency exchange was created in 1996, known by its Spanish acronym –SINEDI- and managed by the Nacional Stock Exchange.\(^6\) Since its creation, it has been the main (and exclusive in later years) platform for central bank intervention in the forex markets.

During the first years of SINEDI, participation of the central bank in the forex market was discretionary, without any pre-announced objective. According to Castillo-Maldonado [2008], it usually responded to misalignments of the exchange rate with respect to its historical trend. In 2001 and 2002 three important financial bills were approved, the first one legalizing the free exchange of foreign currencies, the second one made amendments to the constitutional law of the central bank, and the third one made improvements to the law governing banks and financial institutions. The new financial legislation helped to consolidate the liberalization of the capital account, based on a floating exchange rate regime, and marked the starting point of the transition towards an inflation-targeting framework.\(^7\) Nevertheless, the central bank continued to intervene in the forex markets discretionally, until 2005 when a formal mechanism for intervention was introduced in the form of a participation rule, which has morphed several times, showing different implicit objectives and perhaps allowing more flexibility for the exchange rate. The current rule, stablished in June 2008, gives a specific objective to central bank participation in forex markets, stating that intervention should be limited to moderate the volatility of the nominal exchange rate, without affecting its

\(^6\)SINEDI: ‘Sistema Electrónico de Negociación Divisas’.

\(^7\)That materialized in 2006, when the central bank made the official announcement of the implementation of an IT-regime.
tendency. According to the rule, intervention will be triggered by an intraday nominal exchange rate variation (with respect to the previous five-days moving average) that exceeds 0.60% (either way). Therefore, if an intraday exchange rate is less than the five-day moving average (minus the 0.60% margin), the central bank will purchase US dollars, and if any given intraday exchange rate is higher than the moving average (plus the margin), a sale of US dollars will be triggered. This rule implicitly assumes that intervention policy can effectively influence exchange rates, and it will be used to decrease foreign exchange rate volatility.

This rule introduces a fair amount of transparency regarding the participation of the central bank in forex markets, nevertheless, around 2009, the central bank stated that it will participate in a more discretionary fashion in case of ‘unusual volatility’ without clearly defining what could be considered “unusual”. Therefore it kept room for discretionary interventions. Moreover, there is no evidence whether this rule is too restrictive, in the sense that the intervention rule might be hindering the achievement of monetary policy objectives, by not allowing enough adjustment of the exchange rate, assuming intervention is indeed effective. Even if it is not effective, it might be undermining monetary policy efforts by preventing the anchorage of expectations, and rising doubts about the commitment of the central bank with the inflation target.

3.2.1 Data

The empirical exercise will focus on daily returns of the quetzal vis-à-vis the US dollar, between January 2008 and August 2012, a period in which monetary policy was conducted under inflation-targeting and the central bank intervened frequently. Daily data on interventions was obtained from the Guatemalan Central Bank, as well as the ‘reference’ exchange rate used in this analysis. Figure 3.2 displays all sales and purchases of US dollars conducted by the central bank along with the nominal exchange rate during the sample period.

There are a couple of features noteworthy from this plot. One is that intervention tends to come in clusters, some more apparent than others, but certainty, there are periods in which the central bank intervened more frequently. This feature motivates the

\footnote{Originally, the criterion triggering intervention was a deviation of 0.75% with respect to the five-day moving average, but in 2010 it was set at the current symmetric 0.60%.
cluster-robust estimation of the standard errors in the friction model later on. Another one is that the central bank seems to lean against the wind, i.e. purchases are carried out when the exchange rate is appreciating and sales occur when the exchange rate is depreciating, this is more evident in the first half of the sample, but throughout the plot there are episodes where this pattern can be observed. In order to test if the central bank has in fact “leaned against the wind” a 20-day moving-average component is included in the friction model, as proxy for a time-dependent ‘target’ of the nominal exchange rate.

Since the intervention rule announced by the Guatemalan central bank, explicitly says that the bank would take into account the intraday evolution of the exchange rate in deciding when and how much to intervene, aggregate daily interventions and exchange rate changes could simultaneously determine each other. Ignoring this endogeneity will render downward-biased estimates of the effect of central bank interventions. Fortunately, the ‘reference exchange rate’ reported by the Guatemalan central bank for any given day, is the weighted-average of all transactions carried out the previous day (in the institutional foreign exchange market), while intervention data is reported at the close of the day in which it was performed.\(^9\) This timing is relevant for the estimation

\(^9\)Therefore, exchange rates used in this analysis are quoted at the beginning of the trading day. Daily
strategy later on, since it implies that the exchange rate at time $t$, is predetermined with respect to the amount of intervention at $t$, helping to attenuate simultaneity problems.

In total, the central bank intervened 148 days, purchasing US$855.28 millions and selling US $882.44 millions during the sample period. The most forceful intervention was observed in 2009, when the central bank sold US$365.3 million, apparently, in an attempt to stop a depreciation of about 14% experienced during that year. The higher frequency of intervention was observed in 2011 with 51 days, amounting US$ 181.1 millions (see table 3.2).

### 3.3 Empirical Estimation

There are several characteristics of intervention that complicate the assessment of its effects over the exchange rate. As aforementioned, a pervasive problem that arises when assessing the effects of intervention, is the endogeneity problem. Since intervention quickly reacts to exchange rate movements, exchange rates and intervention are determined simultaneously, therefore, failing to account for this dual causality, is likely to bias the analysis toward finding that intervention has no impact on exchange rates. Additionally, since intervention is only conducted sporadically, there are many dates in any given sample, for which intervention does not occur, taking a zero value. Thus, it has an unusual distribution, with a nonlinear conditional mean. Under these circumstances, using a linear approach for estimation (e.g. ordinary least squares) will render inconsistent estimates.

To overcome these problems, I use a two-stage instrumental variable approach, returns of the exchange rate at time $t$, represent the percentage change in opening prices between $t$ and $t-1$. 

<table>
<thead>
<tr>
<th>Table 3.2: Interventions in Guatemalan Foreign Exchange Rate Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>US$ Millions: 2008 - 2012</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Net Purchases</strong></td>
</tr>
<tr>
<td>2008</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>179.08</td>
</tr>
<tr>
<td><strong>Purchases</strong></td>
</tr>
<tr>
<td>237.38</td>
</tr>
<tr>
<td><strong>Sales</strong></td>
</tr>
<tr>
<td>58.30</td>
</tr>
<tr>
<td><strong>No. of Interventions (days)</strong></td>
</tr>
<tr>
<td>30</td>
</tr>
</tbody>
</table>

* / Until August 12 2012
based on estimates of the central bank reaction function, as in Galati et al. [2005], but without resorting to OLS. For the first stage, in order to avoid inconsistent estimates of the parameters, I estimate a nonlinear model of the interaction between exchange rates and intervention. I then use the conditional expectation of intervention (calculated using estimates from the first stage), as an instrument for realized interventions, in a GARCH model of exchange rate returns, to explore whether intervention or other policy variables can account for the low volatility observed in the Guatemalan exchange rate.

3.3.1 The Friction Model

The friction model constitutes an appropriate characterization of the central bank reaction function under a managed floating system. There is a set of explanatory variables that the central bank will take into account, when deciding whether to intervene or not. For some realizations of these variables, policy makers will not react \textit{i.e.} they will not intervene, creating the observed insensitivity to small changes in the state of the world. Therefore, there will be a mass point in the conditional cumulative distribution function \(-cdf\) of the dependent variable.\(^{10}\) By taking into account this mass point of the \(cdf\), the friction model is expected to fit both, the zero and non-zero amounts of intervention, better than the linear model, since the marginal effect of each explanatory variable on the expected amount of intervention is not fixed, as in the linear case, but varying with the probability of intervention.

The nonlinear system presented here is a friction model, consistent with the observed infrequency of foreign exchange market intervention \(-I_t\). We assume that there are states of the world in which policymakers will decide to sell US dollars \((I_t < 0)\), states in which they will purchase \((I_t > 0)\) and states in which authorities will refrain from participating in forex markets \((I_t = 0)\).

Therefore, what follows is a description of the friction-model framework that characterizes intervention:

\[
I_t^* = x_t \beta + \varepsilon_t, \quad \varepsilon_t | x_t \sim N(0, \sigma^2)
\]  

\(^{10}\)Intervention being the dependent variable in this case, with a mass point around no intervention (or zero intervention).
where \( I_t^* \) (the latent variable), is known to the central bank but unobservable to outsiders, and it measures the necessity of intervention or the desired level of intervention; \( \beta \) is a column vector of parameters and \( x_t \) is a set of explanatory variables, defined as,

\[
x_t\beta = \alpha_1 S_{t-1} + \alpha_2 P_t + \alpha_3 E_t
\]

where the row-vector \( \alpha_1 \) of coefficients, captures the effects of \( S_{t-1} \), which is a column-vector containing a set of explanatory variables related to the exchange rate dynamics, e.g. one-day returns \( (\Delta \ln S_{t-1}) \) or deviations from a moving average \( (\ln S_{t-1} - \ln 1/20\sum_{j=1}^{20} S_{t-1-j}) \) which proxy for a moving target of the exchange rate. All exchange rate related variables will enter the reaction function lagged one period, despite I am using opening prices. The column-vector \( P_t \) are monetary policy-related variables, e.g. the policy interest rate or the interest rate in the money market that is influenced the most by the policy rate (the 7-days repo-rate). Some policy related variables are introduced as leads, since a statistically significant coefficient for these variables will suggest that interventions convey information (or a signal) about future monetary policy. Finally, \( E_t \) is a set of explanatory variables controlling for the possibility that official announcements of inflation data can influence the decision to intervene as in Fatum and Hutchison [2010], Kamil [2008] and Echavarria et al. [2013]. The ‘news’ are extracted from the difference between the announced level of monthly inflation and the market’s expectation of that announcement.

The model assumes that actual intervention (or realized intervention) takes place only if \( I_t^* \) is above the upper threshold \( \theta_1 \) or below the lower threshold \( -\theta_2 \),

\[
I_t = \begin{cases} 
I_t^* - \theta_1; & \text{if } I_t^* > \theta_1 > 0 \\
0; & \text{if } -\theta_2 \leq I_t^* \leq \theta_1 \\
I_t^* + \theta_2; & \text{if } I_t^* < -\theta_2 < 0 
\end{cases}
\]  

(3.2)

where \( I_t \) positive (negative) denotes a realized purchase (sale) of US dollars by the central bank.

Notice that the three conditions in eq.(3.2), can be written as:
\[ \varepsilon_t > \theta_1 - \alpha_1 S_{t-1} - \alpha_2 P_t - \alpha_3 E_t \]
\[ \varepsilon_t < -\theta_2 - \alpha_1 S_{t-1} - \alpha_2 P_t - \alpha_3 E_t \]
\[ -\theta_2 > \alpha S_{t-1} + \alpha_2 P_t + \alpha_3 E_t + \varepsilon_t > \theta_1 \]

By substituting eq.(3.1) into eq.(3.2), we can rewrite it as:

\[
I_t = \begin{cases} 
  x_t \beta - \theta_1 + \varepsilon_t; & \text{if } I_t > 0 \\
  0; & \text{if } I_t = 0 \\
  x_t \beta + \theta_2 + \varepsilon_t; & \text{if } I_t < 0 
\end{cases} \tag{3.3}
\]

Since we assumed normality for the error term \( \varepsilon_t | x_t \sim N(0, \sigma^2) \), the conditional distribution of \( I_t \) (for the differentiable portions) is given by,

\[
I_t | x_t \sim \begin{cases} 
  N \left( x_t \beta - \theta_1, \sigma^2 \right) & \text{if } I_t > 0, \\
  N \left( x_t \beta + \theta_2, \sigma^2 \right) & \text{if } I_t < 0.
\end{cases}
\]

which implies the following likelihood function for observation \( t \):

\[
L_t \left( \theta \right) \equiv L \left( \theta, \beta, \sigma; I_t | x_t \right) = \begin{cases} 
  \phi \left( (I_t - x_t \beta + \theta_1) / \sigma \right) / \sigma & \text{if } I_t > 0, \\
  \phi \left( (I_t - x_t \beta - \theta_2) / \sigma \right) / \sigma & \text{if } I_t < 0.
\end{cases}
\]

where \( \phi \) is the standard normal density function \(-pdf\). For the mass point of the \( cdf \), \((i.e. \text{ when } I_t = 0)\), we have:

\[
L_t(\bar{\theta}) = P(I_t = 0 | x_t) = 1 - P(I_t > 0 | x_t) - P(I_t < 0 | x_t)
\]

where

\[
P \left( I_t > 0 | x_t \right) = P \left( x_t \beta - \theta_1 + \varepsilon_t > 0 | x_t \right) = P \left( \varepsilon_t > -x_t \beta + \theta_1 | x_t \right) = \ldots
\]

\[
1 - P(\varepsilon_t < -x_t \beta + \theta_1 | x_t) = 1 - \Phi \left( -x_t \beta + \theta_1 / \sigma \right)
\]

and \( \Phi \) is the standard normal cumulative distribution function.
In the same way, we can define \( P(I_t < 0|x_t) \) as,

\[
\Phi\left(\frac{-x_t \beta - \theta_2}{\sigma}\right)
\]

therefore,

\[
L_t(\theta) = P(I_t = 0|x_t) = \Phi\left(\frac{-x_t \beta + \theta_1}{\sigma}\right) - \Phi\left(\frac{-x_t \beta - \theta_2}{\sigma}\right).
\]

The complete likelihood function for observation \( t \) is defined as,

\[
L_t(\bar{\theta}) \equiv L(\theta, \beta, \sigma; I_t|x_t) = \begin{cases} 
\phi \left( \frac{(I_t-x_t \beta+\theta_1) / \sigma}{\sigma} \right) & \text{if } I_t > 0, \\
\Phi\left(\frac{-x_t \beta + \theta_1}{\sigma}\right) - \Phi\left(\frac{-x_t \beta - \theta_2}{\sigma}\right) & \text{if } I_t = 0 \\
\phi \left( \frac{(I_t-x_t \beta-\theta_2) / \sigma}{\sigma} \right) & \text{if } I_t < 0.
\end{cases}
\]

In logarithmic terms, \( l_t(\bar{\theta}) = \log L_t(\bar{\theta}) \):

\[
l_t(\bar{\theta}) = \ln(I_t > 0) \cdot \log \left[ \phi \left( \frac{(I_t-x_t \beta + \theta_1) / \sigma}{\sigma} \right) / \sigma \right] \cdots \\
+ \ln(I_t < 0) \cdot \log \left[ \phi \left( \frac{(I_t-x_t \beta - \theta_2) / \sigma}{\sigma} \right) / \sigma \right] \cdots \\
+ \ln(I_t = 0) \cdot \log \left[ \Phi\left(\frac{-x_t \beta + \theta_1}{\sigma}\right) - \Phi\left(\frac{-x_t \beta - \theta_2}{\sigma}\right) \right]
\]

where \( \ln(\cdot) \) is the indicator function, taking a unit value if (\cdot) is true and zero otherwise.

Because intervention usually occurs in sporadic clusters, it is possible that observations within the same cluster are not independent. Failing to account for this characteristic can produce an incorrect variance-covariance estimate \(-vce\). In order to avoid underestimating the variances and covariances, a cluster-robust \( vce \) is performed using an estimator first proposed by Zeger and Liang [1986]. By using this estimator, we are making the (mild and perhaps correct) assumption that intervention ‘episodes’ are independent from each other, but at the same time, we are allowing for some form of correlation among interventions within the same episode or cluster. Each cluster is defined considering the number of consecutive days of no intervention between days of intervention. Consecutive days of intervention or sporadic intervention with less than
fifteen consecutive days of no intervention, are considered a cluster or episode. This procedure is akin to the way Fatum and M Hutchison [2003] define their intervention ‘events’ in their event study approach on sterilized interventions. Using this criterion, twenty six clusters were identified through the entire sample, and then used to estimate the cluster-robust variance-covariance matrix.

In order to get a proxy for realized intervention, I replaced the estimated parameters (from the friction model) into the following conditional mean equation:

\[
\bar{I}_t = E(I_t | x_t) = \left[ \Phi \left( \frac{x_t \beta - \theta_1}{\sigma} \right) \right] (x_t \beta - \theta_1) + \sigma \phi \left( \frac{x_t \beta - \theta_1}{\sigma} \right) \ldots \\
- \left[ \Phi \left( \frac{-x_t \beta - \theta_2}{\sigma} \right) \right] (-x_t \beta - \theta_2) + \sigma \phi \left( \frac{-x_t \beta - \theta_2}{\sigma} \right)
\] (3.5)

3.3.2 The Garch Model

Then, I use the conditional expectation of intervention from eq.(3.5), as an instrument for realized interventions in the following GARCH(1, 2) specification:

\[
\Delta \ln s_t = \gamma_1 \Delta \ln S_{t-1} + \gamma_2 \bar{I}_t + \gamma_3 (i - i^*)_{t-1} + \gamma_4 \pi_{t-1}^e + \gamma_5 \text{New} s_t + \epsilon_t
\] (3.6)

\[
\epsilon_t | \Omega_{t-1} \sim N(0, \sigma_t^2)
\] (3.7)

\[
\sigma_t^2 = \delta_0 + \delta_1 \sigma_{t-1}^2 + \delta_2 \epsilon_{t-1}^2 + \delta_3 \epsilon_{t-2}^2 + \delta_4 \bar{I}_t + \delta_5 \pi_{t-1}^e + \delta_6 \text{fr} + \delta_7 i_t^P + \kappa_t
\] (3.8)

Where \(\Delta \ln S_{t-1}\) is the daily percentage change in the nominal exchange rate. Since \(S_t\) is defined as quetzales per US dollar, a positive change implies a depreciation; \(\bar{I}_t\) is the instrumented level of central bank’s intervention –eq.(3.5); the interest rate differential \((i - i^*)_t\) is between the 7-days repo rate in domestic currency \((i_t)\) and the
same financial instrument denominated in US dollars ($i^*_t$), as negotiated in the interbank market, both in percent per year; $\pi^e$ refers to the expected inflation rate as reported monthly in the central bank’s Survey of Economic Expectations. The last variable, $\text{News}_t$, in the mean equation (eq. 3.6), controls for the possibility that official announcements of inflation data can also influence the exchange rate returns, this will proxy the unexpected component of inflation announcement, since it is the difference between announced inflation and the expectation of that announcement. $\epsilon_t$ denotes the unexpected return which is used to model the conditional volatility of the exchange rate in the volatility equation (eq. 3.8), and $\sigma^2$ is the conditional variance, allowing for the possibility of a time-varying and clustering conditional volatility.

The mean equation (eq. 3.6) analyzes daily changes in the exchange rate return as a function of intervention, controlling for other factors affecting exchange rates. The main interest is on the estimate of $\gamma_2$, the contemporaneous impact of intervention on the level of the exchange rate. If intervention in forex markets is effective, then purchases of foreign currency ($I_t > 0$) will depreciate the domestic one, and therefore, $\gamma_2$ should be positive and significant. The estimation controls for local money market conditions on the exchange rate. The interest differential and expected inflation rate are potential determinants of demand for local currency. I also control for the possible influence of surprises in inflation announcements, that may arrive on the same day on which interventions are performed. The volatility equation (eq. 3.8), in addition to the garch and two arch terms, it considers the effects that intervention might have over the volatility of the exchange rates. I also consider the effects of expected inflation and the state of the international financial markets; the Fed’s funds rate $-fdr_t$ is used as a proxy. The last term accounts for the possible influence that the policy interest rate $-i^P_t$ might have over exchange rate volatility.

### 3.4 Results

#### 3.4.1 Central bank reaction function

Results of the maximum-likelihood estimation of eq.(3.4) can be found in Table 3.3. The results show statistical evidence of the existence of threshold effects in the

In order to obtain a daily frequency, I performed a piecewise cubic spline interpolation using the reported monthly data.
reaction function. In all model specifications, both thresholds appear to be statistically
significant, and at least in model (1), they appear close in magnitude, with the ‘selling’
threshold being somewhat bigger than the purchasing threshold (i.e. $|\theta_2| > |\theta_1|$).
This implies that the central bank has a slight tendency to react more forceful when
attempting to counteract an appreciation of domestic currency, perhaps trying to main-
tain competitiveness of the exporting sector.\textsuperscript{12} It was not possible to find evidence that
current forex intervention conveys a strong signal of future monetary policy actions,
as the leads of the policy rate fail to attract a statistically significant coefficient (the
30-days lead is reported, but the one-day and 15-days leads were also not significant).
The interdependencies between intervention and monetary policy, appear to be non ex-
istent or weak, since the contemporaneous policy rate is not statistically significant, nor
its lags (unreported here). This suggests that there is certain independence between
monetary and exchange rate policies, and that the central bank might be attempting to
use the policy interest rate and interventions as two independent policy instruments.

Regarding the ‘News’ variable, it appears to be statistically significant independ-
ently of model specification, while the expected inflation is not (when it is significant,
it has the wrong sign perhaps due to its high correlation with the exchange rate). This
suggests that the unexpected component of the announcement (i.e. actual minus ex-
pected inflation) is more important as a determinant of intervention, than expected
inflation \textit{per se}. The negative coefficient implies that the the central bank, in reaction
to the announcement of an inflation rate higher than expected, will sell US dollars in the
forex markets, which can be viewed as consistent with policy actions aimed to contain
inflation, making the inflation target credible despite the participation of the central
bank in forex markets. The coefficient for the one-day return of the exchange rate has
the expected sign and is statistically significant, suggesting that the central bank re-
acts systematically to previous-day exchange rate changes when deciding the amount to
intervene. Consistent with the ‘lean against the wind’ hypothesis, the coefficient for de-
viations from the twenty-day moving average, are statistically significant and negative,
independently of model’s specification. This suggest that the central bank attempted
to counteract short term trends of the nominal exchange rate.\textsuperscript{13}

\textsuperscript{12}This result changes when the policy rate and expected inflation are included among the explanatory
variables. But since these two regressors are not always statistically significant, evidence point in the
direction of symmetric thresholds.

\textsuperscript{13}It is also noteworthy that the deviations from the 5-days moving average (an from the 10-days,
Table 3.3: Central bank’s reaction function

<table>
<thead>
<tr>
<th>Friction model results (2008.1-2012.8)</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Threshold ($\theta_1$)</td>
<td>47.65***</td>
<td>59.55***</td>
<td>43.48**</td>
<td>59.97***</td>
<td>43.95**</td>
<td>39.20**</td>
</tr>
<tr>
<td></td>
<td>(15.69)</td>
<td>(20.97)</td>
<td>(20.72)</td>
<td>(21.06)</td>
<td>(21.72)</td>
<td>(19.81)</td>
</tr>
<tr>
<td>Threshold ($-\theta_2$)</td>
<td>-52.28***</td>
<td>-40.16*</td>
<td>-56.24***</td>
<td>-39.74*</td>
<td>-55.76***</td>
<td>-59.83***</td>
</tr>
<tr>
<td></td>
<td>(16.42)</td>
<td>(22.02)</td>
<td>(20.56)</td>
<td>(22.01)</td>
<td>(20.53)</td>
<td>(21.97)</td>
</tr>
<tr>
<td>$\Delta \ln S_{t-1}$ ($\beta_1$)</td>
<td>-50.46***</td>
<td>-50.63***</td>
<td>-51.07***</td>
<td>-50.30***</td>
<td>-50.74***</td>
<td>-50.31***</td>
</tr>
<tr>
<td></td>
<td>(9.51)</td>
<td>(9.62)</td>
<td>(9.91)</td>
<td>(9.70)</td>
<td>(9.99)</td>
<td>(9.83)</td>
</tr>
<tr>
<td>$(\ln S - \ln S^{20})_{t-1}$ ($\beta_2$)</td>
<td>-12.02**</td>
<td>-12.91**</td>
<td>-11.69***</td>
<td>-12.91**</td>
<td>-11.70***</td>
<td>-11.51***</td>
</tr>
<tr>
<td></td>
<td>(4.89)</td>
<td>(5.26)</td>
<td>(4.44)</td>
<td>(5.18)</td>
<td>(4.37)</td>
<td>(4.22)</td>
</tr>
<tr>
<td>Policy Rate $t$</td>
<td>2.20</td>
<td>-2.61</td>
<td>2.28</td>
<td>-2.51</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.65)</td>
<td>(2.74)</td>
<td>(2.65)</td>
<td>(2.73)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy Rate $t+30$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-3.63</td>
<td>(3.02)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3.02)</td>
<td></td>
</tr>
<tr>
<td>Exp. Inflation $t-1$</td>
<td>1.77***</td>
<td></td>
<td>1.75*</td>
<td></td>
<td>2.03**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.899)</td>
<td></td>
<td>(0.901)</td>
<td></td>
<td>(1.01)</td>
<td></td>
</tr>
<tr>
<td>News $t$ ($\beta_3$)</td>
<td>-12.06***</td>
<td></td>
<td>-12.58***</td>
<td></td>
<td>-12.27***</td>
<td>-12.68***</td>
</tr>
<tr>
<td></td>
<td>(3.62)</td>
<td></td>
<td>(3.70)</td>
<td></td>
<td>(3.56)</td>
<td>(3.64)</td>
</tr>
<tr>
<td>ML</td>
<td>-1043.5</td>
<td>-1043.02</td>
<td>-1035.4</td>
<td>-1041.4</td>
<td>-1033.8</td>
<td>-1031.1</td>
</tr>
<tr>
<td>Observations</td>
<td>1680</td>
<td>1680</td>
<td>1680</td>
<td>1680</td>
<td>1680</td>
<td>1650</td>
</tr>
</tbody>
</table>

- Asterisks denote significance of coefficients, with ***, ** and * indicating significance at the 1%, 5% and 10% level, respectively.
- Cluster-robust standard errors are reported in parentheses.
The previous description of the results is limited to the qualitative implications of the estimation, since unlike the linear model, these estimated effects are not fixed but varying with the probability of intervention, which in turn depends on the values of the regressors. In order to get a better idea of the instrument for intervention used in the Garch model, Figure 3.3 depicts the conditional expectation of intervention $E(I_t|x_t)$ – the instrument – against the values of $x_t\hat{\beta}$. The conditional expectation $E(I|x)$, is computed using estimates of model (1) in Table 3.3. The graph shows the non-linearity of the model, and how the conditional expectation varies with the values of regressors. Therefore, the marginal effects will not be simply the estimated coefficients $\beta_i$ (as in a linear model), but they can be derived from eq.(3.5), as follow,

$$\frac{\partial E[I_t|x_t]}{\partial x_{i,t}} = \beta_i \left[ \Phi \left( \frac{x_t\beta - \theta_1}{\sigma} \right) + \Phi \left( -\frac{x_t\beta - \theta_2}{\sigma} \right) \right]$$

(3.9)

In order to get a sense of the magnitudes implied by the friction model, Table (3.4) shows the marginal effects evaluated at the sample means, conditional on the sign. Since the three explanatory variables of model (1) are expressed in percentage deviations (positive and negative), the entire sample mean will inevitably fall very close to zero, therefore, the marginal effects are presented for a ‘positive mean’ which is the mean value of the positive observations of the explanatory variables, and a ‘negative mean’ which refers to the mean of explanatory variables for the days in which a negative variation is observed. For example, the positive mean of $\Delta \ln S_{t-1}$ encompass all the days in which a depreciation was observed with respect to the previous day, i.e. $\Delta \ln S_{t-1} > 0$. The same applies for the deviations from the moving average, a positive $\ln S_{t-1} - \ln S_{t-1}^{20}$ implies a depreciation of the exchange rate with respect to its short-term trend or time-varying target. In the case of the unexpected component of the inflation announcement $-\text{News}_{t-1}$, a positive value implies an inflation rate higher than expected.

The interpretation of the effects is now straight forward. The estimation implies that the central bank, when facing a one percent depreciation of the nominal exchange both not reported) appear to have less explanatory power than the deviation from the 20-days moving average, despite that the rule claimed to be followed by the central bank, conditions its reaction to deviations from a 5-day moving average and it is supposed not to affect the trend.
Figure 3.3: Friction model projection: Conditional mean equation, \( E(I_t|x_t) \)

Table 3.4: Marginal Effects

| Reaction function, model (1) |  
|------------------------------|---|
| Positive Mean               |   |
| \( \Delta \ln S_{t-1} \)    | \( -5.684 \) |
| \( \ln S_{t-1} - \ln S_{t-1}^{20} \) | \( -1.354 \) |
| \( \text{News}_t \)          | \( -1.358 \) |
| Negative Mean               |   |
| \( \Delta \ln S_{t-1} \)    | \( -6.791 \) |
| \( \ln S_{t-1} - \ln S_{t-1}^{20} \) | \( -1.617 \) |
| \( \text{News}_t \)          | \( -1.622 \) |

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rate (with respect to the previous day) reacted by selling 5.7 million US dollars on average, during the sample period. In the same way, when confronted with an appreciation of one percent, the central bank reacted by purchasing about US$ 6.8 million. The reaction is qualitatively the same, when the depreciation is with respect to the time-varying target \((\ln S_{t-1} - \ln S^0_{t-1})\), but it is quantitatively smaller; facing a one-percent depreciation triggered a sale of US$ 1.4 million and a one-percent appreciation resulted in a purchase of 1.6 million US dollars. Regarding the ‘News’ variable, a one-percent surprise (an announced inflation one-percent higher than expected) made the central bank sell US$ 1.4 million on average. Finally, the central bank reacted to the announcement of an inflation one percent lower than expected, by purchasing 1.6 million US dollars, on average during the sample period.

3.4.2 Effects over daily returns of the exchange rate

The results of the mean equation estimated in the second stage (the GARCH model) are summarized in Table 3.5. The estimated coefficients represent the percentage response of the daily returns of the nominal exchange rate, to a unit change of the regressors. The lagged dependent variable is statistically significant, implying that a one-percent appreciation (depreciation) of the domestic currency yesterday, will be associated with a 0.44 percent today. In order to assess the effects of intervention over the daily returns of the exchange rate, the instrumented amount of intervention was included among the regressors. The results for \(\gamma_2\) suggest that forex interventions have not influenced the exchange rate level, as the coefficient (0.008) is not statistically significant.\(^{14}\)

The other explanatory variables are statistically significant, but with a rather mild effect over the daily returns of the exchange rate. A one percent difference between the lagged repo rates of domestic currency and US dollars denominated assets, will induce a slight depreciation of 0.004 percent. Regarding expected inflation, the estimation suggest that if inflation expectations increase by one-percent, the nominal exchange rate will appreciate in 0.002 percent. Although this is a quantitatively small effect (yet statistically significant at 1% level), it conveys an interesting economic point: Since the exchange rate appreciated in response to the expectation of a higher inflation,\(^{14}\)

\(^{14}\)It is possible to have a statistically significant effect, only when using a non-robust estimation of the variance-covariance matrix.
Table 3.5: Impact of central bank intervention over the exchange rate level

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Garch model, mean equation: 2008.1 - 2012.8</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lagged dependent variable ( (\gamma_1) )</td>
<td>0.435***</td>
<td>(0.048)</td>
</tr>
<tr>
<td>Instrumented amount of intervention ( (\gamma_2) )</td>
<td>0.008</td>
<td>(0.007)</td>
</tr>
<tr>
<td>Repo interest rate differential ( (t-1) ) ( (\gamma_3) )</td>
<td>0.004***</td>
<td>(0.001)</td>
</tr>
<tr>
<td>Expected Inflation ( (t-1) ) ( (\gamma_4) )</td>
<td>-0.002***</td>
<td>(0.001)</td>
</tr>
<tr>
<td>News ( (\gamma_5) )</td>
<td>0.022</td>
<td>(0.022)</td>
</tr>
</tbody>
</table>

- Asterisks denote significance of coefficients, with *** , ** and * indicating significance at the 1%, 5% and 10% level, respectively.
- Robust standard errors reported in parenthesis.

It seems that markets believed that the central bank would increase interest rates in response to that higher expected inflation (in order to enforce its inflation objective). The anticipation of higher yields in domestic currency-denominated assets, increased the demand for those assets and induced an appreciation of the exchange rate, which is consistent with the notion that the exchange rates are forward looking asset prices that react to market’s expectations of future changes in fundamentals.\(^{15}\) Finally, the unexpected component of the inflation announcement, a one-percent higher-than-expected inflation was on average associated with a 0.02% depreciation of the exchange rate, nonetheless this result is not statistically significant.\(^{16}\)

Results of the variance equation (see Table 3.6), show that the first three explanatory variables included in the conditional variance equation (eq.3.8) are highly significant, indicating that the GARCH parameters \( \delta_1, \delta_2 \) and \( \delta_3 \) have a significant explanatory power in the daily returns model. The magnitude of the coefficient on the lagged conditional variance \( \delta_1 \), is statistically significant and highly persistent (being

\(^{15}\)Nevertheless, since the effect is so small, it could also cast doubts on the ability of the central bank to anchor inflation expectations, and on how strong its credibility is, with respect to pursuing its primary objective, i.e. price stability.

\(^{16}\)This parameter is significant at the 10% level, but only when non-robust standard errors are estimated.
### Table 3.6: Impact of central bank intervention over exchange rate volatility

Garch model, variance equation: 2008.1 - 2012.8

<table>
<thead>
<tr>
<th>Term</th>
<th>Coefficient</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garch term (δ₁)</td>
<td>0.905***</td>
<td>(0.018)</td>
</tr>
<tr>
<td>Arch term 1ˢᵗ lag (δ₂)</td>
<td>0.240***</td>
<td>(0.043)</td>
</tr>
<tr>
<td>Arch term 2ⁿᵈ lag (δ₃)</td>
<td>-0.173***</td>
<td>(0.040)</td>
</tr>
<tr>
<td>Instrumented interventions (δ₄)</td>
<td>-0.257***</td>
<td>(0.034)</td>
</tr>
<tr>
<td>Expected Inflation (δ₅)</td>
<td>0.186***</td>
<td>(0.065)</td>
</tr>
<tr>
<td>Federal funds rate (δ₆)</td>
<td>-0.970***</td>
<td>(0.356)</td>
</tr>
<tr>
<td>Policy Rate (δ₇)</td>
<td>0.302</td>
<td>(0.199)</td>
</tr>
</tbody>
</table>

- The table reports estimation of the conditional variance equation of the GARCH(1,2) model, including a constant term.
- Asterisks denote significance of coefficients, with *** , ** and * indicating significance at the 1%, 5% and 10% level, respectively.
- Robust standard errors reported in parenthesis.
Results also show that interventions ($\delta_4$) had a dampening effect over the daily exchange rate return’s volatility, reducing it in 0.26. Nevertheless, an even larger and statistically significant effect is registered by the Federal funds rate; the negative coefficient implies that an increase in the federal funds rate, decreases volatility of the nominal exchange rate in Guatemala by 0.97. This is consistent with the idea that low yields in financial centers would result in increased flows of funds into financial peripheries, seeking higher yields. A more dynamic flow of international capital could easily increase the volatility of the nominal exchange rate, and the converse will also be true, when yields are high in the center, the periphery will face a smaller flow of funds, making the nominal exchange rate less volatile. The fact that the coefficient for the federal funds rate ($\delta_6$) is much larger than the one related to interventions ($\delta_4$), suggest that international liquidity conditions (and therefore the amount of international capital flowing into the Guatemalan economy) could be responsible for the remarkable stability of the exchange rate in Guatemala, or at least it is in a larger extent than the central bank intervention.\footnote{Only one estimation of the Garch model is included within the text, on Appendix B, Tables B.2 and B.3, alternative specifications’ results are reported.}

## 3.5 Conclusions

This paper presents empirical evidence on the relationship between central bank’s intervention in forex markets and daily returns of the exchange rate between the quetzal and the US dollar. I first examine the reaction function of monetary authorities using Rosett’s generalization of the Tobit model, allowing for nonlinearities in the reaction function of the central bank, to match the observed insensitiveness to some realization of the variables guiding the decision to intervene. In order to minimize the ubiquitous problems caused by the simultaneous determination of exchange rates and central bank intervention, the exchange rate used in the first stage of the analysis (the friction model), is that quoted at the beginning of the trading day, while intervention data is reported at the close of the day in which it was performed. Since intervention at time $t$ cannot influence the opening quote, timing of data collection helps to attenuate simultaneity problems.

From the first stage, I found statistical evidence of the existence of threshold
effects in the reaction function, as expected for a managed float regime. It was not possible to find evidence that forex intervention conveys a strong signal of future monetary policy actions, it seems that monetary policy is conducted independently from the exchange rate policy, as if the central bank is using intervention as a independent policy instrument. The estimation of the reaction function also suggests that the unexpected component of the inflation announcement is a statistically significant determinant of intervention. Consistent with the ‘lean against the wind’ hypothesis, the coefficient for deviations from the twenty-day moving average, are statistically significant and negative, independently of model’s specification. This suggest that the central bank attempted to counteract short term trends of the nominal exchange rate.

I then investigate the effect of intervention on the level and the variance of the daily returns of the exchange rate, using a Garch model, where intervention is instrumented with the conditional expectation of intervention, generated with estimates of the reaction function. Results suggest that intervention has not influenced the exchange rate level during the sample period, but it had a dampening effect over the daily exchange rate return’s volatility. Since the exchange rate appreciated in response to the expectation of a higher inflation, it seems that markets believed that the central bank would increase interest rates in response to that higher expected inflation, the anticipation of higher yields could be responsible for an immediate appreciation of the spot rate.
Chapter 4

Emigrant Remittances: Both Poverty Relief and Dutch Disease

4.1 Introduction

Emigrant remittances have been growing around the world since 1970, but in the past few years, its growth rate has enlarged significantly. According to Ratha [2006], remittances received by developing countries, estimated using officially recorded data\(^1\), grew up to US$ 167 billion in 2005 (a 73% increase from 2001), continue to grow up to $414 billion in 2013 and it is projected to rise to $540 billion by 2016, The World Bank [2013]. Over the past decade, remittances growth has outpaced private capital flows and official development assistance and they are now nearly three times the size of official development assistance and larger than private debt and portfolio equity flows to developing countries. For some of them, remittances are even larger than total merchandise exports.

This phenomenon has attracted the attention not only of researchers and policy makers, but also of donors, commercial banks, money-transfer operators and microfinance institutions, among others. This widespread interest on remittances should not

\(^1\)The use of officially recorded data tends to underestimate the real magnitude of remittance flows because a substantial portion of these flows is transferred through informal operators or hand carried by travelers (informal channels).
be a surprise, since the topic has many edges and can be seen from very different points of view. Given the magnitude of workers’ remittances and the rising share of foreign income that they represent, we could ask: what are the microeconomic implications or the macroeconomic effects, or even the social consequences of these transfers of wealth? It would be interesting per se, attempt to answer for example, how remittances help in poverty reduction, or what are the social consequences of having disintegrated families (because some members had to emigrate seeking better economic opportunities). In fact, a large portion of the existing literature on remittances has focused on the motivation for these transfers and their microeconomic implications, but it has been largely silent on the macroeconomic effects of these flows, at least in the context of a fully specified general equilibrium model, with only few exceptions, see for instance Acosta et al. [2009]. These authors develop a two-sector DSGE model to analyze the effects of remittances on emerging market economies. Their main finding is that an increase in remittances flow, leads to an increase in consumption of leisure and goods, the latter biased toward non tradables. The higher non tradable prices serve as incentive for an expansion of that sector, culminating in reallocation of labor away from the tradable sector.  

Undoubtedly, international migration can generate substantial welfare gains for migrants and their countries of origin. Several papers find that remittances are associated with lower poverty indicators, high growth rates and a positive impact on economic development, by increasing the level of investment in human and physical capital (Adams Jr and Page [2005], Acosta et al. [2008], Adams Jr and Cuecuecha [2010]). However, when workers’ remittances are considerably large relative to the size of the receiving economy, they may also bring a number of undesired problems. Among others, I am concerned with the idea that large and sustained remittance inflows can cause an appreciation of the real exchange rate and make the production of tradable goods less profitable, a Dutch-Disease-like phenomenon. The idea that transfers can affect the real exchange rate, can be traced back to Keynes [1929] in his treatment of the German transfer problem, and it has been studied recently by Amuedo-Dorantes and Pozo [2004], Lopez et al. [2007], Lartey et al. [2008] and Lartey et al. [2012], in these more recent studies, transfers are considered in the form of workers’ remittances.

\footnote{Also, see Castañeda and Catalán [2008] a for an alternative DSGE model with inelastic labor supply.}
In this paper, I use a dynamic stochastic general equilibrium model of a small open economy to analyze the effect of remittances on resource reallocation and the real exchange rate. I use macroeconomic data from Guatemala, a country where remittances have increased their nominal value in 142.4 percent over the last decade, and their importance as a source of foreign exchange has grown considerably. At the same time, an appreciation of about 45% of the real exchange rate has been observed, parallel to the surge in remittances.

4.1.1 Remittances in Guatemala

In some way, remittances are the economic expression of migration. In Guatemala, according to OIM [2003], the migratory flow began slowly in the 1970’s motivated partially by the effects of the earthquake of 1976. In the 80’s, the number of emigrants was multiplied by four, mainly because of the economic crisis and political violence prevailing at that time. The migratory pattern kept its pace and in the 90’s the number of emigrants was trebled. Between 1995 and 2002, more than 90,000 Guatemalans left the country each year, which in average means approximately 250 people per day. This flow led to an estimate for 2010 of 1.6 million Guatemalans residing abroad, OIM [2013]. The majority of these emigrants chose the United States as a destiny; 98.2 % of remittance senders live in that country.

Remittances are today, the most important single source of foreign exchange in Guatemala, more important than other traditional sources of foreign exchange, like tourism or coffee and sugar exports (the two main export products). They represent the second largest foreign exchange source measured as a share of total foreign exchange, just behind total exports, and more important than net capital flows (FDI included). The flow of worker’s remittances showed a small set back in 2009, most likely due to the financial recession of 2007 (in the US and other advanced economies), but now they seem to be growing at the same rate observed before the crisis. Looking at the flow in terms of a GDP ratio, it is clear that the acceleration of remittances flow has decreased and somewhat stabilized around ten percent of GDP (see Figure 4.1).

From a Microeconomic perspective, worker’s remittances are a well studied phenomenon in Guatemala. Adams [2004] reports four key findings: first, both internal and
international remittances represent important components of household income. Second, both types of remittances reduce the level, depth, and severity of poverty. Third, remittances have a greater impact on reducing the severity rather than the level of poverty in Guatemala. Fourth, his study shows that including remittances in household income has little impact on income inequality, as it remains relatively stable (Gini coefficient \( \approx 0.49 \)). Adams [2005], analyzes how the receipt of remittances affects the marginal spending behavior of households on various consumption and investment goods. Contrary to other studies, he finds that the majority of remittance earnings are not spent on consumption goods. He reports that while households without remittances spend 58.9 percent of their increments to expenditure on consumption goods, households receiving international remittances only spend 55.9 percent. In other words, at the margin, households receiving remittances spend less on consumption than do households without remittances. Adams also finds that the marginal spending behavior of households receiving remittances is qualitatively different from that of households which do not receive remittances. Instead of spending more on consumption, households receiving remittances tend to spend more on investment than on consumption goods. For example, receiving households spend considerably more on education (although absolute levels of expenditure on education are small). Another relevant finding of his work is that his analysis confirms other studies’ findings regarding the amount of remittance money that goes into housing. At the margin, households receiving international remittances spend 2.2 percent more of their income on housing than those households which do not receive remittances.
Additionally, Adams Jr and Cuecuecha [2010] uses a nationally-representative household survey to analyze how the receipt of internal and international remittances affects the marginal spending behavior of households. The authors report two main findings: first, controlling for selection and endogeneity, households receiving international remittances spend less food (at the margin), compared to what they would have spent on this good without remittances. Second, recipients of remittances (both internal and international) spend more at the margin on two investment goods: education and housing, again compared to what they would have spent on these goods without remittances.

All these evidence at the microeconomic level results relevant from the standpoint of this paper, since the surge in remittances could augment the demand for non traded goods (e.g. education and housing) driving up their prices, which in turn modifies the relative price between traded and non traded goods, affecting the real exchange rate.

### 4.1.2 Real Exchange Rate

As aforementioned, the real exchange rate has been appreciating for the last decade coinciding with a surge in remittances, which went from being 3.1% of GDP in 2001 to 9.6% in 2013. The real exchange rate -RER- plays an important role in the economy, its appreciation is usually associated with a loss in external competitiveness, but it also has the potential to generate a number of additional macroeconomic effects, for example: a worsening of the current account deficit, a weaker monetary control and sectorial misallocation of investment among others.

Despite the importance of the real exchange rate in macroeconomics, there is no definition or measurement of the RER that is universally accepted. The real exchange rate has been defined as the nominal exchange rate amended by the external to internal price ratio. This definition corresponds to the idea that variations of the nominal exchange rate lack a precise meaning in a world with inflation, so variations in the value of external and internal currencies (measured by their respective inflation rates) must be taken into account; in this context, some researchers consider the RER as the purchasing power parity exchange rate, Edwards [1990]. Based on this definition, some researchers took movements of the real exchange as deviations from PPP, often thinking of them as reflecting misalignments, rather than equilibrium responses to real shocks. Despite the
fact that the "PPP-RER’ is a very common way to measure the real exchange rate, all
the problems related to the PPP theory are inherited by this measurement of the real
exchange rate.

More recently, the RER has been defined as the relative price between non trad-
able and tradable goods (perhaps nowadays the typical theoretical definition), and it is
proposed as a better indicator of external competitiveness. This definition of the real
exchange rate is not exempt of criticisms. For example, Harberger [2004] argues that
the definition of the RER as the relative price of non tradables \(- \left( \frac{P_N}{P_T} \right) \) – can get us
into trouble when the disturbances in question are changes in the international prices
of particular tradable goods or when we are interested in the consequences of imposing
import tariffs or export taxes.

Nevertheless, for the purposes of the present investigation, the \( \left( \frac{P_N}{P_T} \right) - \text{type} \)
appears to be a sufficient and correct definition of the RER, thus in what follows, this
definition is going to be adopted, unless something else is said explicitly. It is important
to have in mind that, as pointed out by Edwards [1990], variations of both definitions
of the RER can differ, even go in opposite directions.

4.1.2.1 The Equilibrium Real Exchange Rate

It is essential for the sake of clarity, to define what will be considered an Equi-
librium Real Exchange Rate -ERER- in this paper. There are a number of definitions
for the ERER in the literature, here we briefly a few of them and point out an important
distinction between the long run ERER and the RER of equilibrium in the short run.

The first definition comes from the early days of fiat currencies and floating
regimes, at the dusk of the Bretton Woods System. Mundell [1971] provides a for-
mal analysis of the determination of the equilibrium real exchange rate; despite the fact
that he does not explicitly use the RER term in his study, his analysis describes rigor-
ously the determination of the relative price between non tradable and tradable goods,
and defines the ERER as the relative price between international and internal goods
that clears simultaneously the money, the international good, and the internal good
markets. The second one comes from a textbook model: Dornbusch [1980] develops an

\footnote{The two definitions being the "PPP-RER’ and the \( \left( \frac{P_N}{P_T} \right) - \text{type}.\)
open economy model to study how the equilibrium real exchange rate is determined. In the simplest version of his model, he considers an economy with two goods, one tradable and the other non tradable, and he defines the equilibrium real exchange rate as the relative price between these two goods at which all markets clear. The equilibrium real exchange rate has also been defined as the relative price of non traded to traded goods consistent with balance-of-payments equilibrium and the principal equilibrating variable of a country’s trade and payments. Despite the many definitions and concepts of the real exchange rate, in this paper the real exchange rate is viewed essentially as an equilibrating variable, a relative price at which internal and external markets clear, as suggested by Harberger [2004].

By any means this implies that the equilibrium real exchange rate has to be constant, as it needs to respond to different kinds of real disturbances. On the one hand, if we think that in the long run there is enough time to allow all productive inputs to adjust and consequently make them perfectly mobile, then it is reasonable to think that the only real disturbances that matter are those coming from changes in the relative productivity of tradable and non tradable sectors. This is the key insight of the celebrated Balassa-Samuelson Model, in which productivity differentials determine the domestic relative price of non tradables—the real exchange rate. With perfectly mobile and homogenous capital and labor, the relative price of non tradables is governed entirely by the production side of the economy, therefore, the long run equilibrium real exchange rate is probably going to be affected only by productivity disturbances. On the other hand, factor adjustment is a costly and time consuming endeavor in the short run. But we could still think of a particular value of the RER, which reflects an equilibrium situation in the short run, despite the fact it might be misaligned with respect to the long run equilibrium. For example, a temporary income transfer from abroad is going to increase the RER that makes possible an equilibrium between internal and external sectors, but it is going to be misaligned with respect to the long run equilibrium, until the effects of the transfer disappear. Actually in the short run, the equilibrium exchange rate is going to be exposed to a long list of real disturbances, among which we can mention: productivity shifts, import or export restrictions, rises in real prices of export goods, capital inflows and of course, remittances.

Based on previous arguments, I develop a general equilibrium model intended
to characterize the short run equilibrium RER and establish a theoretical relationship between short run equilibrium real exchange rate and remittances and then I compare the predictions of the model with actual data from national accounts. The rest of the paper is organized as follows. Section 4.2 presents a few stylized facts of the Guatemalan economy. Section 4.3 describes the model. Section 4.4 briefly describes calibration. Results are presented in Section 4.5 and Section 4.6 provides some final remarks.

4.2 Guatemalan Economy: Stylized Facts

Most data in section comes from the Guatemalan System of National Accounts—SNA93. This system is a conceptual framework that sets the international statistical standard for the measurement of the market economy. It provides an accounting framework within which economic data can be compiled and presented in a format that is designed for purposes of economic analysis, decision-taking and policy-making. Within the compilation framework, the SNA93 considers a product nomenclature divided into three levels; the first one conformed by 65 groups of products, the second level includes 226 products, and the third level comprises 7,308 products. I took the 226 products from the second level, classified them between tradable and non tradables, and then constructed measurements of production, consumption and investment for both sectors: tradable and non tradable.\(^4\) I also use this data to measure the real exchange rate \((\left( \frac{P_N}{P_T} \right) - type)\), using the ratio between the implicit output deflator of each sector, and compare its variations with those of the aggregate variables.

In absolute terms, aggregate variables (production, consumption and investment) have grown over the past decade (see Figure 4.2). We cannot infer much from these aggregate variables, but if we observe these same variables in terms of the share they represent from total GDP, an interesting story emerges. First, if the observed appreciation was produced by a Balassa-Samuelson effect, we should see a tradable sector expanding (due to productivity differentials) and a non tradable sector contracting in order to release the resources needed in the booming tradable sector; but what we actually observe in national accounts data (not in absolute terms but at least as shares

\(^4\)In order to perform this classification, we used two criteria: first, we classify goods that are extremely costly to transport as non tradables, but because this is not a clear cut division, we used a second criterion: all goods for which their trade-to-production ratio was below 10 percent, were classified as non tradables. “Trade” for each product represents the addition of its imports and exports.
of total GDP) is completely the opposite. The tradable production reduces its participation in total production, while the RER is appreciating. The same pattern can be observed in tradable investment and consumption: as the RER appreciates, investment in tradable sector and tradable consumption reduce their participation in total GDP (see Figure 4.3). In contrast, non tradable production and consumption, increase together with the appreciation of the RER (Non tradable investment appears to be more stable), see Figure 4.4. This changes in the structure of production, suggest that the observed appreciation of the real exchange rate could be explained by changes in demand factors, instead of the traditional ‘supply-side’ determination of the real exchange rate.

4.3 The Model

In this section, I develop a stochastic, dynamic, general equilibrium model, useful to explain the determinants of the real exchange rate. The aim is to study the relationship between the RER and the demand side of the economy; specifically, its relationship with remittances in a fully optimizing model. The model includes adjustment costs for capital and heterogeneous labor, intended to capture an equilibrium exchange rate compatible with the short run conditions. Because of the absence of policy interventions and nominal rigidities (which in the short-run may be important in practice), both the steady state values and the deviations from it, reflect optimal decisions of the economic agents, therefore the dynamics displayed by all variables in the model, are ‘equilibrium
Figure 4.3: National Accounts: Tradable Sector

Figure 4.4: National Accounts: Non Tradable Sector
dynamics’, and I consider the RER that emerges from the model, as the “short-run equilibrium real exchange rate”.

Consider a small open economy that produces two goods, tradables and non tradables. The main difference between these two goods is that the supply of non tradables is determined exclusively by domestic production, while the supply of tradables does not face this constraint, since it is possible to export or import an unbounded quantity of this good. Outputs of both goods are determined by constant returns to scale production functions that employ capital and labor as inputs. Both goods are traded in competitive markets where the respective relative price is determined. The tradable good is used as numeraire. The small open economy assumption, implies that agents can finance its aggregate expenditure not only internally, but also issuing debt at international financial markets, without influencing the international interest rate. We also assume that unanticipated shocks to productivity can occur in both sectors, so the rental price of capital can differ from capital’s marginal product ex post, because it is assumed that capital must be installed one period ahead of its use.

Since I am modeling a real economy, the focus is entirely on the relative price of the non tradable good in terms of the tradable one, not on nominal prices. Government is not taken into account, simply because the scope of the paper does not encompass fiscal issues. I am also assuming that there are no nominal rigidities, and no monetary side of the economy.

Household’s preferences are defined over two consumption goods and over time spent working in both productive sectors. Since I am building a model compatible with short-run conditions, I introduce capital adjustment costs and heterogeneous labor. In this model, labor in tradable sector and labor in non tradable sector, are taken as two different “services” which are compensated with different wages, and therefore, they are not perfect substitutes. There are a number of reasons to believe that heterogeneous labor reallocation is a costly and time consuming process. As pointed out by Gust [1997], labor market imperfections such as the specialized nature of labor, imperfect information in matching workers with jobs, and reallocation costs, all tend to impede the mobility of labor. At least in the short run, labor is not perfectly mobile; modeling it as heterogeneous permits the co-existence of differentiated wages and impedes a fully
compensating reallocation of labor. This allows us to capture (in a simple fashion) the consequences of the fact that in the short run labor does not adjust immediately. Regarding to capital, it is assumed that there are two types, tradable and non tradable, and each one must be produced within the corresponding sector. It is the same capital (same good), but before it can be transferred from one sector to the other, uninstallation and reinstallation costs must be paid. Therefore, the law of motion for the capital stock, in both sectors, will include adjustment costs.\footnote{Without which investment flows appear to be implausibly volatile.}

4.3.1 Households

The economy is inhabited by infinitely lived households, who obtain utility from consumption of a tradable good \(-C_{T,t}\), a non tradable good \(-C_{N,t}\) and disutility from time spent working in two different industries. Households seek to maximize the expected value of their lifetime utility function \(\sum_{t=0}^{\infty} \beta^t U (C_t, h_{N,t}, h_{T,t})\), where \(\beta \in (0,1)\) is the subjective discount factor and \(U (C_t, h_{N,t}, h_{T,t})\) is the utility in period \(t\), defined as:

\[
U (C_t, h_{N,t}, h_{T,t}) = \frac{1}{1-1/\sigma} \left\{ \left[ C_t - \frac{\omega_o}{1+\omega} \left( h_{N,t}^{1+\omega} + h_{T,t}^{1+\omega} \right) \right]^{1-\frac{1}{\sigma}} - 1 \right\}
\]  

(4.1)

Where \(C_t\) is given by

\[
C_t = \left[ a C_{T,t}^\alpha + (1-a) C_{N,t}^\alpha \right]^{\frac{1}{\alpha}}
\]  

(4.2)

Households offer labor services to both sectors; \(h_{T,t}\) are work hours offered to the tradable sector and \(h_{N,t}\) are work hours offered to the non tradable sector. With preferences described by (4.1), labor in one sector is not a perfect substitute for labor in the other one. Work hours in the tradable sector are compensated with a wage \(w_{T}^{t}\), and in the non tradable sector with a wage \(w_{N}^{t}\). They own the stock of capital installed in tradable \(-k_{T,t}\) and non tradable \(-k_{N,t}\) sectors, which they rent at the rates \(r_{T}^{t}\) and \(r_{N}^{t}\) respectively. They receive income transfers from abroad \(-Rem_t\) (remittances) and we introduce them in the model as a share of aggregate output \((Y_t)\) : \(RSH_t = \frac{Rem_t}{Y_t}\) . We assume further that households are able to borrow or lend freely in international financial markets, by buying or issuing risk-free bonds denominated in tradable goods —which pay the interest rate \(i_t\); total foreign liabilities are introduced as a share of
aggregate output \(-f_t\). Because households own the capital, they use some of their resources for capital formation, so we define \(x_{T,t}\) and \(x_{N,t}\) as gross investment in each sector. Finally, \(a, \omega, \) and \(\omega\) are weight parameters, \(\alpha\) determines the intra-temporal elasticity of substitution between tradable and non tradable consumption and \(\sigma\) is the inter-temporal elasticity of substitution.

The budget constraint for households, normalized by \(P^T_t\) (price of the tradable good), can be written as:

\[
C_{T,t} + Q_t \cdot C_{N,t} + (1 + i_t) f_t \cdot Y_t + x_{T,t} + Q_t \cdot x_{N,t} = w_{T,t} k_{T,t} + ... \tag{4.3}
\]

...\(w_{N,t} k_{N,t} + r^T_t k_{T,t} + r^N_t k_{N,t} + f_{t+1} \cdot Y_{t+1} + RSH_t \cdot Y_t\)

where \(Q_t = \frac{P^N_t}{P^T_t}\), is the relative price of non tradables in terms of tradables.

### 4.3.2 Some Definitions and Conventions

Capital stock is formed separately within each sector and there is a sector-specific law of motion for capital:

\[
k_{T,t+1} = (1 - \delta) \cdot k_{T,t} - g_T \left( \frac{x_{T,t}}{k_{T,t}} \right) \cdot k_{T,t} = 0 \tag{4.4}
\]

\[
k_{N,t+1} = (1 - \delta) \cdot k_{N,t} - g_N \left( \frac{x_{N,t}}{k_{N,t}} \right) \cdot k_{N,t} = 0 \tag{4.5}
\]

Where:

\[
g_J \left( \frac{x_{J,t}}{k_{J,t}} \right) = c_2 \left( \frac{x_{J,t}}{k_{J,t}} \right)^2 + c_1 \left( \frac{x_{J,t}}{k_{J,t}} \right) + c_0; \quad J = T, N.
\]

Function \(g_J(\cdot)\) is concave\(^6\) and twice continuously differentiable, it reflects investment adjustment costs in capital. Parameter \(c_2\) is fixed in order to replicate investment’s volatility and parameters \(c_1\) and \(c_0\) are determined by de fact that there are no adjustment costs at the steady state. \(\delta \in (0,1)\) is the depreciation rate of capital that we assume to be equal across sectors.

Households are subject to a “no-ponzi game” constraint of the form:

\(^6\)Since \(c_2\) is negative.
\[
\lim_{j \to \infty} E_t \frac{f_{t+j}}{P_{s=0}^j (1 + i_s)} \leq 0
\] (4.6)

Finally, we assume that the following equation must hold in equilibrium:

\[
i_t = i^*_t + \psi \left( \exp(f_t - \overline{f}) - 1 \right)
\] (4.7)

Where \(i^*_t\) is the international risk-free interest rate, \(\overline{f}\) is the steady state level of net foreign debt position and \(\psi\) is a scale parameter. With this equation we are assuming that international financial markets are incomplete and foreign financing cost is increasing with the net foreign debt position. This can be interpreted as households facing a country specific risk premium.

The households’ problem can be summarized as follow:

\[
\max \left\{ C_{t,T}, C_{N,T}, h_{T,t}, h_{N,t}, x_{T,t}, x_{N,t}, k_{T,t}, k_{N,t}, f_{t+1} \right\}
\]
\[
E_t \left[ \sum_{t=0}^{\infty} \beta^t \cdot \frac{1}{1 - \frac{1}{\sigma}} \left\{ \left[ C_t - \frac{\omega_o}{1 + \omega} \left( h_{N,t}^{1+\omega} + h_{T,t}^{1+\omega} \right) \right]^{1-\frac{1}{\sigma}} - 1 \right\} \right]
\]

Subject to equations: (4.2) - (4.6). Letting \(\lambda_t, \eta_t\) and \(\theta_t\) denote the Lagrange multipliers on (4.3), (4.4) and (4.5) respectively, the first-order conditions of the households’ maximization problem are (4.2) to (4.6) holding with equality and:

\[
\frac{\partial U}{\partial C_{T,t}} = \beta \cdot E_t [\lambda_{t+1}]
\] (4.8)

\[
\frac{\partial U}{\partial C_{N,t}} = \beta \cdot Q_t \cdot E_t [\lambda_{t+1}]
\] (4.9)

\[- \frac{\partial U}{\partial h_{T,t}} = \beta \cdot E_t [\lambda_{t+1}] \cdot w^T_t \] (4.10)

\[- \frac{\partial U}{\partial h_{N,t}} = \beta \cdot E_t [\lambda_{t+1}] \cdot w^N_t \] (4.11)
\[ \eta_t = \beta \cdot E_t \left[ \lambda_{t+1} \cdot r_t^R + \eta_{t+1} \left( g_T + \frac{\partial g_T}{\partial k_{T,t}} \cdot k_{T,t} \right) + \eta_{t+1} (1 - \delta_T) \right] \]  

\[ \theta_t = \beta \cdot E_t \left[ \lambda_{t+1} \cdot r_t^N + \theta_{t+1} \left( g_N + \frac{\partial g_N}{\partial k_{N,t}} \cdot k_{N,t} \right) + \theta_{t+1} (1 - \delta_N) \right] \]  

\[ \lambda_t = \beta \cdot E_t \left[ \lambda_{t+1} \right] \cdot (1 + i_t) \]  

\[ E_t \left[ \lambda_{t+1} \right] = E_t \left[ \eta_{t+1} \right] \cdot \frac{\partial g_T}{\partial k_{T,t}} \cdot k_{T,t} \]  

\[ Q_t \cdot E_t \left[ \lambda_{t+1} \right] = E_t \left[ \theta_{t+1} \right] \cdot \frac{\partial g_N}{\partial k_{N,t}} \cdot k_{N,t} \]

### 4.3.3 Firms

There are two firms that seek to maximize their benefits by choosing optimal levels of labor, given the salary, and optimal levels of capital, given capital’s rental rate. The first firm produces a tradable good and the second a non tradable. Both goods can be used for consumption and investment; one unit of the consumption good can be transformed into a unit of capital at the cost imposed by \( g_J \); \( J = N, T \). In both sectors, firms operate a Cobb-Douglas production function with constant returns to scale.

#### 4.3.3.1 Tradable Sector

There is a single firm that produces a tradable good combining labor and capital in the production function:  
\[ y_t^T = z_t \cdot \left( k_t^T \right)^{\alpha_T} \cdot \left( h_t^T \right)^{1-\alpha_T} \]. Because we are normalizing by the tradables’ price \(-P_t^T\), the problem that the firm solves, period by period, can be presented as:

\[ \max_{\{k_t^T, h_t^T\}} \Pi_t^T = y_t^T - r_t^T \cdot k_t^T - w_t^T \cdot h_t^T \]

Where \( z_t \) is a stochastic productivity factor. \( \alpha_T \in (0,1) \) is a constant parameter that determines capital’s participation within the production function. We can write
firm’s first-order conditions for capital and labor, respectively, as

\[ r_t^T = \alpha^T \cdot z_t \cdot \left( k_t^T \right)^{\alpha^T - 1} \left( h_t^T \right)^{1 - \alpha^T} \]  

(4.17)

\[ w_t^T = \left( 1 - \alpha^T \right) \cdot z_t \cdot \left( k_t^T \right)^{\alpha^T} \left( h_t^T \right)^{-\alpha^T} \]  

(4.18)

4.3.3.2 Non tradable Sector

There is a single firm that also uses capital and labor as inputs to produce a non tradable good. It has access to the technology described by a Cobb-Douglas production function of the form: \( y_t^N = A_t \cdot \left( k_t^N \right)^{\alpha^N} \cdot \left( h_t^N \right)^{1 - \alpha^N} \). It sells its output at a price \( P_t^N \), so the problem that the firm solves in every period is given by,

\[
\max \{ k_t^N, h_t^N \} \Pi_t^N = Q_t \cdot y_t^N - r_t^N \cdot k_t^N - w_t^N \cdot h_t^N
\]

where \( A_t \) is a stochastic productivity factor. \( \alpha^N \in (0, 1) \) is the parameter that determines the participation of capital and labor respectively within the production function. We can write firm’s first-order conditions for capital and labor, respectively, as

\[ r_t^N = Q_t \cdot \alpha^N \cdot A_t \cdot \left( k_t^N \right)^{\alpha^N - 1} \left( h_t^N \right)^{1 - \alpha^N} \]  

(4.19)

\[ w_t^N = Q_t \cdot \left( 1 - \alpha^N \right) \cdot A_t \cdot \left( k_t^N \right)^{\alpha^N} \left( h_t^N \right)^{-\alpha^N} \]  

(4.20)

Where \( Q_t = \frac{P_t^N}{P_t^T} \), as before.

4.3.4 Exogenous Stochastic Processes

We model three sources of uncertainty: The first two are productivity shocks in each sector, tradable and non tradable, the third one is a stochastic process for foreign transfers. As usual, we assume that all shocks follow an autoregressive process of order one.

\[ z_{t+1} = (1 - \rho_z) \cdot z_{t+1} + \rho_z \cdot z_t + \varepsilon_{t+1} \]  

(4.21)
\[ A_{t+1} = (1 - \rho_A) \cdot A_{ee} + \rho_A \cdot A_t + \varepsilon_{t+1}^A \]  \hspace{1cm} (4.22)

\[ RSH_{t+1} = (1 - \rho_R) \cdot RSH_{ee} + \rho_R \cdot RSH_t + \varepsilon_{t+1}^R \]  \hspace{1cm} (4.23)

Where \( \rho_j \in (0, 1) \) for \( j = z, A, R \). We assume:

\[ \varepsilon_t^j \sim N \left( 0, \sigma_{\varepsilon_j}^2 \right) \]

i.e. all random shocks are white noise.

### 4.3.5 Market Clearing

In equilibrium, all markets must clear. For capital and labor markets this means:

\[ K_{T,t}^T = k_{T,t}^T = k_{T,t}; \forall t \]  \hspace{1cm} (4.24)

\[ K_{N,t}^N = k_{N,t}^N = k_{N,t}; \forall t \]  \hspace{1cm} (4.25)

\[ H_{T,t}^T = h_{T,t}^T = h_{T,t}; \forall t \]  \hspace{1cm} (4.26)

\[ H_{N,t}^N = h_{N,t}^N = h_{N,t}; \forall t \]  \hspace{1cm} (4.27)

The clearing condition for the non tradable’s market is easy to define, because it is constrained by domestic production,

\[ C_{N,t} + x_{N,t} = y_{t}^N; \forall t \]  \hspace{1cm} (4.28)

The tradable sector does not face this constraint, so in equilibrium, it must be true that:

\[ C_{T,t} + (1 + i_t) f_t \cdot Y_t + x_{T,t} = y_{t}^T + f_{t+1} \cdot Y_{t+1} + RSH_t \cdot Y_t; \forall t \]  \hspace{1cm} (4.29)

With this market clearing conditions, the exogenous stochastic processes and the
optimal conditions described before for each agent in the economy, we fully characterize
the artificial economy.

4.4 Calibration

The parameter values are set, so that the behavior of the model economy matches the features of some measurements taken from the Guatemalan economy, in as many dimensions as there are unknown parameters (see Table 4.1). Some of the parameters are of common use in the literature and some others deserve a more detailed explanation (which can be found on Appendix B.1). To perform this calibration, I use information from national accounts, the national survey of income and expenditure of households –ENIGFAM\(^7\), and the national survey of income and employment –ENEI.\(^8\)

<table>
<thead>
<tr>
<th>Parameter values</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i^*)</td>
</tr>
<tr>
<td>0.00735</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>(\text{Remee})</th>
<th>(\text{Remee2})</th>
<th>(\rho_R)</th>
<th>(\sigma_{\rho_R})</th>
<th>(\psi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.02595</td>
<td>0.1025</td>
<td>0.8914</td>
<td>0.1782</td>
<td>0.00081</td>
</tr>
</tbody>
</table>

4.5 Model Results

4.5.1 Impulse Response: Shock to Remittances-to-Income Ratio

The response of the model to a transitory (yet persistent) remittances-to-income ratio shock, can be described as follows: when \(RSH_t\) increases, an appreciation of the equilibrium real exchange rate is observed on impact (see Figure 4.5).\(^9\) The enlarged flow of remittances provides households with additional disposable income, which they spread across the two consumption goods, investment in both sectors and leisure. Despite the work hours devoted to non tradable sector show an increase of about 2%, work hours in tradable sector decrease more than 4%, which results in less aggregate work hours

\(^7\)By its acronyms in Spanish.

\(^8\)Idem.

\(^9\)A 7.7 standard deviations shock is needed to generate an increase of 308 percent in the remittances-to-income ratio. This corresponds to the observed shift in the remittances-to-income ratio; from 2.5% to the current observed value of about 10.2%. 

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(since households became richer, they consume more leisure). Additionally, the ‘gift’ received by households allows them to increase tradable consumption and investment in that sector simultaneously, since the transfer is received in tradable goods. In the case of non tradable consumption, they have to save for about three quarters to finance the investment in the non tradable sector, that makes possible a higher non tradable consumption in the coming years. The economy accumulates net foreign assets, which in turn, drive down the risk premium of the interest rate. The flow of remittances also affect production of both goods; non tradable production increases contemporaneously with the shock (almost 2% over its steady state value), while tradable production decreases for about seven quarters after the shock, and then overshoots its steady state value (before converging).

It is interesting to notice that after the shock, an equilibrium real exchange rate appreciation of about 9% is observed, but only on impact, the path followed by the RER after the shock is a depreciation path, totally different to the appreciation observed year after year since 2001. This depreciation “story” emerges even when the model includes quadratic investment costs and heterogeneous labor, no matter how big or small the shock is, when it is transitory, we observe a contemporaneous appreciation and then a story of depreciation until the RER converges to its steady state.

4.5.2 Permanent Increase in Remittances-to-Income Ratio

In this subsection, a permanent change in the remittances-to-income ratio is simulated. I want to explore the consequences for the equilibrium real exchange rate, stemming from a change in the level of remittances-to-income ratio that prevailed before 2001 (2.595%), to the current level of remittances-to-income ratio (about 10%). As mentioned before, the flow of remittances as a GDP ratio, has decreased its growth rate and seems to be stabilizing somewhat around ten percent (see right panel of Figure 4.1). Despite there is no enough data to conclude that the flow of remittances will indeed stabilize around ten percent, from the perspective of the present investigation, it is of no use trying to guess if remittances are going to keep growing or if they will stabilize in one or another value. The scope of this investigation limits to study whether the observed surge in remittances can cause an appreciation of the equilibrium real exchange rate, and what are the potential consequences over allocation of productive factors.
Figure 4.5: Remittances-to-GDP Ratio: Transitory shock
Figure 4.6: Remittances-to-GDP ratio: Permanent shock
The transition of model’s variables are depicted in Figure 4.6. The red dashed line represents the original value for remittances-to-GDP ratio (about 2.5%); the blue solid line represents the current level of the same ratio (about 10%) and the black dotted line are transition dynamics. Notice that when a permanent change in the remittances-to-income ratio is simulated, we do not only observe an initial appreciation of the short run ERER, but also an “appreciation story” after that. In other words, the dynamics followed by the ERER show an appreciation for several quarters, as the one that we have witnessed in the Guatemalan economy. This result suggests that the economic agents in Guatemala perceive the change in the remittances-to-income ratio as permanent.

The model predicts that both consumptions should be higher at the new level of remittances-to-GDP ratio. Tradable consumption appears to be about 17% higher, while non tradable consumption is only about 8% percent higher. Also, less tradable capital is used, as a 12% reduction is observed (there is less need to invest in tradables, since they are being received in the form of remittances). On the contrary, non tradable capital is 8% higher with the new level of remittances, but it converges slowly. Labor hours behave as expected. On the one hand, because households receive an increased endowment of the tradable good in the form of a foreign transfer, they do not need to produce large amounts of this good and they devote less hours to this sector. On the other hand, non tradable consumption is constrained by domestic production, so the only way in which households can increase their non tradable consumption, is that the economy produces more non tradable good, for which they increase work hours (and capital) in the non tradable sector. Regarding production, we observe that non tradable output increases more than 8% with respect to its original state, while tradable productions decreases, about 13%. In the whole process, the economy accumulates foreign liabilities.

The most important fact that the model is supposed to mimic, is the appreciation story of the RER that has been observed during the last decade. But also, the resulting resource allocation can help us to establish if the observed RER appreciation was somewhat generated or caused by the surge in emigrant remittances. Figure 4.6 shows that when we simulate the shift in the remittances-to-income ratio as permanent, the model generates a persistent ERER appreciation that runs for 44 quarters and reaches an appreciation of 6%. With this quarterly ERER generated by the model, an annual
index is calculated and then compared with the $\left( \frac{P_N}{P_T} \right) - type$ RER index obtained from the SNA93. As shown on Figure 4.7, the model generates an appreciation of the short-run ERER of 6% percent which is weaker than the observed RER appreciation (24%).

The model also generates a contraction in tradable sector similar to that observed in the national accounts. According to the model, tradable production reduces its share of total GDP in 13.1 percent, going from 32.3% (of total GDP) in the first year to 28.1% in the eleventh, while in national accounts, tradable production reduces its share in 12.6 percent (going from 36% in 2001 to 31% in 2011, see Figure 4.8). On the contrary, non tradable production has increased its participation in total GDP in 6.7% from 2001 to 2011 according to national accounts data; the model replicates this fact very well. On Figure 4.9 we can see that non tradable production generated by the model rises from 68.2% to 71.9%, accounting for an increase of 5.5% percent. Regarding to non tradable investment (as share of total GDP), it appears to be stable in national accounts data, as well as in the model; in the case of investment in tradable sector, it has decreased about 32.4% in national accounts, going from 10.6 to 7.2 percent of GDP, while in the model, it rises from about 2% to 6% (see appendix, Figure C.1). Tradable consumption in national accounts represents a 35% of GDP on average for the 2001-2011 period, it has decrease an 11.7 percent during those years. Meanwhile, the model generates a

![Figure 4.7: Equilibrium Real Exchange Rate](image)
tradable consumption with an average of about 32 percent of GDP, but it appears to be more stable. Finally, non tradable consumption seems to increase as a share of total GDP in both, the national accounts and the model. It represents 57% of total GDP in national accounts and 58% of total output in the model, both averages correspond to an eleven-year period (see appendix, Figure C.2).

4.6 Final Remarks

Motivated by the observed increased in remittances flow and the parallel appreciation of the real exchange rate, this paper explores the consequences for the equilibrium real exchange rate and resource allocation. It began trying to characterize some aspects of the Guatemalan economy, making some interesting discoveries. The first one is that tradable production (as total output share) has been contracting during a period in which the remittances flow has enlarged and the real exchange rate has been ap-
preciating, years 2001-2011. Also non tradable production (as total output share) has been expanding during the same period and under the same conditions (an increase in remittances flow and RER appreciation). These findings are very suggestive that the observed real exchange rate appreciation was influenced primarily by demand factors. Let us consider one of the most common determinants of the real exchange rate that can be found in the literature: differential technological process. One of the basic predictions of the Balassa-Samuelson model is that productivity differentials determine the domestic relative price of non tradables; movements of the relative price of non tradables reflect divergent trends of productivity between tradable and non tradable productions. Now, suppose that the observed appreciation in Guatemala arises from a Balassa-Samuelson effect, let’s say, from higher productivity in the tradable sector. Then we should observe an expanding tradable sector seizing the greater productivity and a non tradable sector experiencing a contraction. But what we actually observe is totally the opposite, an expansion in non tradable sector and a contraction in tradable sector. This behavior (of tradable and non tradable productions) is better associated with the argument that a positive transfer of resources to a country hurts its competitiveness in world markets; the reduction of tradable sector takes place because the transfer appreciates the country’s real exchange rate.

The model developed in this paper generates an appreciation path for the real exchange rate, a tradable sector contraction, and a non tradable sector expansion, similar to those that are observed in national accounts data. These results highlight the possibility of emigrant remittances appreciating the real exchange rate and, hence, reducing Guatemala’s competitiveness in world markets. The model provides an analytic framework within which this can occur, where capital adjustment costs and heterogeneous labor play a predominant role in mimicking the dynamics of the observed real exchange rate. In addition, the model implies that in a world of rational and optimizing agents, the observed dynamics of the real exchange rate can be replicated only when the increment in remittances is modeled as permanent; this result suggests that in Guatemala, economic agents are perceiving the observed shift in the remittances flow as permanent.

It is important to notice, that despite the appreciation generated by the model (6%) is weaker than the observed RER appreciation (24%) in national accounts, the 6% is an appreciation of the short-run equilibrium real exchange rate, and therefore,
economic policies directed to reduce such appreciation would be ineffective and could result merely in a loss of resources. The difference also might well be explained by fundamental determinants on the equilibrium real exchange rate not modeled here, since the purpose of the this particular model, is to determine whether a shock affecting aggregate demand (as remittances) could explain the appreciation of the ERER, which traditionally is explained through the supply side of the economy.

This is important, since not all of the observed appreciation can be related to transitory factors or temporary overvaluations that impose higher costs to the tradable sector. Despite that an overvaluation of this latter kind might be subject to policy intervention, policy actions should be considered carefully even in that case. The first course of action in which one could think of is sterilization, but if sterilizing operations are required on a sustained basis, they may prove unfeasible, mainly because the unsustainable quasi-fiscal costs that these operations could imply when remittances are considerably large. Other government interventions, like efforts aimed at making domestic markets more efficient and more flexible (specially productive factor markets), could ease exchange rate pressures without imposing other macroeconomic costs.

It is essential to keep in mind that policy makers will have to accept some real exchange rate appreciation, because of the substantial and sustained nature of remittances flows in Guatemala. It is also important to better understand the different impacts of remittances over the receiving economy, in order to formulate economic policies that take full advantage of these transfers of wealth and enhance its development prospects.
Appendix A

Chapter 2

A.1 Impulse responses for all variables

A.1.1 Demand shock

![Graphs showing impulse responses for demand shock]
A.1.2 Productivity Shock
A.1.3 Country premium shock
A.2 Simulation: Random disturbance in each period

So far, the dynamic responses analyzed were those coming from a single realization of the exogenous shocks. In order to see if the results hold for any realization of the random disturbance, a simulation involving a 2000-period run was conducted for each type of shock, reaching to the same conclusions: according to the model, central-bank intervention in the forex market can in principle be a highly effective tool for macroeconomic stabilization. In particular, it can be used to decrease inflation volatility at least when shocks affecting the economy are supply shocks.

The simulation exercise was done by generating artificial inflation series by hitting the economy in every period with a random disturbance for each of the three exogenous shocks (technology, demand and borrowing premium). After getting the simulated inflation series (generated by each of the exogenous shocks), the standard deviation was computed for the last 400 periods of each inflation series. On the top row of Figure A.1, it can be observed how the standard deviation of inflation series is lower (about 35%)
Top row shows the standard deviation of inflation generated by each type of shock and bottom row, shows simulated inflation series for each type of shock for both: Intervention and No-Intervention cases.

Figure A.1: Inflation Volatility

when the central bank follows a hybrid policy and intervenes in the forex market, than when it follows a pure IT-policy. The converse is true for the other two shocks; when the economy experiences demand shocks or shocks to the foreign borrowing premium, intervening in the forex market exacerbates inflation volatility.

The bottom row of Figure A.1 shows the simulated inflation series for both, the Intervention and No-Intervention policies. It can be observed that for supply shocks, the discontinuous line (inflation in the No-Intervention case) serves as an upper bound for the continuous one (inflation in the Intervention case). Again, the converse is true for the other two shocks, were deviations from steady-state inflation appear to be larger under the Intervention policy, and therefore the continuous line serves as the upper bound, enclosing the inflation series generated under the No-Intervention policy.
A.3 Sensitivity Analysis

A.3.1 Sensitivity to the International reserves adjustment coefficient:

This parameter ($\omega_s$) determines how aggressively the central bank will intervene in the forex market, when confronted with any given discrepancy between the market exchange rate and operational exchange rate target, (the exchange rate ‘desired’ by the central bank).

A.3.2 Sensitivity to the Inflation coefficient in operational exchange rate target:

The parameter $\gamma_s$ links the operational target for the exchange rate $-\bar{S}_t$ with the objective of central bank (inflation). The relationship is characterized by $\partial\bar{S}_t/\partial\pi_t = -\gamma_s$. 

Figure A.2: Model dynamics after a technology shock for different values of $\omega_s$. 

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ergo, the monetary authority confronted with a higher inflation, will desire a more appreciated level for the exchange rate, and therefore it will set a higher value for $\bar{S}_t$ through eq.(2.2). But whether this higher operational target translates into intervention, will still depend on the intervention rule (eq.(2.3) and parameter $\omega_s$).
Appendix B

Chapter 3

B.1 Nomenclature & Alternative specifications for the GARCH model

This appendix contains three tables, the first one describing the variables used in the estimation process and the other two contain alternative specifications for the GARCH model. Results for these alternative estimations of the GARCH model are separated into a mean and a variance equations for space management purposes.
Table B.1: Variable Nomenclature

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta \ln S_{t-1}$</td>
<td>Daily return of the nominal exchange rate vis-à-vis the US dollar, calculated by the logarithmic difference in opening prices between $t$ and $t-1$.</td>
</tr>
<tr>
<td>$i_t^e$</td>
<td>Seven-day repo-rate, US dollar denominated instruments, interbank market.</td>
</tr>
<tr>
<td>ln $S_{t-1} - \ln S_{t-1}^{20}$</td>
<td>Log-deviation of the exchange rate from a twenty-day moving average of nominal exchange rates.</td>
</tr>
<tr>
<td>$ffr_t$</td>
<td>US Federal funds rate, annual percent.</td>
</tr>
<tr>
<td>$i_t$</td>
<td>Seven-day repo-rate, domestic currency denominated instruments in the interbank market.</td>
</tr>
<tr>
<td>Policy Rate ($i_t^p$)</td>
<td>The 7-day interest rate set by the Monetary Board.</td>
</tr>
<tr>
<td>Exp. Inflation ($\pi^e$)</td>
<td>Expected inflation rate, reported monthly in the central bank’s Survey of Economic Expectations.</td>
</tr>
<tr>
<td>$I_t$</td>
<td>Intervention ( Millions of US$ ). Purchase = positive; Sales = negative.</td>
</tr>
<tr>
<td>$News_t$</td>
<td>Difference between the announced level of monthly inflation and market’s expectations of that announcement, computed the day in which inflation data is released.</td>
</tr>
<tr>
<td>$I_t^*$</td>
<td>Latent variable, measuring the necessity for intervention.</td>
</tr>
<tr>
<td>$\hat{I}_t$</td>
<td>Instrumented level of central bank’s intervention, eq. (3.5), which is given by the conditional expectation of intervention $E[I_t</td>
</tr>
<tr>
<td>$\theta_1, \theta_2$</td>
<td>Thresholds in the friction model.</td>
</tr>
<tr>
<td>$\phi$</td>
<td>Standard normal density function.</td>
</tr>
<tr>
<td>$\Phi$</td>
<td>Standard normal cumulative distribution.</td>
</tr>
</tbody>
</table>

Table B.2: Alternative GARCH: Mean Equation

<table>
<thead>
<tr>
<th>Mean Equation</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dep. variable</td>
<td>0.422***</td>
<td>0.441***</td>
<td>0.439***</td>
<td>0.421***</td>
<td>0.417***</td>
<td>0.420***</td>
</tr>
<tr>
<td>Interventions</td>
<td>0.006</td>
<td>0.010</td>
<td>0.010</td>
<td>0.006</td>
<td>0.005</td>
<td>0.006</td>
</tr>
<tr>
<td>Repo: ($i - i^*$)$_{t-1}$</td>
<td>0.003***</td>
<td>0.003***</td>
<td>0.003**</td>
<td>0.003***</td>
<td>0.003***</td>
<td>0.003***</td>
</tr>
<tr>
<td>E[Inflation]</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
<td>-0.002***</td>
</tr>
<tr>
<td>News</td>
<td>0.023</td>
<td>0.023</td>
<td>0.022</td>
<td>0.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Policy Rate</td>
<td>0.0006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Asterisks denote significance of coefficients, with *** , ** and * indicating significance at the 1%, 5% and 10% level, respectively.
- Robust standard errors reported in parenthesis.
Table B.3: Alternative GARCH: Variance Equation

<table>
<thead>
<tr>
<th>Variance Equation</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
<th>(6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garch term $(\delta_1)$</td>
<td>0.910***</td>
<td>0.909***</td>
<td>0.910***</td>
<td>0.911***</td>
<td>0.907***</td>
<td>0.915***</td>
</tr>
<tr>
<td></td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.017)</td>
<td>(0.016)</td>
<td>(0.017)</td>
<td>(0.016)</td>
</tr>
<tr>
<td>Arch term 1st lag $(\delta_2)$</td>
<td>0.237***</td>
<td>0.241***</td>
<td>0.242***</td>
<td>0.234***</td>
<td>0.233***</td>
<td>0.262***</td>
</tr>
<tr>
<td></td>
<td>(0.042)</td>
<td>(0.042)</td>
<td>(0.042)</td>
<td>(0.042)</td>
<td>(0.043)</td>
<td>(0.045)</td>
</tr>
<tr>
<td>Arch term 2nd lag $(\delta_3)$</td>
<td>−0.170***</td>
<td>−0.173***</td>
<td>−0.175***</td>
<td>−0.167***</td>
<td>−0.170***</td>
<td>−0.190***</td>
</tr>
<tr>
<td></td>
<td>(0.040)</td>
<td>(0.040)</td>
<td>(0.040)</td>
<td>(0.039)</td>
<td>(0.040)</td>
<td>(0.043)</td>
</tr>
</tbody>
</table>
| Interventions $(\delta_4)$ | 0.250*** | 0.249*** | 0.249*** | 0.249*** | 0.257*** | −0.111*
|                   | (0.039) | (0.040) | (0.040) | (0.038) | (0.032) | (0.067) |
| Expected Inflation $(\delta_5)$ | 0.229*** | 0.232*** | 0.233*** | 0.233*** | 0.183*** | 0.173*
|                   | (0.074) | (0.074) | (0.075) | (0.075) | (0.062) | (0.102) |
| Federal funds rate $(\delta_6)$ | −0.846** | −0.860** | −0.861** | −0.861** | −0.956*** | |
|                   | (0.387) | (0.391) | (0.392) | (0.392) | (0.349) | |
| $\text{News}_t$  | 1.851   | 1.295   | −1.554  |         |         |         |
|                   | (1.246) | (1.374) | (1.241) |         |         |         |
| Policy Rate $(\delta_7)$ | 0.297   | −0.320  |         |         |         |         |
|                   | (0.195) | (0.450) |         |         |         |         |

* Asterisks denote significance of coefficients, with ***, ** and * indicating significance at the 1%, 5% and 10% level, respectively.

- Robust standard errors reported in parenthesis.
Appendix C

Chapter 4

C.1 Figures

Figure C.1: Investment
C.2 Calibration

The utility function per period is a CES function that includes a consumption aggregator $C_t$ and parameters that measure the tradable and non-tradable consumption shares inside the utility function ($0 < \alpha < 1$) and the degree of substitutability ($\frac{1}{1-\alpha}$) between these two consumptions. ($\alpha$) is the substitution parameter, which helps to derive the intra-temporal elasticity of substitution. To estimate this parameter by econometric methods, it would be necessary to have long enough series of tradable and non-tradable consumption, which is not available for Guatemala. Because of this limitation, we search estimates for other economies to adopt a reference value and then perform some sensitivity analysis. Gonzalez-Rozada and Neumeyer [2003] estimate an elasticity of substitution in consumption between tradables and nontradables for Argentina, ranging from 0.40 to 0.48 using econometric techniques. This elasticity of substitution implies $\alpha \approx -1.22$. In estimating the tradable and non-tradable consumption shares ($a$) and $(1-a)$, I took the first order conditions for consumption, equations: (4.8) and (4.9) in steady state to show that this parameter was a function of consumption, parameter
and the real exchange rate. Using data from the -SNA93- for consumption and the real exchange rate, I found a value of $a = 0.3328$. The risk aversion coefficient of utility function is $\frac{1}{\sigma} = 4.347$, which implies an inter-temporal elasticity of substitution of $\sigma = 0.23$ that is consistent with the literature for developing economies. The parameter $\omega$ is set to unity and $\omega_0$ is calibrated to obtain $H_T + H_N = 1$ in steady state.

Because the production functions are Cobb-Douglas (in both sectors) and they exhibit constant returns to scale, each input is paid its marginal product. In this case, the parameter $(1 - \alpha^j)$ is referred to as the labor’s share and $\alpha^j$ is the capital’s share (both in sector $j$), because they will earn that fraction of output. These parameters are of common use in the literature so we take the values used for the Colombian\(^1\) economy: $\left(1 - \alpha^T\right) = 0.6651$. Which implies a participation of capital in the production function of: $\alpha^T = 0.3349$. Also, for the non tradable sector we use a labor’s share of $\left(1 - \alpha^N\right) = 0.7088$. Which in turn, implies a participation of capital of: $\alpha^N = 0.2912$. The steady state level of net foreign asset position $-f^\top$ is calibrated in such a way that the model imitates the ratio of trade balance-to-output of Guatemalan data (16.74\%). We set the scale parameter of the risk premium in a value that allows the model to exhibit the same variability of the trade balance-to-output ratio that is observed in the Guatemalan economy, this is $\psi = 0.00081$. Capital’s quarterly depreciation rate is set to 0.012 which is equivalent to an annual depreciation rate of 0.048.

The subjective discount factor is determined by eq.(4.14) in steady state, it’s easy to see from that equation that $\beta$ is a function of the international risk-free interest rate: $\frac{1}{1 + i^*}$. I took the average of annual return’s rate of the 3-month US Treasury bill for the past 6 years (2.9391\%), and then calculate a quarterly equivalent rate, to get $i^* = 0.0073$; with this international risk-free quarterly interest rate, we get $\beta = 0.9927$. For the steady state value of remittances to income ratio -$RHSee$-, I took quarterly data and estimate remittances to GDP ratio for the period 1995 - 2001; the mean level of this ratio appears to be 2.595\%, so $RHSee = 0.02595$. The evolution of remittances in recent years has led this ratio to 10.2287\% for 2006 (using estimated data for GDP). Finally, I estimated the remittances shock persistence ($\rho_R$) using logarithmic deviations from the steady state (instead of the plain variable) to be in consonance with the model, where

\[\text{See Hammam and Rodriguez [2006]. I did not calibrate this parameters with Guatemalan data because in order to find labor and capital shares for each sector, we need information of the input-output matrix of national accounts and by the time we calibrate our model this matrix was not available.}\]
variables are transformed in this way and then performed a regression. In this way I get
estimators $\hat{\rho}_R$ and $\hat{\sigma}_R$, that are used as the values of parameters $\rho_R = 0.891437$ and
$\sigma_R = 0.178223$ respectively.

C.2.1 Participation of tradable consumption $C_{T,t}$ and non-tradable consumption $C_{N,t}$ in the utility function of households: ($a$)

From households’ first-order conditions, we take equations (4.9) and (4.9) in steady state, and combining them we get:

$$
\left( \frac{C_{T,ee}}{C_{N,ee}} \right)^{\alpha - 1} \cdot \frac{a}{1 - a} = \frac{1}{Q_{ee}}
$$

(C.1)

From this relationship, we can find the value of parameter $a$ that is consistent with the model. Adding up the final consumption expenditure in both sectors and taking averages to obtain the relationship: $\left( \frac{C_{T,ee}}{C_{N,ee}} \right)$. For $Q_t = \left( \frac{P_N}{P_T} \right)$, I use the implicit output deflator of tradable and non-tradable sectors obtained from national accounts. Then, using equation (C.1) we can solve for $a = 0.3328$.

C.2.2 Steady state value of net foreign asset position: ($fee$)

In order to understand the calibration of this parameter, it’s important to have in mind the foreign asset accumulation view of the current account. Under this view, as presented by Obstfeld et al. [1996], the current account balance over a period is the change in the stock of its net claims on the rest of the world; the change in its net foreign assets. With this in mind, we can calibrate the steady state value of debt in our model. First we take the definition of trade balance of the model and the equation that governs the accumulation of external debt inside the model, eq.(4.29):

$$
TB_t = y_t^T - C_{T,t} - x_{T,t}
$$

(C.2)

$$
C_{T,t} + (1 + i_t) f_t \cdot Y_t + x_{T,t} = y_t^T + f_{t+1} \cdot Y_{t+1} + RSH_t \cdot Y_t;
$$

(C.3)
Taking (C.3) in steady state:

\[ C_{T,ee} + (1 + i_{ee}) f_{ee} \cdot Y_{ee} + x_{T,ee} = y_{ee}^T + f_{ee} \cdot Y_{ee} + RSH_{ee} \cdot Y_{ee}; \]  

(C.4)

and rearranging we get,

\[ i_{ee} f_{ee} = \frac{y_{ee}^T - C_{T,ee} - x_{T,ee}}{Y_{ee}} + RSH_{ee}; \]  

(C.5)

So, we would have a debt-to-GDP ratio:

\[ i_{ee} f_{ee} = \left( \frac{TB_t}{Y_t} \right) + RSH_{ee} \]  

(C.6)

C.2.3 Steady state value of remittances: \((Remee)\)

For the steady state value of remittances, I took quarterly data and estimated the remittances to GDP ratio for the period 1995 - 2001. In this period, the ratio appears to be stationary, as suggested by Figure C.3.
Also the stationarity of this ratio is confirmed by a Dickey-Fuller Test, which rejected at a 5% significance level the null hypothesis that remittance to GDP ratio had a unit root. The mean level of this ratio appear to be 2.595%, so we set the steady state level of remittances to $\text{Rem}_0 = 0.02595$. The evolution of remittances in recent years can be interpreted as a transition to a higher steady state value of remittances flow, so we use the new level of the remittance-to-GDP ratio (10.2%) as a new steady state value, $\text{Rem}_{02} = 0.10259$.

### C.2.4 International risk-free interest rate: ($i^*$)

I take the 3-month US Treasury bill as the risk-less asset, and its returns as proxy for the international risk-free interest rate. Therefore, I took the average for the annual rate of return of the past 6 years (2.9391%) , and then calculate a quarterly equivalent rate, to get $i^* = 0.0073$. 

Figure C.3: Steady state of remittances as share of GDP
C.2.5 Subjective discount factor ($\beta$):

The subjective discount factor is determined by eq.(4.14) in steady state, it’s easy to see from that equation that:

$$\beta = \frac{1}{1 + i^*}$$ \hspace{1cm} (C.7)

With an international risk-free quarterly interest rate of 0.0073, we have that $\beta = 0.9927$.

C.2.6 Remittances shock persistence ($\rho_R$):

I took quarterly data of remittances $-Rem_t-$ and estimate by OLS:

$$\log \left( \frac{Rem_t}{Remee} \right) = \rho_R \cdot \log \left( \frac{Rem_{t-1}}{Remee} \right) + \varepsilon^R_t$$ \hspace{1cm} (C.8)

Using logarithmic deviations from the steady state instead of the plain variable, to be in consonance with the model where variables are transformed in this way. Form the regression, we obtain the estimators $\hat{\rho}_R$ and $\hat{\sigma}_{\varepsilon_R}$, that are used as the values of parameters $\rho_R$ and $\sigma_{\varepsilon_R}$ respectively. From this procedure, I found that $\rho_R = 0.891437$ and $\sigma_{\varepsilon_R} = 0.178223$. 

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