

ESSAYS ON MONETARY POLICY IN OPEN ECONOMIES

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ABSTRACT

EZEQUIEL R. CABEZON: ESSAYS ON MONETARY POLICY IN OPEN ECONOMIES.

(Under the direction of Richard Froyen.)

This dissertation studies whether monetary policy has short run effects on output in emerging economies and characterizes the mechanisms of transmission of the monetary policy. Specifically it focuses on the real effects of the monetary policy in Brazil, where policymakers introduced structural reforms earlier than other emerging economies. Chapter I identifies the effects of monetary policy in Brazil using a vector autoregressive model. It finds that monetary policy has short run effects on output and nearly none on prices. This contrasts with the policy wisdom that monetary policy in EMEs can only affect prices. Chapter II, studies the interest rate channel of monetary policy in Brazil. It finds that surprise changes in the monetary policy interest rates have larger effects on the market interest rate during expansions than in recessions. This is attributed to the larger expected duration of expansion over recessions. Chapter III, uses a Dynamic Stochastic General Equilibrium model to study the effects of monetary policy when firms borrow to finance their working capital in an open economy. This issue is crucial in cases like Brazil where working capital credit explains half of the firms' borrowing and it quadrupled in the last 15 years. A monetary policy tightening has two effects: i) It discourages consumption (the traditional demand channel) and ii) It increases the production cost (known as the working capital channel). The final effect on inflation is unclear as these effects work in opposite directions. The model concludes that in an open economy where there is working capital borrowing, the aggregate demand channel dominates the working capital channel. This is due to the strong response of consumption to the exchange rate.

To my wife, Elizabeth Thomasson, and our families.

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Chapter 1

Does Monetary Policy Have Real Effects? The Brazilian Case

1.1 Introduction

This chapter's goal is to measure the effect of monetary policy in Brazil for the period 2000 to 2012. Specifically, it intends to document if monetary policy has a real effect on output. There is no clear consensus about the size of these effects across different countries. In addition the evidence about the effects of monetary policy across different industries is limited.

This question can be translated in theoretical terms as determining if a New Keynesian (NK) model or a Real Business Cycle (RBC) better fits the Brazilian economy movements. A New Keynesian model predicts that after a monetary policy tightening output will decrease as a result of price stickiness and prices will reduce with less intensity. Meanwhile, a Real Business Cycle model predicts no real effect on output and negative effects on prices. In fact, NK predicts stronger effects on output and weaker effects on prices, while the RBC predicts stronger effects on prices and weaker effects on output.

In empirical terms several authors measured these effects for Brazil, but most of the literature focused on sample periods before the mid 1990s. Since 1999, Brazil has introduced important structural reforms. In particular, in 1999 it established an inflation targeting framework and a flexible exchange rate. Since then the economy has stabilized significantly. Now there is a reasonable number of observations available to explore the real effects of monetary policy in this new environment.

An accurate measure of the sign and size of the response of output to monetary policy shocks is crucial to set monetary policy size and its timing. In theoretical terms, determining whether a NK model or a RBC model is a better representation of the economy, has important implications in the setup of the monetary policy rules. If the RBC model is the correct model (meaning that it better represents the economy) the optimal monetary policy rule must be an strict inflation targeting, while if the correct model is the NK model, then there is room for discussion about setting a flexible inflation targeting scheme.

Using a Vector Autorregression (VAR) and a wide range of specifications, this chapter found that output responds significantly to monetary policy shocks and that prices have a weak response. Specifically it found that after a 25 basis points unanticipated increase in the monetary policy rate industrial production decreases around 3.0% and prices increases 0.27% after 12 months.

This chapter is divided into 6 sections. Section 1.1 provides the background. Section 1.2 reviews the VAR methodology and previous literature. Section 1.3 analyzes the effect of monetary policy on aggregate output. Section 1.4 studies the industry effects of monetary policy (durable, non-durable, intermediate inputs and capital goods). Section 1.5 compares how output and prices responses under the inflation targeting and flexible exchange rate regime (2000-2012) differ from the responses observed under the fixed exchange rate regime (1994-1998). Section 1.6 sets the conclusions.

1.2 VAR Methodology and Literature Review

This section provides a review of VARs methodology and summarizes the evidence documented in previous research.

1.2.1 VAR Methodology

The goal of a VAR is to identify how innovations in monetary policy instruments affect other variables such as output, prices, etc. The estimation of VAR's impulse responses implies using a Wold decomposition to express a set of variables in terms of the current and previous period's

exogenous innovations¹. Sims (1980) introduced VARs to measure the idea that unanticipated movements in money aggregates have real effects on output. Sims's contribution was pointing that these unanticipated movements or surprises can be measured as the errors from the VAR's equations. In particular the errors of the equation that measures the monetary policy stance can be interpreted as exogenous monetary policy shocks.

A VAR is specified in general as:

$$A_0 Z_t = A(L)Z_t + F(L)X_t + Be_t \quad (1.1)$$

Equation 1.1 describes a structural relationship among “n” endogenous variables in the vector Z_t (of dimension $n \times 1$). A_0 describes the contemporaneous relationship among variables, $A(L)$ is a polynomial including “L” lags. X_t is a vector of “m” exogenous variables (e.g.: constant, trend, or known variables in period t), $F(L)$ is a polynomial with “L” lags, e_t are structural innovations of the system, and B describes the contemporaneous relations among these structural innovations. By re-writing Equation 1.1 it is possible to obtain Equation 1.2, which is known as the reduced form of the VAR.

$$C(L) = A_0^{-1}A(L), \quad D(L) = A_0^{-1}F(L), \quad u_t = A_0^{-1}Be_t$$

$$Z_t = C(L)Z_t + D(L)X_t + u_t \quad (1.2)$$

The key point in a VAR estimation is the identification conditions of structural and reduced innovations. In other words the set up of matrices A_0 and B is what matters. This is because they relate u_t and e_t by $u_t = A_0^{-1}Be_t$. There are two main ways to identify these matrices: i) a recursive identification or ii) a structural identification.

A recursive identification is when A_0 is a triangular matrix and B is an identity matrix (this is known as Choleski specification)². This assumes that structural innovations are independent

¹VARs focus on deviations of the systematic monetary policy. This is not trivial as these are the only situations where the effect of exogenous monetary policy shocks on other economic variables can be measured.

²Note that if A_0 is lower triangular then A_0^{-1} is also lower triangular. See Appendix A.1, for an for example of identification.

between each other and that the reduced innovations are related by the lower triangular set up. u_t is a vector of unobservable innovations (reduced form innovations) that can be estimated directly from Equation 1.2. The coefficients from A_0 can be estimated from Equation 1.3.

$$E(u_t u_t') = E(A_0^{-1} e_t e_t' [A_0^{-1}]') \quad (1.3)$$

A structural identification (or Structural VAR) imposes restrictions based on prior theory. A first approach is to set zero or arbitrary constrains on the contemporaneous relationships (that is on the coefficients of A_0 and B) and a second approach is to impose constrains on the cumulative response functions. The second is denoted as identification by long run constrains.

1.2.2 VAR's Evidence

Evidence for the U.S.

Literature assessing the effects of monetary policy for the U.S. concludes that after a monetary tightening output and prices respond negatively. The second conclusion is that prices response is weak. Sims (1980), using a recursive identification, found that after a monetary tightening industrial production falls and prices have non-significant increment. Bernanke and Blinder (1992) estimated a recursive VAR where they found similar results but they used the interest rate as the monetary policy stance. Christiano, Eichenbaum and Evans (1999) reached the same results (i.e.: a significant effect on output and a non-significant effect on prices) using a wide range of data specifications. A summary of the main VARs estimations for U.S. is included in Table A.1., Appendix A.2.

Evidence for Open Economies

Estimations of VARs in open economies provide less clear results in terms of output (output is not always significant and it is small when it is significant) and in most cases show price puzzles³

³A price puzzles refers to a situation where after an monetary policy tightening an increase in prices is observed.

as well as exchange rate puzzles⁴. The main contributions can be summarized by⁵:

- i Sims (1992), using a recursive identification, documents that output responds negatively to interest rate innovations for the G-5 countries. He reported price and exchange rate puzzles and argued that the introduction of a proxy variable for anticipated inflation can reduce both puzzles.
- ii Kim and Roubini (2000) avoided price and exchange rate puzzles by introducing a structural VAR, which constrains contemporaneous relationships. They allowed monetary policy to respond contemporaneously to the price of oil and the exchange rate. The idea of including oil prices was to offset supply shocks. They concluded that after an unexpected increase in the interest rate, there is: 1) a reduction of monetary aggregates, output and prices and 2) a nominal exchange rate appreciation.

1.2.3 Evidence for Brazil

VAR estimations that measure the effects of monetary policy for Brazil either focus on periods before inflation targeting framework was established or rest on unrealistic assumptions. The main related studies to the current paper are:

- i Rabanal and Schwartz (2001) estimated a VAR for the period 1995-2000 and found that output responds negatively and significantly to changes in the interest rate. They also documented a price puzzle. The issue with this paper is that the period 1995-2000 involves two different foreign exchange policy regimes⁶. This may be introducing distortions in his estimations.
- ii Minella (2003) studied the period 1994-2000 and found similar results to Rabanal and Schwartz but no effect on prices. His estimation suffers from the same problem as Rabanal and Schwartz. It is argued that inflation targeting frameworks allow agents to anticipate monetary policy and therefore reduce the effects of monetary shocks. For this reason it is relevant to check if the estimation is still accurate.

⁴An exchange rate puzzle refers to a situation where after an increase in interest rate, an increase in nominal exchange rate is observed.

⁵A detailed list can be found in Table A.2., Appendix A.2.

⁶For 1995-1998 Brazil followed a peg exchange rate and since 1999 it established a flexible exchange rate.

iii Catão and Pagan (2010) analyzed the credit channel in Brazil with a VAR for the inflation targeting period but their specification rests on a structural model where the financial sector plays a key role in financial intermediation. It is difficult to support this assumption considering the distortions in the Brazilian financial sector. Public banks and the national development bank (BNDES) play a crucial role in the financial sector providing credit to target sectors and at targeted rates⁷. Their estimation found that after an increase in the nominal interest rate output and price fall. The estimations I develop below find similar results, but without modeling the financial sector.

1.3 Estimation and Results

1.3.1 Estimation

In this subsection a recursive VAR is estimated and it is shown that under several specifications output responds negatively to innovations in the monetary policy rate. The effects on prices are not significant in most cases. Estimation was done using monthly data (January 2000 until December 2012) because the larger number of observations allows for more accurate estimations. The estimated VAR is set as:

$$Z_t = C_1 Z_{t-1} + C_2 Z_{t-2} + D_{V,0} X_{V,t} + D_{V,1} X_{V,t-1} + D_{2,V} X_{V,t-2} + D_{C,0} X_{C,t} + u_t \quad (1.4)$$

The selection of the variables is consistent with Kim and Roubini (2000).

$$Z_t = \left[IP_t \quad CPI_t \quad R_t \quad M_t \quad NER_t \right]' \quad (1.5)$$

$$X_{V,t} = \left[FF_t \quad PCom_t \right]' \quad (1.6)$$

$$X_{C,t} = \left[Trend_t \quad Constant \right]' \quad (1.7)$$

⁷Loans to targeted sectors reached 35% of all loans in 2010 and BNDES loans were 21% of the total loans of the financial sector. These banks' funding is based on forced savings from the social security revenues. This may imply that the financial intermediations is partially explained by government financing loans with social security funds.

- IP_t : log of industrial production index, seasonally adjusted.
- CPI_t : log of consumer price index, seasonally adjusted.
- R_t : Monetary policy target rate (SELIC) - monthly average.
- $M1_t$: log of nominal M1 - monthly average, seasonally adjusted.
- NER_t : log of nominal exchange rate \$BR / US\$ - monthly average.
- FF_t : Fed Funds target rate - monthly average.
- $PCom_t$: log of the commodity price index BCB.

The estimation was done in log levels except for interest rates as in most of the literature. A trend term was added in the regression, in order to turn the variables stationary and estimate the VAR using OLS. Although unit root test performed suggest that the series follow a first difference stationary process (See Appendix A.6), this chapter uses log levels and explicit trend for two reasons: i) This chapter follows most of the literature, which works in log-levels (Christiano et al. (1999)⁸) and ii) It has been shown that the power of several unit root test is low, meaning that they frequently fail to reject the unit root hypothesis when it is actually false (Maddala and In-Moo (1999)). The benchmark estimation uses a Choleski identification consistent with Christiano et al. (1999).

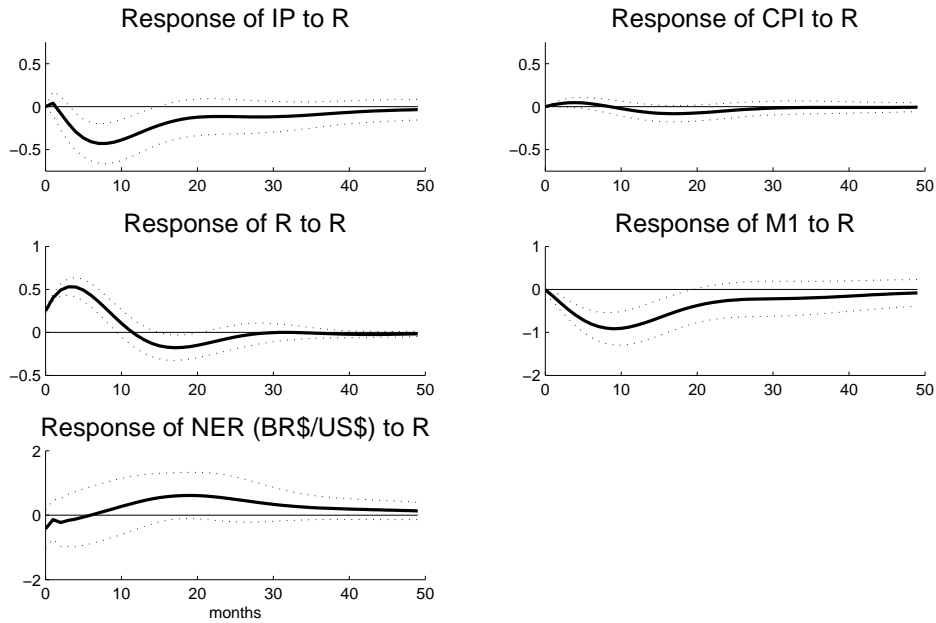
The impulse response functions and the 90% confidence bands of the benchmark estimation are shown in Figure 1.1. The specification points out that after a 25 basis points unexpected increase in the monetary policy rate we observe:

- i A significant and temporary contraction in industrial production.
- ii A contraction of prices after a year, but not significant.
- iii A significant and temporary contraction of M1.
- iv No exchange rate puzzle.

⁸Christiano et al. work in log-level even the reference study for the US time series indicates that those series are integrated of order 1 (Nelson and Plosser 1982).

Figure 1.1: Recursive Specification

Impulse response function in percent points and the 90% confidence interval



1.3.2 Robustness

VAR estimations are subject to several issues and for this reason sometimes they are not considered a reliable tool. The main issues to be taken into account are: i) Impulse response estimations are highly sensitive to the identification assumptions⁹, ii) Estimations are sensitive to the unit of frequency and the sample period, iii) Estimations are sensitive to lag specifications, and iv) There are doubts about the appropriate variable to measure monetary stance.

This chapter tries to answer part of these issues by doing robustness checks. The first issue is partially addressed by using structural identifications. The second issue is partially tested using quarterly data to perform the estimations¹⁰. The third issue is answered considering different lag

⁹Recursive VAR appear to identify the effects of monetary policy without a structural model, but actually they are still implying a structural model as they assume A_0 to be lower triangular matrix to identify endogenous monetary policy actions from exogenous monetary policy actions. In most literature specification is ad-hoc except for Sims and Zha (1998) which is the only paper that tries to provide a theoretical microfundamented model for the identification used.

¹⁰The result is partial in the sense that: i) Using different frequency will change the assumptions about the exogeneity of variables and therefore it will change the specification, making the robustness check irrelevant and ii) the limited number of observations constrains comparisons across different subsample periods.

structures, and the fourth issue does not represent a problem since the background provides clear information that the monetary policy instrument is the nominal interest rate.

Structural Identifications

This chapter will perform two structural identifications. The first will include the idea of the interest rate only responding to inflation. The second identification will incorporate the idea that price shocks affect output.

The first structural VAR was estimated using identification constraints similar to Kim and Roubini (2000). The main difference is that the interest rate responds to current inflation in order to reflect the inflation target. This identification scheme will be referred to as “Structural I” from now on.

$$\underbrace{\begin{pmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ 0 & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{pmatrix}}_{A_0} \begin{pmatrix} u_{IP,t} \\ u_{CPI,t} \\ u_{R,t} \\ u_{M1,t} \\ u_{NER,t} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} e_{IP,t} \\ e_{CPI,t} \\ e_{R,t} \\ e_{M1,t} \\ e_{NER,t} \end{pmatrix}$$

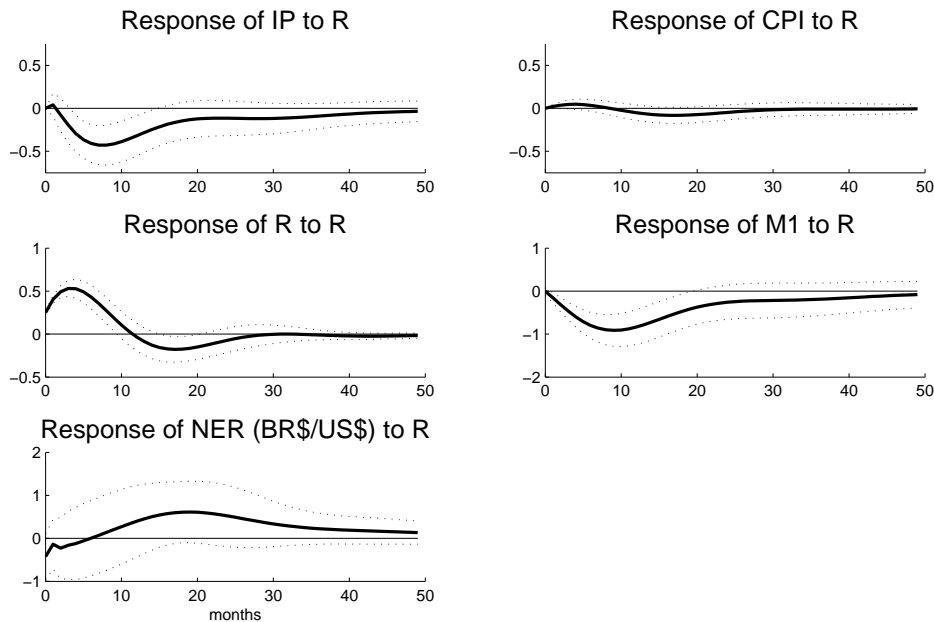
The first line of the matrix A_0 states that the structural innovation on output (IP) only depends contemporaneously with itself. The idea is that within a period output only responds to productivity shocks. The second line states the idea that output and inflation are related through a Phillips curve. The exchange rate is excluded from the price equation, reflecting that the pass-through from the exchange rate to prices is not instantaneous. The third line states the monetary rule where the central bank of Brazil responds to prices¹¹. Note that the exchange rate is excluded from the monetary policy reaction function because the monetary framework sets inflation as the only goal. The fourth line is the money demand which depends contemporaneously on the interest rate, the level of prices and the activity. Finally the exchange rate is contemporaneously related with all variables as it is a forward looking variable.

¹¹The assumption of the central bank responding to current prices is accurate considering that Brazil has measures of prices published every 15 days. On the other hand the central bank cannot observe the current activity until the following month.

The impulse response of the “Structural I” estimation is shown in Figure 1.2. They present similar results as the benchmark case. There is a small price puzzle as it is observed in many papers and the reason is that the central bank responds in anticipation to the inflation.

Figure 1.2: Structural Specification I

Impulse response function in percent points and the 90% confidence interval

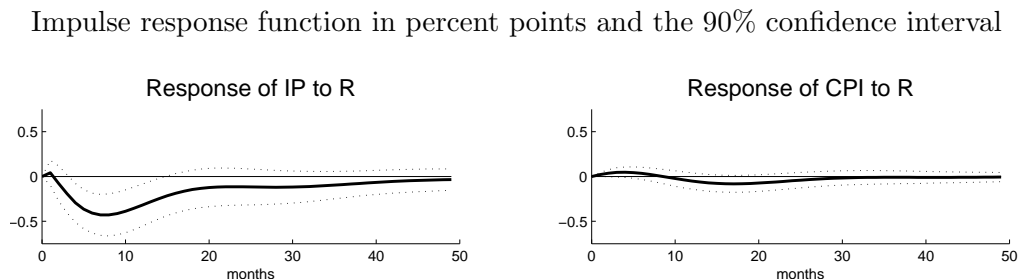


The second structural identification scheme allows prices to be independent contemporaneously, while prices and output are related by the Phillips curve. Basically the order between IP and CPI was exchanged compared with the benchmark case. The matrix below shows the identification changes. This identification scheme will be denoted “Structural II” from now on.

$$\underbrace{\begin{pmatrix} * & * & 0 & 0 & 0 \\ 0 & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{pmatrix}}_{A_0} \begin{pmatrix} u_{IP,t} \\ u_{CPI,t} \\ u_{R,t} \\ u_{M1,t} \\ u_{NER,t} \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}}_B \begin{pmatrix} e_{IP,t} \\ e_{CPI,t} \\ e_{R,t} \\ e_{M1,t} \\ e_{NER,t} \end{pmatrix}$$

The impulse response of the “Structural II” estimations are shown in Figure 1.3. They describe similar results as the benchmark case: significant and short term negative effects on IP and negative but non-significant effects on prices.

Figure 1.3: Structural Specification II



Frequency Sensitivity

The second robustness issue analyzed is the sensitivity of impulse response functions to the data frequency. In order to address this issue the estimations are done using quarterly data and the same identification assumptions as in the monthly frequency estimations. The results (shown in Figure 1.4) are very similar to the monthly results. Output responds significantly and prices respond but non significantly. Appendix A.3 analyzes all the robustness cases at quarterly frequency.

Lag Sensitivity

The third robustness tests are related with the lag specification. The argument for checking lag sensitivity rests on the idea that there may be some omitted variables. Although the test for lag extension indicates that the correct lag extension is two lags (see Appendix A.5), in this section we estimate a 6 lags VAR to check the sensitivity. The reason for choosing six lags is that it is widely accepted that monetary policy takes at least two quarters to affect the economy. In Figure 1.5 Panel A and B show the impulse response of a VAR including 6 lags. The results are similar to the results of the benchmark case (Figure 1.1): strong effects on output and weak effect on prices.

Sensitivity to Output and Price Measures

The fourth robustness check is related to the measure of activity. Bernanke and Mihov (1998) argue that the broader measures of economic variable are more appropriate to capture the response

Figure 1.4: Recursive Specification - Quarterly Estimation

Impulse response function in percent points and the 90% confidence interval

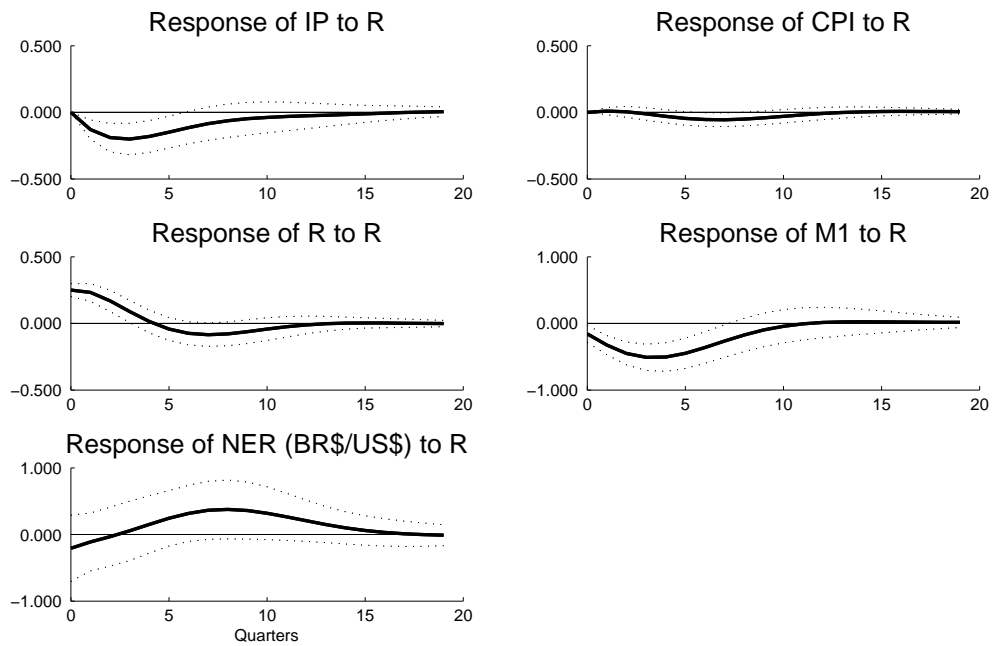
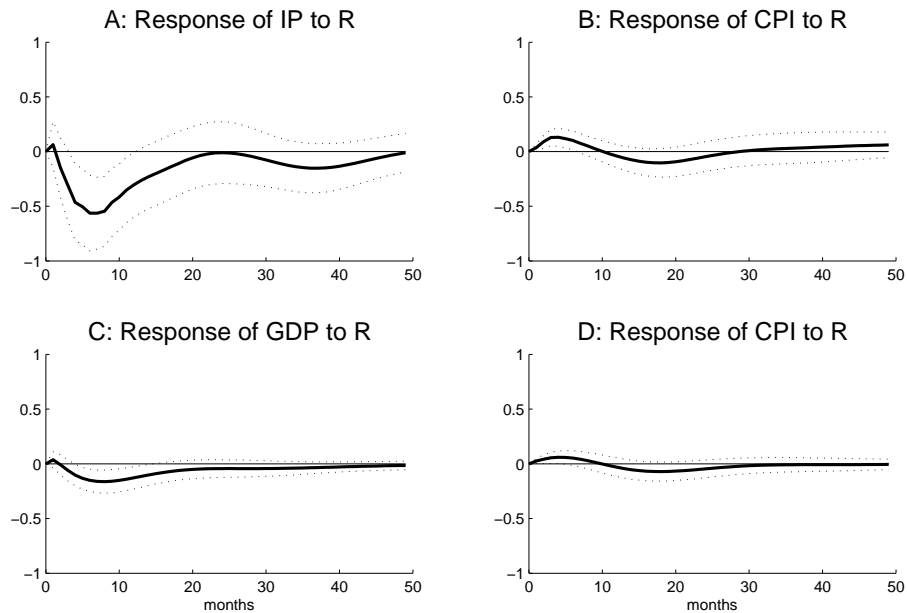


Figure 1.5: Recursive Specification - Lag Sensitivity

Impulse response function in percent points and the 90% confidence interval



of the economy. For this reason we replace the IP index with the Central Bank Index of Economic

Activity¹², which approximates GDP better than IP. This index shows a smaller variance as a result of the effect of the services. The results of this estimation are shown in Figure 1.5 Panels C and D. These results are similar to the benchmark case. Output responds negatively in the short run and prices fall after a year. The main difference with the benchmark case is that the output response is half of the response observed in the benchmark case. One reason for the weaker effects on output is that the Index of Economic Activity includes information from the farming sector and services. The low response of farming is attributed to the high sensitivity of the sector to weather conditions. In the services industry, the low response to interest rates is explained by the high persistence in services such as government services and education.

The fifth robustness check is related to the price measures. Most VARs estimations are subject to price puzzles. In general there are two main explanations for these puzzles. The first one is that there is an omitted variable problem (meaning that expected prices are not included in the VAR). The second explanation is that a large component of CPI corresponds to regulated prices, which may not respond. Most of the papers that find a negative effect of interest rate on prices use broad measures of prices such as GDP deflator. This measure responds more to economic conditions because it includes wholesale prices, which are more flexible. For these reasons we re-estimate the benchmark VAR and its impulse response functions by replacing CPI by two different measures of prices: 1) CPI-Free Prices (non-regulated goods and services) and 2) Index of General Prices¹³, which approximates the GDP deflator.

In Figure 1.6 Panels A and B show the impulse response functions of IP and prices for the case where CPI is replaced by CPI-Free Prices (non-regulated). The idea is to exclude the prices which are not allowed to respond to market incentives. Finally Panel C and D show the results for the estimation using the Index of General Prices (IGP). The results do not change significantly from the benchmark. Industrial production responds strongly and prices show mixed results. While

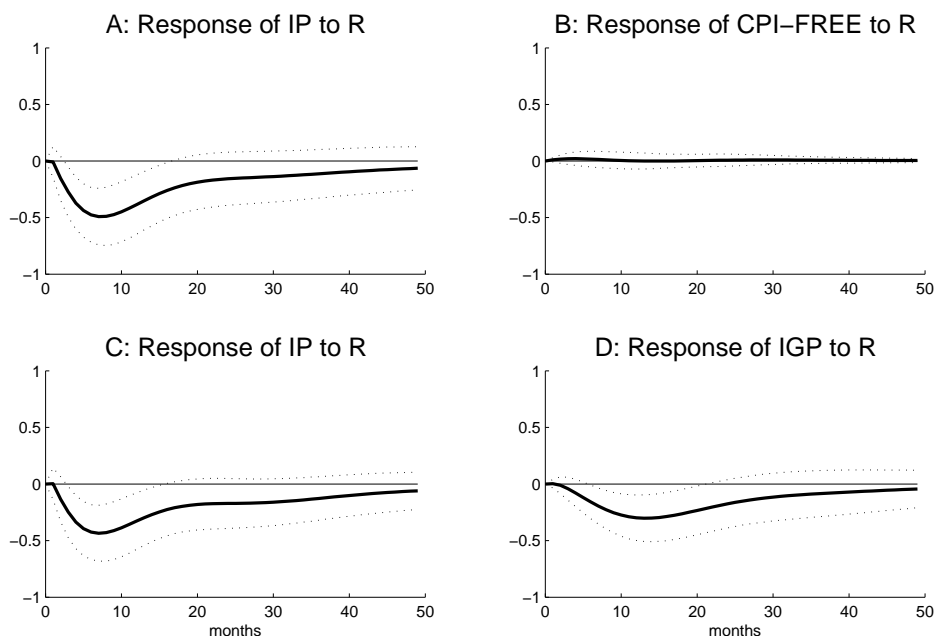
¹²The index is available since 2003. For January 1999 until December 2002, the index was estimated using the Chow and Lin (1971) method. This method estimates monthly GDP from quarterly GDP data using monthly information from industrial production, real retail sales and basic construction inputs. For the period where the Economic Index Activity and the estimation are available the correlation is 99.78.

¹³Index of General Prices (IGP) is collected by Getulio Vargas Foundation and it corresponds to a mix of consumer price index, whole sale prices and construction cost prices. The index approximates the GDP deflator with a correlation of 0.99 and observes higher volatility than CPI.

CPI-Free Prices register no response, IGP responds negatively and significantly.

Figure 1.6: Recursive Specification - Sensitivity to Output and Price Measures

Impulse response function in percent points and the 90% confidence interval



Summarizing the Responses

This section concludes that monetary policy has strong effects on output and weak effects on CPI prices. Considering the cumulative impulse response functions (Table 1.1) the chapter concludes that an unanticipated 25 basis point increase in monetary policy rates, reduces IP 3.63 percent and increases CPI 0.14 percent after 12 months. CPI only responds negative after 24 months at -0.70 percent. The impulse response function also shows that the same change in the monetary policy rate reduces the deflator (IPG) -1.94 percent after 12 months.

Table 1.1: Summary: Cumulative Impulse Response Functions

Model	# Lag	Δ 12 Months		Δ 24 Months	
		Output	Prices	Output	Prices
Choleski (IP)	2	-3.63	0.14	-5.59	-0.70
Structural I	2	-3.63	0.14	-5.59	-0.70
Structural II	2	-3.63	0.14	-5.59	-0.70
Choleski (IP)	6	-4.57	0.70	-5.90	-0.29
Choleski (GDP)	2	-1.32	0.32	-2.13	-0.40
Choleski (CPI-Free)	2	-4.42	0.14	-7.14	-0.17
Choleski (IGP)	2	-3.88	-1.94	-6.39	-4.93

1.4 Industry Effects of Monetary Policy

This section documents the response of output in different industries to monetary shocks. Studies such as Peersman and Smets (2005) and Dedola and Lippi (2005) document industry effects for the Euro Area. They concluded that industries related to durable consumption goods and capital goods are more sensitive to monetary shocks. There are two main reasons for heterogeneous effects of monetary policy across industries: i) certain goods' demands depend significantly on the borrowing cost as these goods are purchased with credit; ii) certain industries depend more on bank financing than others to finance their working capital. Therefore changes in the interest rate will affect the demand and the borrowing cost of the firms asymmetrically across industries.

This section considers only four different groups (Capital Goods, Durable Goods, Non-Durable Goods and Intermediate Inputs) to keep the number of parameters to be estimated at a low number. The first two groups' demands depend on financing conditions. In particular Brazil has shown an important growth in the credit lines for vehicles financing and personal loans (mainly allocated to Durable Goods). The microeconomics behind this is that a monetary shock that increases the cost of borrowing affects negatively the demand of Durable Goods, such as cars, refrigerators, TV, etc. The Capital Goods' demand depends on the interest rate because the present value of the investment projects depends on the interest rate. A monetary shock that increases the interest rate significantly reduces the demand for Capital Goods. Finally certain goods' demand depends less on the interest rate. The demand of Non-Durable Goods due to its nature is almost independent of the interest rates (e.g. food and beverages) while the Intermediate Inputs depend highly on foreign markets (e.g. basics chemical inputs, steel and rubber).

The estimations assume that shocks to different industries are independent in order to avoid arbitrary assumptions about the interrelation among industries.

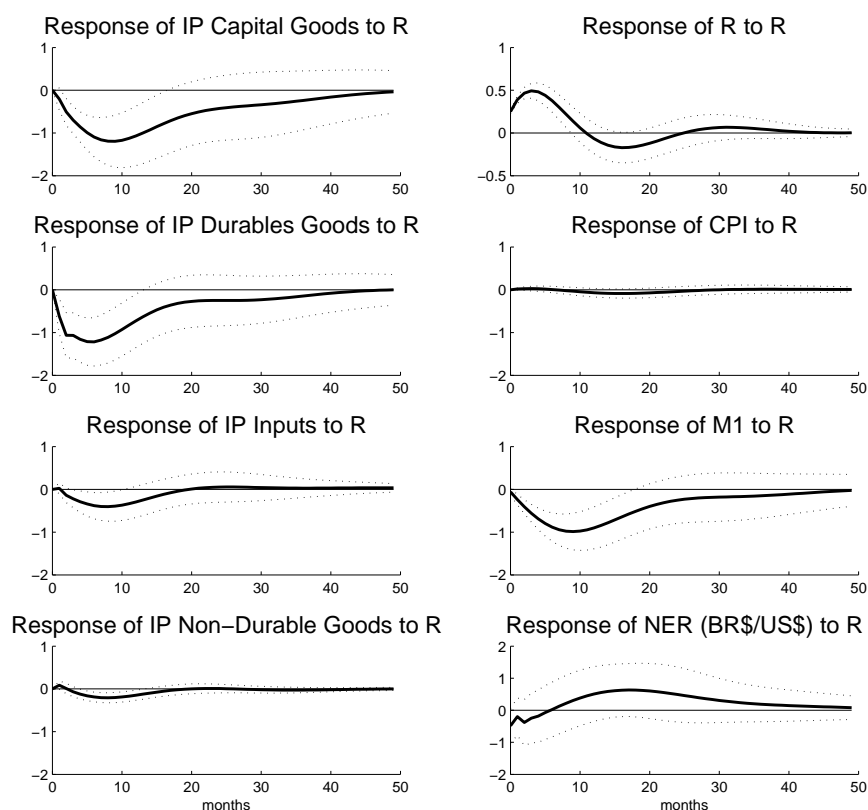
$$Z_t = \left[IP_t^{KG} \quad IP_t^{DCG} \quad IP_t^{NDCG} \quad IP_t^{IIG} \quad CPI_t \quad R_t \quad M_t \quad NER_t \right]' \quad (1.8)$$

- IP_t^{KG} : log of Capital Goods IP index, S.A.
 IP_t^{DCG} : log of Durable Consumption Goods IP index, S.A.
 IP_t^{NDCG} : log of Non-Durable Consumption Goods IP index, S.A.
 IP_t^{IIG} : log of Intermediate Inputs Goods IP index, S.A.

$$\underbrace{\begin{pmatrix} * & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & * & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & * & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & * & 0 & 0 & 0 & 0 \\ * & * & * & * & * & 0 & 0 & 0 \\ * & * & * & * & * & * & 0 & 0 \\ * & * & * & * & * & * & * & 0 \\ * & * & * & * & * & * & * & * \end{pmatrix}}_{A_0} \begin{pmatrix} u_{KG,t} \\ u_{DCG,t} \\ u_{IIG,t} \\ u_{NDCG,t} \\ u_{CPI,t} \\ u_{R,t} \\ u_{M,t} \\ u_{FX,t} \end{pmatrix} = \begin{pmatrix} e_{KG,t} \\ e_{DCG,t} \\ e_{IIG,t} \\ e_{NDCG,t} \\ e_{CPI,t} \\ e_{R,t} \\ e_{M,t} \\ e_{FX,t} \end{pmatrix}$$

Figure 1.7: Industry Effects - Recursive Specification

Impulse response function in percent points and the 90% confidence interval



The results in Figure 1.7 show that a unexpected monetary shock of 25 basis points has: i) strong effects on Capital Goods and Durable Goods output, ii) weaker effects on Intermediate Inputs production and iii) almost no significant effect on Non-Durable Goods production. The prices show similar results as in the benchmark case: no effect on prices.

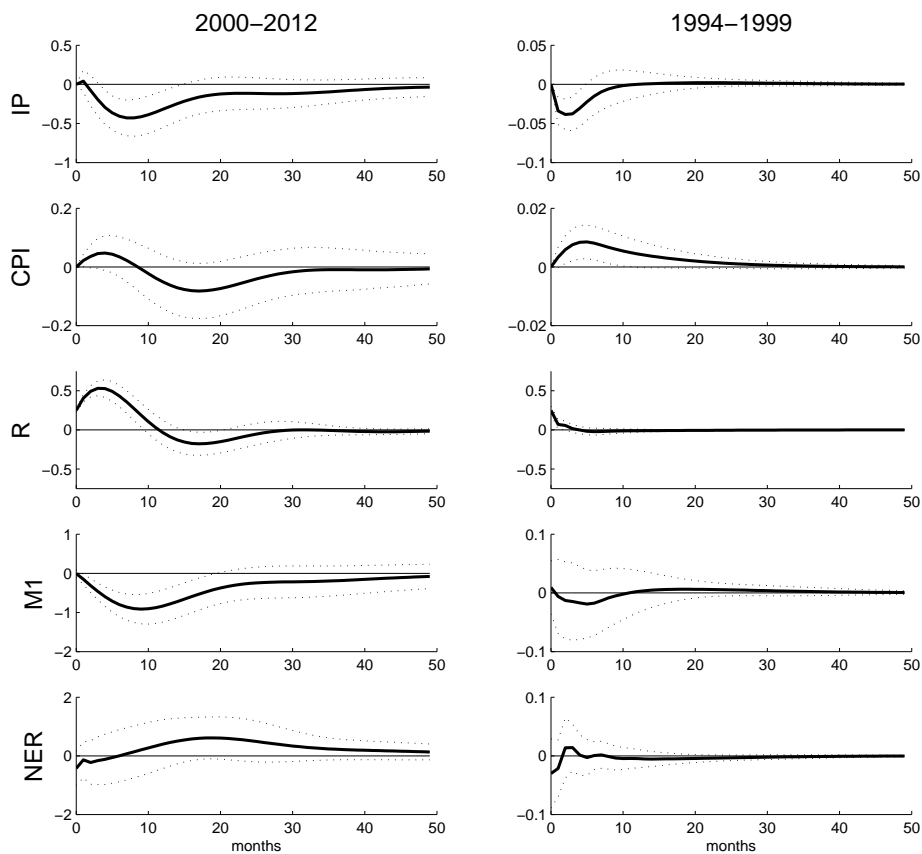
1.5 Effects of Monetary Policy during 1994-99 and 2000-12

This section compares the effect of monetary policy during the periods 1994-1998 and 2000-2012. The idea of this section is to identify if the response of the system changed after the implementation of the inflation targeting and the flexible exchange rate. The goal is to characterize the changes in the response. Using the benchmark specification detailed above the paper computes the impulse response of output, prices, interest rate, M1 and nominal exchange rate to a 25 basis point unexpected interest rate shock.

The estimation is constrained by the limited number of observations in the period 1994.09-1999.12. During 1994-1998 the Brazilian Real was pegged to a basket of currencies. The peg system was replaced by a flexible exchange rate at the beginning of 1999. We extend the sample period until the end of 1999 to allow the agents to incorporate the new policy. Figure 1.8 shows that the effect of monetary policy are larger during the sample 2000.01-2012.12 than during 1994.09-1999.12. The main conclusions are: i) Response of the different variables during 1994-1999 was around one tenth of the response observed during 2000-2012 and ii) The response of monetary policy rate was less persistent. The weakness of the response of different variables during 1994-1999 is largely explained by the lack of credibility of the monetary regime and the high interest rates driven by sovereign risk premiums.

Figure 1.8: Recursive Specification - 1994-1999 and 2000-2012

Impulse response function in percent points and the 90% confidence interval



1.6 Conclusions

Considering the Brazilian economy for the period 2000-2012, impulse response functions from VARs point out that monetary policy has real effects on output and weak effects on prices in the short and medium term. This implies that the estimation of a model that includes nominal rigidities will better represent the Brazilian economy.

The second relevant conclusion is that the negative response of output is heterogeneous across industries. We document that capital goods and durable goods present larger contractions after a monetary policy tightening, while intermediate inputs and non-durable goods show small or no responses to the same shock.

Finally this chapter documents that after the implementation of the inflation targeting and flexible exchange rate framework, the main economic variables have become more sensitive to unanticipated changes in the monetary policy rate.

Chapter 2

Monetary Policy and Market Interest Rates in Brazil

2.1 Introduction

The interest rate channel is one of the main transmission mechanisms of monetary policy. This channel has been frequently studied for advanced economies. This chapter inquires about the effectiveness of this mechanism for Brazil, where interest rate volatility is twice of that observed in the United States¹ and financial development is low.² Specifically this chapter asks: i) How do changes in the monetary policy rate affect longer³ term interest rates? and ii) Does the response of market interest rates to changes in the monetary policy rate depend on the state of the economy?

Studying the Brazilian experience is relevant as it is one of the main emerging economies. Brazil implemented structural reforms earlier than other emerging countries, therefore Brazil can set a precedent for those countries. Among these reforms was the adoption of an inflation targeting framework and a flexible exchange rate. These reforms stabilized the economy and set the interest rate as the core monetary policy instrument.

¹E.g. For the period 2000-2010, the standard deviation of the 1-year interest rate (Swap) in Brazil was 5.25% while in the United States it was only 1.90%.

²E.g. For the period 2000-2010, domestic credit to the private sector was 39.5% of GDP in Brazil while in the United States it was 190.8% of GDP. For the same period, the stocks traded were 24.9% of GDP while in the United States they were 242.8% of GDP.

³By "longer" this chapter means any interest rate with maturity that is larger than one day. The term "longer" will include short, medium and long term rates.

By changing the relevant interest rates, the central banks can affect the short run output levels⁴. The literature provides two main arguments for this. The first argument assumes a nominal rigidity. Under this assumption changes in the monetary policy rate affect the real allocations of the households and firms, at least in the short run. The second argument assumes that firms finance their working capital with short term borrowing. By changing the interest rate the central bank can modify the borrowing cost of firms and thus can modify the operational marginal cost. Therefore output changes. A change in the 1-day interest rate alone (such as the monetary policy rate), with no change in the longer term interest rates, will generate small or no intertemporal consumption substitution and therefore no real effects. Similarly for the firms, the 1-day interest rate changes do not significantly affect the firms' behavior because the interest rates that matter for firms are the rates used to finance inputs 6 to 12 month ahead. Then the relevant question is how the monetary policy affects the relevant interest rate for households and firms. Understanding how the monetary policy rate affects the relevant rates is crucial for the central banks.

This chapter will analyze the effects of monetary policy rate changes on the longer term interest rates using high frequency (daily) data. Daily events data allow researchers to assume that variables, such as prices and income, are given from one day to the next. The choice of daily data avoids identification issues observed in monthly and quarterly data.⁵

This chapter explores how a change in the monetary policy rate (a 1-day interest rate) affects the 3, 6, 9 and 12 month market interest rates. Specifically it will decompose the changes in the monetary rate into anticipated and unanticipated components by using futures markets information. It extends the previous literature in order to check if these results differ during economic expansions and recessions. This is done using a Markov Switching estimation that allows the parameters to be state dependent.

⁴Christiano, Eichenbaum and Evans (1999), Bernanke and Blinder (1992), and Cushman and Zha (1997).

⁵The main identification issue is that at monthly and quarterly frequencies, it is not clear in which the order interest rate, income and price shocks affect interest rate, prices and income.

The main result is that in Brazil unanticipated shocks explain most of the changes in the longer term interest rates, consistent with the literature on the United States (Kuttner (2001)). A second relevant result is that the impact of unanticipated shocks is state dependent. In particular unanticipated shocks have a larger impact during expansions. This asymmetry is attributed to the longer expected duration of expansions and a stronger response of risk premia during recessions in emerging economies.

2.2 Previous Studies

Previous papers have studied why long term rates respond to changes in short term rates and by how much they respond in the United States, but the topic has been scarcely studied for emerging economies.

2.2.1 Theoretical Perspective

The effects of short term interest rate changes on the long term interest rates are explained by the expectation hypothesis. That hypothesis states that the longer term interest rates are a weighted average of the current short term interest rate and the expected future short term interest rates, plus a risk premium that is assumed constant.

$$r_t(k) = \frac{r_t(1)}{(k+1)} + \frac{\sum_{l=1}^k E_t r_{t+l}(1)}{(k+1)} + \rho_k$$

$r_t(k)$: interest rate in period t , with maturity k periods ahead.

ρ_k : risk premium.

Under the expectation hypothesis an increase in the monetary policy rate increases the short term rate ($r_t(1)$) and therefore increases the longer term interest rate ($r_t(k)$). The expectation hypothesis has been criticized because it assumes that the risk premium and the long term inflation are constants. Assuming uncertainty about the future short term interest rates implies the risk premium is changing and therefore it is a serious challenge to the expectation hypothesis. Although the expectation hypothesis has been challenged, it can still explain a significant part of the movements in the interest rates.

2.2.2 Empirical Perspective

Cook and Hahn (1988) looked at the effects of the changes in the monetary policy rates on the term structure using daily events. By regressing the changes of the longer term interest rates on the changes of the Fed Funds Target Rate, they found that a change in the target rate generates large movements in the short term interest rate and smaller movements in long term interest rates.

Roley and Sellon (1995) argued that the relationship between long term and short term interest rates depends on the stage of the business cycle. They argued that the effects of a change in the Fed Funds Target Rate on long term rates would depend on how market participants interpret that change. If the agents believe that the change in the target rate would be persistent, then long term rates would respond more.

Cook and Hahn (1988) did not distinguish between the effects of anticipated and unanticipated monetary policy actions. A second generation of studies, such as Kuttner (2001) and Cochrane and Piazzesi (2002) considered the role of unanticipated monetary policy.⁶ These studies found similar conclusions: 1) unanticipated changes in the monetary policy rate are the main drivers of the movements in the longer term interest rates and 2) these effect are stronger for the shorter maturities.

Gurkaynak, Sack and Swanson (2005) adopt a different approach. They stated that changes in the target rate affect long term interest rates because they affect the expected long term inflation. In particular since agents imperfectly predict long term inflation, thus unanticipated monetary surprises imply adjustments in the expected long term inflation.⁷ They argue that the short term interest rate will move in the same direction as the change in the monetary policy rate, due to the expectation hypothesis. On the other hand the long term rates can move in the opposite direction of the change in the monetary policy rate. This happens when agents perceive that the central

⁶The main difference between Kuttner's and Cochrane and Piazzesi's studies is that Kuttner used futures markets data to measure unanticipated shocks, while Cochrane and Piazzesi used the change in the 1 month euro-dollar interest rate to measure monetary surprises.

⁷The idea is that long term inflation expectation is not strongly anchored. This goes against the standard argument that changes in the short term interest rate should have small effects on the long term interest rates because the short term interest rate will converge to its steady state.

bank will change its long term inflation target with lags proportional to the current inflation. This implies that as expected inflation goes down, the central bank may keep responding to current inflation by raising the monetary policy rate and this results in a smaller long term inflation.

Beechey (2006) found that monetary policy surprises affect interest rates by changing the risk premiums and not the expected future short term interest rate as argued by the expectation hypothesis. Using an affine term structure model, Beechey found that a positive monetary surprise increases the expected future short term interest rate but reduces the risk premium by an amount sufficient to offset that increment. In a recent study Beechey and Wright (2009) decomposed the effect of monetary surprises on nominal yields into the effect on the real interest rate and inflation compensation. They conclude that after a positive monetary policy surprise inflation compensation drops and the real interest rate rises.

The literature on monetary policy using daily events data is limited for emerging economies. Larrain (2007) studied the effect of monetary surprises in Chile for the period 2001-2005. He found that monetary policy surprises have significant but small effects on longer term interest rates. For Brazil, Miranda Tabak (2003) documented the effects of monetary policy shocks on the term structure of interest rates. He showed that changes in the target monetary policy rate affect the 3, 6 and 12 months reference rates by using the change in the monetary policy target rate as exogenous shocks for the period 1996-2001. In addition, Wu (2009) using Gurkaynak, Sack and Swanson (2005) methodology found that the monetary surprises have significant effects for the period 2004-2008 for Brazil.

2.3 Estimation

This section extends previous empirical evidence in terms of: 1) extending the sample and 2) performing an estimation that allows the parameter to depend on the state of the economy (expansions or recessions).

2.3.1 Data

In Brazil the monetary policy rate is the SELIC rate.⁸ The SELIC rate is the nominal interest rate at which banks trade reserves one day ahead using government securities as collateral. The SELIC rate operates as the Fed Funds Rate does in the United States.

The limited development of the Brazilian financial market constrains the analysis of the term structure to rates up to a year. The market interest rates for the Brazilian economy are the Swap DIxPRE for 3, 6, 9 and 12 months. The sample period is January 2, 2003 until May 31, 2013⁹ and it includes 96 monetary policy committee meetings. In 67 of these meetings, the monetary policy target rate was changed, while in the other 29 meetings monetary policy rate registered no change.

2.3.2 Estimating the Effect of Anticipated and Unanticipated Monetary Shocks

Changes in the monetary policy target rate are decomposed into anticipated and unanticipated shocks using futures market data.¹⁰ Unanticipated monetary shocks are defined as the difference between the target monetary policy rate (R_t) after the monetary policy committee meetings and the expectation of the monetary policy rate ($E_{t-1}[R_t]$) before these meetings. The expectation of the monetary policy rate in period t is computed as the future contract on a close proxy rate (future on CDI rate).¹¹ Then the expectation of the SELIC is $E_{t-1}(R_t) = \text{Future CDI}_{t-1}$.¹² Finally, anticipated monetary policy shocks are defined as the difference between the change in the monetary

⁸Portuguese acronym for *Sistema Especial de Liquidação e Custodia* (SELIC) (Special Clearance and Settlement System).

⁹The period 1999-2002 was excluded due to the extreme volatility in the financial markets generated by the Argentinian Crisis (2001-2002), the Brazilian election (2002) and in order to consider that before 2003 the central bank allowed the chair of the policy committee to change the target monetary policy rate outside of the monetary policy committee meetings.

¹⁰Similar to Kuttner (2001).

¹¹The Certificate of Interbank Deposit (CDI is the Portuguese acronym) rate is the rate at which the banks exchange short term liquidity. CDIs are highly liquid assets and the CDI rate and the SELIC rate only differ because the SELIC rate requires Brazilian federal government bonds as collateral while the CDI rate does not requires Brazilian Federal government bonds as collateral. The correlation between both rates is 0.999. The future contracts on CDI is also a highly liquid asset. It is traded to insure financial agents against fluctuations in the domestic interest rates.

¹²This means that the expectation of SELIC is value of the CDI rate of the futures contracts traded on the day of the committee meeting. Information about the monetary policy changes is released after the financial markets close.

policy target rate and the unanticipated shock. Considering the definitions:

r_t^{jm} :	j month market interest rate (Swap DIxPRE)
R_t :	monetary policy target rate (SELIC target)
ΔR_t :	monetary policy shock (change in the monetary policy target rate)
$E_{t-1}(R_t)$:	expectation on SELIC on the day of the committee meeting
ΔR_t^u :	unanticipated monetary policy shock ($\Delta R_t^u = R_t - E_{t-1}(R_t)$)
ΔR_t^a :	anticipated monetary policy shock ($\Delta R_t^a = \Delta R_t - \Delta R_t^u$)
ξ_t	$\stackrel{iid}{\sim} N(0, \sigma)$

It is possible to write the change of the j months maturity rate as:

$$\Delta r_t^{jm} = a + b_a \Delta R_t^a + b_u \Delta R_t^u + \xi_t$$

Table 2.1: Estimation - 2003-2013

Anticipated and Unanticipated Monetary Policy Shocks				
	Δ Market interest rate:			
	3m	6m	9m	12m
unanticipated shock	59.99 (9.71) ***	63.89 (11.31) ***	62.13 (11.15) ***	60.52 (11.79) ***
anticipated shock	13.85 (2.30) ***	15.21 (2.78) ***	14.25 (2.83) ***	13.32 (2.88) ***
Constant	-4.68 (1.48) ***	-4.53 (1.82) **	-4.26 (1.96) **	-3.75 (2.05) *
Observations	96	96	96	96
R-squared	0.53	0.43	0.36	0.32

Robust standard error in brackets
* significant at 10%; ** significant at 5%; *** significant at 1%

The estimation shows that both shocks are statistically significant, but that unanticipated monetary shocks explain a larger part of the changes in the 3, 6, 9 and 12 month interest rates. For example, an unanticipated increase in the target rate of 100 basis points results in an increase of 60 basis points in the 12 months market interest rates. This result is consistent with Kuttner's estimations for the economy of the United States. The explanation for this response is the expectation hypothesis. After an unanticipated shock, agents review their expectations about the future monetary policy rate and then long term rates respond. Results are also robust for different sample period and interest rates series as shown in Appendix B.3.

2.3.3 Effects of Monetary Shocks During Recessions and Expansions

Background

This subsection explores whether the impact of anticipated and unanticipated monetary shocks have similar magnitude during economic recessions and expansions. The intuition behind the hypothesis is that the market interest rates respond differently during expansions and recessions to unanticipated monetary shocks. The argument is based on: i) The expectation hypothesis of interest rates and ii) The expected duration of expansion and recessions. Assuming there is technological growth, expansions are longer than recessions. During expansions, agents expect that after an increase in the monetary policy rate, the short term interest rates are expected to be high (keep at the new level or go up) for a long period. Therefore long term rates will be affected more because short term interest rates are expected to be higher for a long period. On the other hand, during a recession agents expect that after a decrease in the monetary policy rate, the short term interest rates are expected to return to their mean level within a few quarters, because historically recessions are shorter than expansions. Hence the long term rates will be affected less because the short term rates are expected to be lower for a shorter period.

A simple way to test this hypothesis is to split the sample in two subsamples and estimate the coefficients. The sample was separated into a low state when the economy is in recession and high state when the economy is in expansion. The period of expansion was measured using the real GDP per capita in U.S. dollars. A recession is determined by two consecutive quarters of contraction on the real GDP per capita in U.S. dollars. This criteria differs from the standard NBER definition of two consecutive quarters of real GDP contractions. This allows us to consider the effect of depreciation in the exchange rate. Sudden depreciation of the exchange rate in Brazil signals periods of financial uncertainty at the early stages of recessions.

The regression results show that the response of the 3, 6, 9 and 12 months interest rates to unanticipated shocks is larger during expansions (HIGH) than during recessions (LOW). Although this pattern is not statistically different as shown by the probability at the bottom of Table 2.2. That line shows the probability of rejecting the null hypothesis of equality of the unanticipated

Table 2.2: Subsample Estimation - 2003-2013

Anticipated and Unanticipated Monetary Policy Shocks								
Δ Market interest rate:								
	LOW				HIGH			
	3m	6m	9m	12m	3m	6m	9m	12m
unanticipated shock	44.44 (15.23) ***	42.60 (22.08) *	36.79 (24.74)	34.87 (25.74)	69.63 (13.09) ***	75.03 (13.52) ***	75.11 (11.40) ***	74.28 (12.17) ***
anticipated shock	12.06 (3.48) ***	11.51 (5.00) **	9.58 (5.68)	9.18 (5.89)	14.43 (3.19) ***	16.45 (3.48) ***	16.08 (3.49) ***	14.43 (3.42) ***
Constant	-2.63 (3.02)	-3.74 (4.16)	-3.50 (4.85)	-2.57 (5.12)	-6.33 (1.67) ***	-5.88 (1.91) ***	-5.77 (1.90) ***	-5.50 (1.87) ***
Observations	30	30	30	30	66	66	66	66
R-squared	0.39	0.23	0.14	0.12	0.60	0.52	0.48	0.43
Robust standard error in brackets								
* significant at 10%; ** significant at 5%; *** significant at 1%								
Unanticipated shock								
Wald Test (Ho: $b_{Low} - b_{High} = 0$): Probability of Rejecting Ho					0.17	0.17	0.15	0.15

coefficients in the two states (Ho: $\beta_{Low} - \beta_{High} = 0$).

The approach of splitting the sample is subject to the issue that the state of the economy is subject to uncertainty. During certain periods of time it is not easy to determine if the economy is in an expansion or a recession. This is known *ex post*, after data is released. In the best case the agents assign probabilities of being in each state at each time. In order to consider this issue in the following subsection the paper follows an approach that allows us to estimate the probability of being in each state and the parameters of the responses.

Estimation

In order to measure these effects, this paper estimates a two state regime model similar to Hamilton (1988). The two states are “Low” and “High”. In the “Low” state, the economy is in a recession, while in the “High” state, it is in an expansion. The methodology jointly estimates the parameters in each state and the probability of being in each state.

The state of the economy (S_t) can be either an “High” (H) or a “Low” (L). In state H the parameters will be different from the parameters in state L :

$$\Delta r_t^j = a_L + b_{a,L} \Delta R_t^a + b_{u,L} \Delta R_t^u + \xi_{t,L} \quad \xi_{t,L} \stackrel{iid}{\sim} N(0, \sigma_L^2)$$

$$\Delta r_t^j = a_H + b_{a,H} \Delta R_t^a + b_{u,H} \Delta R_t^u + \xi_{t,H} \quad \xi_{t,H} \stackrel{iid}{\sim} N(0, \sigma_H^2)$$

The state of the economy S_t is not directly observable, but it is possible to parameterize S_t by S_t^* which is measured with error. Assume:

$$S_t = \begin{cases} L & \text{if } S_t^* \leq 0 \\ H & \text{if } S_t^* > 0 \end{cases}$$

The state S_t is parametrized as $S_t^* = a_z + b_z Z_t + e_t$ where:

$$Z_t = IP_t - Trend_t$$

IP_t : Industrial Production index SA¹³

$Trend_t$: Industrial Production Hodrick-Prescott filter

$e_t \stackrel{\text{iid}}{\sim} N(0, 1)$: measurement error

Then the probability in state “Low” and “High” are defined as:

$$\begin{aligned} P(S_t = L) &= P(S_t^* \leq 0) \\ &= P(a_z + b_z Z_t + e_t \leq 0) \\ &= P(e_t \leq -a_z - b_z Z_t) \end{aligned}$$

and

$$P(S_t = H) = 1 - P(S_t^* \leq 0)$$

Given this information the likelihood function is defined as:

$$\begin{aligned} LL &= \sum_{t=1}^T [f(Y_t|X_t, S_t = L; \theta_L)P(S = L|Z_t; \theta_Z) \\ &\quad + f(Y_t|X_t, S_t = H; \theta_H)P(S = H|Z_t; \theta_Z)] \end{aligned}$$

Where:

$$Y_t \in \{\Delta r_t^{3m} \Delta r_t^{6m} \Delta r_t^{9m} \Delta r_t^{12m}\}$$

$$X_t = \{\Delta R_t^a, \Delta R_t^u\}$$

$$\theta_H = \{a_H, b_{a,H}, b_{u,H}, \sigma_H\}$$

¹³Industrial Production is used and not real GDP per capita in U.S. dollars (as in previous section) because IP is released with less lag than GDP.

$$\theta_L = \{a_L, b_{a,L}, b_{u,L}, \sigma_L\}$$

$$\theta_Z = \{a_z, b_z\}$$

$$f(Y_t|X_t, S_t = L; \theta_L) = \phi\left(\frac{\Delta r_t^j - a_L - b_{a,L} \Delta R_t^a - b_{u,L} \Delta R_t^u}{\sigma_L}\right)$$

$$f(Y_t|X_t, S_t = H; \theta_H) = \phi\left(\frac{\Delta r_t^j - a_H - b_{a,H} \Delta R_t^a - b_{u,H} \Delta R_t^u}{\sigma_H}\right)$$

$$P(S = L|Z_t; \theta_Z) = \Phi(-a_z - b_z Z_t)$$

$\phi(\cdot) \equiv$ pdf of a normal standard

$\Phi(\cdot) \equiv$ cdf of a normal standard

The estimation is performed through a Expectation - Maximization (EM) algorithm. The idea of this method is described in the following steps:

1. Given an initial guess of θ_Z^0 , $P(S = L|Z_t; \theta_Z^0)$ is computed (where 0 is the initial estimation counter).
2. The parameters θ_L^0 and θ_H^0 are estimated by maximizing the LL given θ_Z^0 .
3. Using θ_L^0 and θ_H^0 the parameters θ_Z^1 are estimated by maximizing the LL given θ_L^0 and θ_H^0 and $P(S_t = L|Z_t; \theta_Z)$ is re-computed.
4. The parameters θ_L^1 and θ_H^1 are estimated given θ_Z^1 .

The process continues by repeating steps 2-4 until the algorithm finds convergence between the parameters (i.e. $\theta_M^k - \theta_M^{k-1} = 0$, for M=H,L,Z).

The log-likelihood function shows several local maximums. For this reason a grid search for the parameters was applied to find the global maximum. Appendix B.2 shows a representation of the Log-likelihood using the two sensitive parameters (a_Z, b_Z) as support.

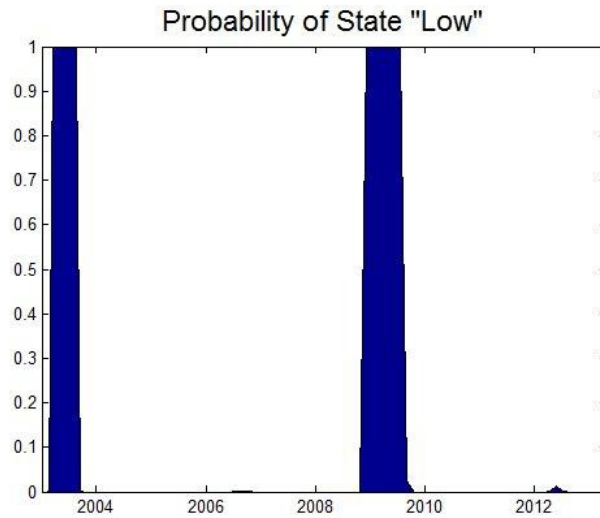
Table 2.3 presents the results. The estimation signals that the effects of unanticipated shocks on interest rates are larger during expansions. That is, an unanticipated shock of a 100 basis points during an expansion has an effect of 84 basis points in the 12 month interest rate, while it has no significant impact during a recession. Finally Figure 2.1 shows the probability of being in state “Low” estimated with the 3 month interest rates. The probabilities for the other interest rate terms are similar as the parameters of the cumulative distribution function are similar (as shown in Table 2.3).

Table 2.3: State Dependent Estimation - 2003-2013

State: Low Activity				
Anticipated and Unanticipated Monetary Policy Shocks				
Δ Market interest rate:				
	3m	6m	9m	12m
unanticipated shock	25.41 (13.77) *	12.40 (12.87)	0.50 (11.42)	-2.42 (22.77)
anticipated shock	7.98 (3.61) **	3.93 (2.82)	0.64 (2.87)	1.39 (5.75)
Constant	-0.93 (5.69)	-3.57 (1.77) *	-4.03 (1.87) **	-0.85 (8.39)
Observations	12	12	12	12
R-squared	0.36	0.08	0.00	0.01
Sigma ²	1.13	1.70	2.04	2.96
State: High Activity				
Anticipated and Unanticipated Monetary Policy Shocks				
Δ Market interest rate:				
	3m	6m	9m	12m
unanticipated shock	70.41 (11.62) ***	79.07 (12.87) ***	80.20 (11.42) ***	79.13 (11.80) ***
anticipated shock	16.52 (2.47) ***	19.15 (2.82) ***	18.69 (2.87) ***	17.52 (2.87) ***
Constant	-5.80 (1.41) ***	-5.86 (1.77) ***	-5.78 (1.87) ***	-5.50 (1.83) ***
Observations	84	84	84	84
R-squared	0.60	0.52	0.48	0.45
Sigma ²	1.00	1.72	2.06	2.26
States probability				
Δ Reference interest rate:				
	3m	6m	9m	12m
IP-Gap	11.50 (0.03) ***	11.50 (0.03) ***	11.50 (0.03) ***	11.50 (0.03) ***
Const	25.00 (0.10) ***	25.00 (0.10) ***	25.00 (0.10) ***	25.00 (0.10) ***
Robust standard errors in brackets				
* significant at 10%; ** significant at 5%; *** significant at 1%				
# obs. In State Low	12	12	12	12
# obs. In State High	84	84	84	84

Robustness test show similar results (See Appendix B.3), but the limited sample size makes the estimations for the state “Low” to be unreliable.

Figure 2.1: Sample 2003-2013 - 3-Month Interest Rate



2.4 Conclusions

This chapter examines the interest rate channel and concludes that it is an active transmission mechanism of monetary policy in Brazil. This conclusion was reached based on high frequency data, which shows that unanticipated changes in the monetary policy rate result in changes in the market interest rates. Estimations show that the 12 month rate responds by 60 basis points to an unanticipated monetary shock of a 100 basis points. Using a state dependent estimation for recessions and expansions, evidence shows that these responses are not homogeneous during expansions and recessions. Expansions are associated with higher responses of interest rates to unanticipated monetary policy shocks. In particular the estimation shows that an unanticipated monetary shock of a 100 basis points increases the 12 month interest rate by 79 basis points, while the same shock in a recession has no significant impact.

During recessions the effectiveness of interest rate channel seems to be weaker. The response of interest rate to unanticipated changes in the monetary policy rate is weak because the recession is expected to last a few quarters. In contrast during expansions, unanticipated changes in the monetary policy rate are expected to have longer effects as expansion have historically been longer than recessions.

Chapter 3

Working Capital, Financial Frictions and Monetary Policy

3.1 Introduction

The working capital constraint states that firms are required to borrow to finance wages and inputs before output is sold. In this way the interest rate directly affects the cost of the firms and generates what is known as the working capital channel or cost channel of monetary policy. This implies that interest rate movements affect the aggregate supply.

The working capital channel and the traditional interest rate channel affect inflation in opposite directions, leaving open the question about the final effect of a monetary shock on inflation. Via the interest rate channel, an increase in the interest rate will reduce output and afterwards it will reduce inflation (mainly affecting aggregate demand). Through the cost channel of monetary policy, an increase in the interest rate will increase the cost of the firms and therefore will raise inflation. In a closed economy the effect on inflation is ambiguous; it depends on the size of both the interest rate channel and the working capital channel of monetary policy. The larger the proportion of working capital that is financed with credit, the stronger the cost channel will be.

This chapter inquires about the size of these channels in an open economy. In such environment a monetary tightening implies contractions on output and prices that are larger than in a closed economy. This is attributed to the exchange rate channel, which generates a short term appreciation of the domestic currency and therefore a substitution between domestic and foreign goods. Thus the interest rate channel and the exchange rate channel might dominate any effect of the working capital.

This chapter asks: If there is an increase in the proportion of the working capital financed with credit, what are the implications for monetary policy in an open economy? From the central bank's perspective, what is the difference between an expansion of working capital lending in a closed economy and the same expansion in an open economy? How does the sensitivity of economic variables (such as output and inflation) to monetary policy change in the presence of a working capital channel?

This chapter is motivated by the recent changes in the financial behavior of the firms in Latin America and in particular in Brazil. Data indicate that in several Latin American countries, the share of working capital financed with credit has increased¹ (Table 3.1). In Brazil firms financed 43.7% of working capital with credit in 2006, compared with 54.4% in 2010. Credit lines that finance working capital² increased from 1.3% of GDP in 2000 to 8.5% of GDP in 2012 (Figure 3.1)³ and they explain more than half of the commercial bank lending to firms.

Table 3.1: Percent of Working Capital Financed with Credit

Country	2006	2010	Diff.
Brazil	43.7	54.4	10.7
Colombia	46.8	57.3	10.5
Peru	46.2	55.5	9.4
Argentina	30.6	40.0	9.3
Uruguay	24.0	32.6	8.6
Bolivia	31.0	37.3	6.2
Paraguay	34.7	36.7	2.1
Ecuador	45.5	46.6	1.1
Chile	41.5	42.5	1.0
Venezuela	14.3	13.4	-0.9

Source: based on World Bank, Enterprise Surveys.

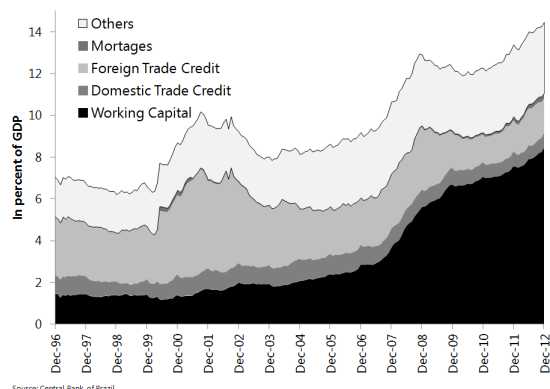
An important feature of working capital credit is that it is a short term lending consistent with the lack of domestic long term funding in emerging economies documented by the original

¹Based on the World Bank Enterprise Surveys, which record financial sources of working capital. The financial sources are based on information collected during interviews with the management of firms.

²A wider definition of working capital credit can also include domestic trade credit, but This chapter follows the central bank's definition to simplify. Some caution is needed if foreign trade credit lines are included in the working capital credit definition. Foreign trade credit is funded by foreign banks and suppliers whose lending is less sensitive to domestic monetary policy.

³This rise is mainly explained by the inflation stabilization and the financial development observed since 1999. Araujo and Funchal (2006) documented that the reform of the Brazilian Corporate Bankruptcy Law (2005) has a crucial role in explaining the growth of credit, since it has increased the protection of lenders.

Figure 3.1: Lending to Firms in Brazil



sin literature (Eichengreen, Hausmann and Panizza (2003)). According to that research, firms in emerging economies can only access long term financing in foreign currency. While short term financing was mostly in foreign in the early 1990s in many emerging economies, this has changed since the early 2000s in some Latin American countries. In Brazil, nowadays a large part of the short term borrowing by the firms is done through the domestic banking sector⁴. Thus focusing on short term lending in domestic currency for Brazil is a sensible assumption that allows for the original sin argument, but restricts the original sin to long term financing⁵.

Financial frictions have a critical role amplifying the working capital channel. In developing and emerging economies, spreads between lending and borrowing interest rates are important and reflect financial frictions. In Brazil the spreads move in the same direction as the monetary policy rate. The spreads amplify the effect of the interest rate in the cost of the firms. Financial frictions make domestic inflation less sensitive to a monetary shock because they strengthen the cost channel.

The main contribution of this chapter is to analyze the effects of introducing working capital in a small open economy with financial frictions. This chapter applies a general equilibrium framework in order to explain the potential consequences of specific and concrete structural changes that are taking place in Brazil. The main results are that: i) When the economy is more open, the working

⁴In Brazil foreign currency bank lending is banned by law.

⁵Although This chapter recognizes that in Brazil long term financing is mostly foreign currency lending, the relevance and complexity goes beyond the scope of This chapter and it will be included in future extensions.

capital constraint becomes less relevant for monetary policy as the cost push effects of working capital channel on prices are minimal and ii) These results are robust to the inclusion of foreign inputs.

Previous literature looked at the working capital constraint in closed economies. Such studies found that inflation responds less to interest rate shocks when working capital is introduced. This chapter focuses on the effects of working capital in an open economy with financial frictions. In this environment, the effects of the working capital channel can be reduced due to foreign goods substitution, while the effects of the working capital channel can be amplified by the presence of financial frictions, such as risk premiums in lending rates.

This chapter is organized as follows: Section 3.2 presents a literature review. Section 3.3 describes the model. Section 3.4 details the simulations and results. Section 3.5 provides an extension of the model that considers the role of imported inputs. Section 3.6 summarizes the models presented and Section 3.7 provides the conclusions.

3.2 Literature Review

The idea that interest rate fluctuations affect marginal cost was introduced by Bernanke and Gertler (1989) through a balance sheet effect. Christiano and Eichenbaum (1992) were the first to include a borrowing constraint that affected the marginal cost. The effects of working capital constraints were documented by Barth and Ramey (2000). They found that in the United States monetary shocks have supply effects on industrial output and different intensities across industries. They argued that the asymmetric response across industries can be explained by the differences in the funding of working capital in those industries⁶.

At an early stage, Real Business Cycle models added the working capital constraint in order to explain the effects of the changes in the world interest rate on output (Neumeyer and Perri (2005) and Oviedo (2005)). New Keynesian models, such as Christiano et al. (2005), introduced working capital in order to match the empirical impulse response of inflation to monetary shocks. This

⁶Dedola and Lippi (2005) found similar results for five OECD countries.

empirical impulse response showed a small rise in inflation after a monetary shock (Christiano, Eichenbaum and Evans (1999)). Other studies that use the New Keynesian framework including working capital, such as Ravenna and Walsh (2006) and Chowdhury et al. (2006), found that in the presence of a cost channel, inflation becomes less sensitive to monetary policy tightening.

Ravenna and Walsh (2006) argued that the cost channel introduces a monetary policy trade off in terms of stabilizing inflation and the output gap for the United States⁷. Chowdhury et al. (2006) reached a similar conclusion for the G7 countries. They concluded that in addition to the working capital, financial frictions that amplify the interest rate fluctuations are required to generate a significant cost channel effect in inflation. Rabanal (2007) documented that for the United States, the demand channel dominates the cost channel and therefore policy makers should not be concerned about the cost channel effects. He concluded that either high stickiness of wages or prices is required for the cost channel to be relevant.

Christiano, Trabandt and Walentin (2010) analyzed how the working capital constraint affects the existence of a unique equilibrium⁸. They found that when a large part of the working capital is financed with credit, an aggressive response to inflation (Taylor Principle) can generate higher inflation and multiple equilibria.

Although the literature has extensively studied the implications of the working capital channel in closed economies, the question has been scarcely analyzed in open economies. This chapter follows the idea of Ravenna and Walsh (2006), in term of analyzing the effect of monetary policy in a model with and without working capital constraint, but uses the Gali and Monacelli (2005) open economy model. Openness and financial frictions will determine the effect of the working capital on the economy.

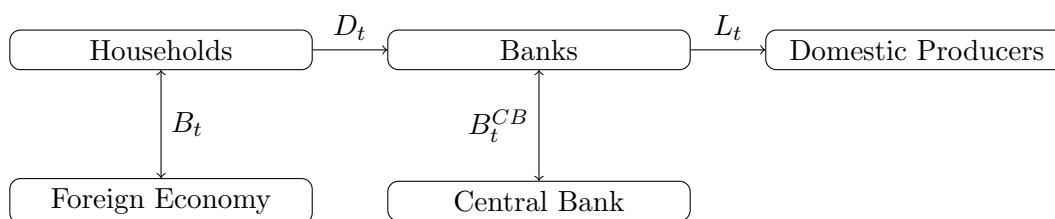
⁷They also noted that in a model with working capital the flexible prices allocation is not independent of the nominal interest rate.

⁸Recall that the existence of a unique equilibrium is important because it means that all the agents converge to the same equilibrium and therefore the economy is stable.

3.3 The Model

This chapter extends the Gali and Monacelli (2005) model to include working capital. In this extended model the households lend to the banks as deposits (D_t) or to the foreign households in bonds (B_t) indifferently, but can only borrow from foreign agents. These contracts are denominated in domestic currency. The interest rate is set by the central bank according to a rule that responds to inflation and the central bank can lend to the banks (BC_t). The banks lend to the domestic firms (L_t) to finance their working capital. That working capital is a fraction of the wage bill. The firms' costs are modified so that they are directly affected by the interest rate. The interest rate at which the firms can borrow includes a spread that amplifies the movements in the monetary policy rate.

Figure 3.2: Assets Flow



The world economy is assumed to be composed of a continuum of small open economies that are indexed in the $[0,1]$ interval. Therefore each economy's size is almost zero and each economy's events have no effect on the aggregate world economy. The model presented implies purchasing power parity (PPP) does not hold and that Uncovered Interest Parity (UIP) holds. The deviations from PPP will result from assuming stickiness in the price of imports, while UIP will be a direct consequence of assuming that domestic and foreign currency bonds are perfect substitutes. UIP and the deviations of PPP will allow the model to show overshooting in the nominal exchange rate as in Dornbusch (1976).

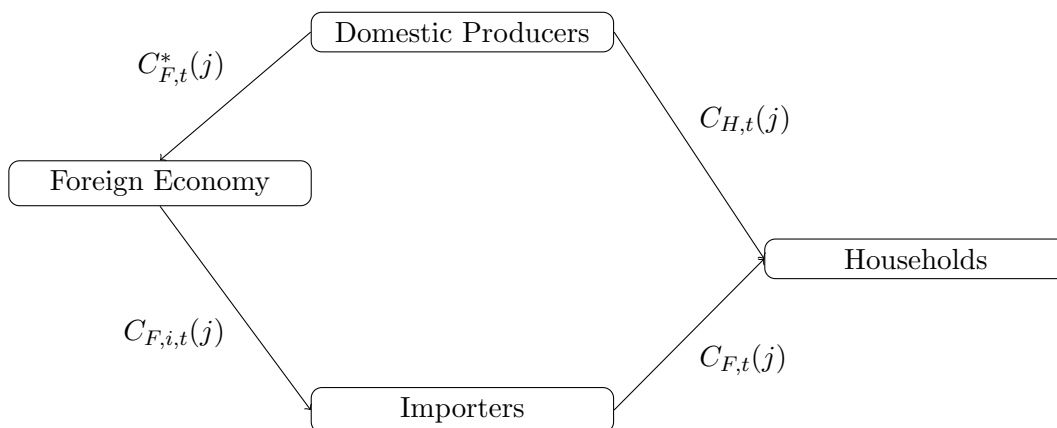
While the model presented below shares some features with Dornbusch's model, in the sense of displaying overshooting, my model is drastically different from Dornbusch's model. In particular my model is a dynamic stochastic general equilibrium model, which means that it considers dynamic responses of policy makers, while in Dornbusch's model policy makers do not have dynamic

responses. For example in my model after a monetary shock the monetary authority follows an inflation targeting rule, while in Dornbusch's model the central bank only increases monetary supply once and for all to generate the shock. The dynamic dimension plays a crucial role in the model presented below.

In this economy the households consume two kinds of goods: i) domestically produced goods and ii) imported goods of different varieties (Figure 3.3). The households' utility includes a low habit persistence in consumption to replicate standard preferences and it is separable in consumption and labor.

There are two kinds of firms: i) domestic producers and ii) importers. Domestic producers operate in a monopolistic environment. Each of these firms produces a variety j that is differentiated from the other domestically produced goods. Firm j sells domestically produced good variety j (denoted $C_{H,t}(j)$, where j indexes goods varieties), to the households and also to the foreign economy (denoted $C_{F,t}^*(j)$). The asterisk (*) denotes foreign economy variables. Importers also operate in a monopolistic environment and they import consumption goods from different countries (denoted $C_{F,i,t}(j)$, $i \in [0, 1]$, where i indexes countries). Those goods are packaged together and sold to the households as the imported consumption good variety j (denoted $C_{F,t}(j)$). The model assumes a finite set of states in each period, although notation showing the state of the nature dependence is omitted to simplify.

Figure 3.3: Goods Flow



3.3.1 Households

Households maximize utility subject to the budget constraint and a cash in advance constraint. The utility depends positively on consumption and negatively on labor. It also includes external habit in consumption. The representative household in the home economy that solves:

$$Max_{\{C_t, N_t, D_t, B_{t+1}, M_{t+1}\}} E_0 \left[\sum_0^{\infty} \beta^t \left(\frac{(C_t - H_t)^{1-\sigma}}{1-\sigma} - \frac{N^{1+\phi}}{1+\phi} \right) \right] \quad (3.1)$$

s.t. ($\forall t$):

$$P_t C_t + D_t + B_{t+1} + M_{t+1} = W_t N_t + R_t D_t + R_t^B B_t + M_t + T_t + \Pi_t^P \quad (3.2)$$

$$P_t C_t + D_t = W_t N_t + M_t \quad (3.3)$$

$$B_0 = \bar{B}$$

$$\lim_{t \rightarrow \infty} B_t \geq 0$$

$$D_t \geq 0$$

Where:

- C_t : Consumption.
- H_t : External habit in consumption with $H_t = hC_{t-1}^A$.
- C_t^A : Aggregate consumption, given for the households.
- N_t : Labor hours.
- R_t^B : Gross interest paid by bond (B_t).
- R_t : Gross interest on domestic deposits (D_t).
- P_t : Price level.
- B_t : Bonds that pay R_t^B units of domestic currency in t .
- D_t : Deposits that pay R_t units of domestic currency at the end of t .
- M_t : Nominal quantity of money.
- W_t : Nominal wage.
- T_t : Transfers.
- Π_t^P : Profits.

Then the FOCs imply:

$$(C_t - hC_{t-1})^\sigma N_t^\phi = \frac{W_t}{P_t} \quad (3.4)$$

$$\beta E_t \left[\left(\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right)^{-\sigma} \left(\frac{P_t}{P_{t+1}} \right) \right] = \frac{1}{R_t^B} \quad (3.5)$$

$$R_t = R_t^B \quad (3.6)$$

Consumption

The consumption is described by an index, which weights domestic and foreign goods defined by:

$$C_t \equiv \left[(1 - \alpha)^{\frac{1}{\eta}} C_{H,t}^{\frac{\eta-1}{\eta}} + \alpha^{\frac{1}{\eta}} C_{F,t}^{\frac{\eta-1}{\eta}} \right]^{\frac{\eta}{\eta-1}} \quad (3.7)$$

The price of the consumption good is defined as:

$$P_t^{1-\eta} \equiv (1 - \alpha) P_{H,t}^{1-\eta} + \alpha P_{F,t}^{1-\eta} \quad (3.8)$$

Where $C_{H,t}$ and $C_{F,t}$ are the demands of the domestically produced good and imported good, respectively. $P_{H,t}$ and $P_{F,t}$ are the prices of the domestic good and imported good, respectively. η is the elasticity of substitution between domestic and foreign goods and α is the contribution of the composite imported good in the aggregate consumption goods. This parameter measures the degree of openness of the economy. The FOC of the expenditure minimization problem imply:

$$C_{H,t} = (1 - \alpha) \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \quad (3.9)$$

$$C_{F,t} = \alpha \left(\frac{P_{F,t}}{P_t} \right)^{-\eta} C_t \quad (3.10)$$

Domestic Consumption Good

The domestic consumption good ($C_{H,t}$) is assumed to be an index that combines different varieties of domestically produced goods ($C_{H,t}(j), j \in [0, 1]$). The domestic consumption good and its price are defined by:

$$C_{H,t} \equiv \left[\int_0^1 C_{H,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \quad (3.11)$$

and

$$P_{H,t}^{1-\epsilon} \equiv \int_0^1 P_{H,t}(j)^{1-\epsilon} dj \quad (3.12)$$

Where $\epsilon > 1$ is the elasticity of substitution between different domestic goods. The FOCs of the expenditure minimization problem are:

$$C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}} \right)^{-\epsilon} C_{H,t} \quad \forall j \quad (3.13)$$

Foreign Consumption Good

Similarly the foreign consumption good ($C_{F,t}$) and its price are defined by:

$$C_{F,t} \equiv \left[\int_0^1 C_{F,t}(j)^{\frac{\epsilon-1}{\epsilon}} dj \right]^{\frac{\epsilon}{\epsilon-1}} \quad (3.14)$$

and

$$P_{F,t}^{1-\epsilon} \equiv \int_0^1 P_{F,t}(j)^{1-\epsilon} dj \quad (3.15)$$

The FOCs of expenditure minimization imply:

$$C_{F,t}(j) = \left(\frac{P_{F,t}(j)}{P_{F,t}} \right)^{-\epsilon} C_{F,t} \quad \forall j \quad (3.16)$$

3.3.2 Firms

It is assumed that there are two kinds of firms (Figure 3.3). There are domestic producers and importers. Both domestic producers and importers do business in monopolistic environments. The domestic producer j , produces goods $Y_t(j)$ that are either sold to the domestic households or exported. The importer firm j imports goods of variety j produced in different countries $i \in [0, 1]$ and sells the good $C_{F,t}(j)$ to households.

Domestic Producer

There is a continuum of firms (indexed by $j \in [0,1]$) in the domestic production. Each firm produces a consumption domestic good that is different from the other consumption domestic goods. Each firm's technology is given by $Y_t(j) = A_t N_t(j)$. A_t is the productivity, which is the same for all the firms and $N_t(j)$ is the labor hired by firm j .

The domestic consumption good j is either demanded by households or exported. $C_{H,t}(j)$ is the domestic demand of good j and $C_{F,t}^*(j)$ is the foreign demand of domestic consumption good j ($Y_t(j) = C_{H,t}(j) + C_{F,t}^*(j)$). The firms cannot discriminate between foreign and domestic sales. From the households it was shown that $C_{H,t}(j) = \left(\frac{P_{H,t}(j)}{P_{H,t}}\right)^{-\epsilon} C_{H,t}$.

This chapter assumes that the law of one price holds for exports but not for imports as it will be detailed below. Assuming that the law of one price holds for exports and that the countries have symmetric preferences it is possible to derive the exports demand $C_{F,t}^*(j) = \left(\frac{P_{F,t}^*(j)}{P_{F,t}^*}\right)^{-\epsilon} C_{F,t}^*$ and $C_{F,t}^* = \alpha \left(\frac{P_{F,t}^*}{P_t^*}\right)^{-\eta} C_t^* = \alpha \left(\frac{P_{H,t}}{e_t} \frac{1}{P_t^*}\right)^{-\eta} C_t^*$. $C_{F,t}^*$ is the aggregate foreign economy consumption of imported goods, that is the demand for exports for the domestic economy, while C_t^* is the aggregate consumption of the world economy. e_t denotes the nominal effective exchange rate. The last equality follows from assuming that the law of one price holds $P_{F,t}^* = e_t P_{H,t}$.

Each firm j chooses how much labor to hire ($N_t(j)$) and the price of its product ($P_{H,t}(j)$). In addition, the firms borrow from the banks to finance their working capital (The working capital in this model is a fraction Λ of the wage bills, which is assumed to be paid in advance). The firms borrow at the gross rate R_t^L and pay back at the end of the period. The advance payments reflect the idea that inputs are paid before all the production is sold.

The problem can be split into two parts: i) finding the minimum cost subject to the technology and ii) finding the optimal price $P_{H,t}^*(j)$ ⁹.

i) Minimizing Cost

$$\text{Min}_{\{N_t(j)\}} (1 - \Lambda)W_t N_t(j) + \Lambda R_t^L W_t N_t(j) \quad (3.17)$$

s.t.

$$Y_t(j) = A_t N_t(j) \quad (3.18)$$

⁹This model assumes constant returns to scale, which determines that all the firms have the same marginal cost and therefore the employment level is determined by the labor supply.

FOC imply:

$$(1 - \Lambda + \Lambda R_t^L) W_t N_t(j) = \mathbf{m}c_{H,t} Y_t(j) \quad (3.19)$$

where $\mathbf{m}c_{H,t}$ is the Lagrange multiplier of the production function and it is interpreted as the nominal marginal cost. This nominal marginal cost is independent of the amount of inputs hired due to constant returns to scale. The real marginal cost is defined as $\mathbf{r}m\mathbf{c}_{H,t} \equiv \frac{\mathbf{m}c_{H,t}}{P_{H,t}}$.

ii) Setting Prices

Finding the optimal price: Let $P_{H,t}^\bullet(j)$ denote the price of the firms which are allowed to optimize the price in period t . The firm sets the price in period t following a Calvo pricing structure with indexation described by the function below.

$$P_{H,t}(j) = \begin{cases} P_{H,t-1}(j) \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^b, & \text{with probability } \theta_H. \\ P_{H,t}^\bullet(j) \equiv \text{optimal price}, & \text{with probability } 1 - \theta_H. \end{cases} \quad (3.20)$$

With the probability θ_H the firm j will not be allowed to optimize and it will only adjust its price based on the previous period's inflation with intensity b . The parameter $b \in [0, 1]$ describes the intensity of the indexation.

With probability $1 - \theta_H$, the firm j solves:

$$\text{Max}_{\{P_{H,t}^\bullet(j)\}} \sum_{l=0}^{\infty} (\beta \theta_H)^{t+l} E_t \left(\left[\frac{P_{H,t+l}(j) - \mathbf{m}c_{H,t+l}}{P_{H,t+l}} \right] Y_{t+l}(j) \right) \quad (3.21)$$

s.t.

$$P_{H,t+l}(j) = P_{H,t}^\bullet(j) \left(\frac{P_{H,t+l-1}}{P_{H,t-1}} \right)^b \quad \forall t \quad (3.22)$$

$$Y_{t+l}(j) = C_{H,t+l}(j) + C_{F,t+l}^*(j) \quad \forall t \quad (3.23)$$

$$C_{H,t+l}(j) = \left(\frac{P_{H,t+l}(j)}{P_{H,t+l}} \right)^{-\epsilon} C_{H,t+l} \quad \forall t \quad (3.24)$$

$$C_{F,t+l}^*(j) = \left(\frac{P_{H,t+l}(j)}{P_{H,t+l}} \right)^{-\epsilon} C_{F,t+l}^* \quad \forall t \quad (3.25)$$

Solving implies:

$$\frac{P_{H,t}^{\bullet}(j)}{P_{H,t-1}} = \left(\frac{\epsilon}{\epsilon - 1} \right) \frac{\sum_{l=0}^{\infty} (\beta \theta_H)^{t+l} E_t [\text{rmc}_{H,t+l} Y_{t+l}(j)]}{\sum_{l=0}^{\infty} (\beta \theta_H)^{t+l} E_t \left[\left(\frac{P_{H,t+l-1}}{P_{H,t+l}} \right)^b \left(\frac{P_{H,t-1}}{P_{H,t+l}} \right)^{1-b} Y_{t+l}(j) \right]} \quad (3.26)$$

Assuming symmetry among firms that optimize in period t , then $P_{H,t}^{\bullet}(j) = P_{H,t}^{\bullet}(k)$ for all $k \in [0, 1]$. This implies that the average price of the domestically produced good will be:

$$P_{H,t}^{1-\epsilon} = \theta_H \left(P_{H,t-1} \left(\frac{P_{H,t-1}}{P_{H,t-2}} \right)^b \right)^{1-\epsilon} + (1 - \theta_H) (P_{H,t}^{\bullet})^{1-\epsilon} \quad (3.27)$$

Importers

There is a continuum of monopolistic firms that import input j from different countries $i \in [0, 1]$. Each firm imports a variety j from different countries ($C_{F,i,t}(j)$) and combines them to produce $C_{F,t}(j)$. Each importer of variety j , sets the mix of imports from different countries $i \in [0, 1]$ and the price of the good ($P_{F,t}(j)$).

The problem can be split into two parts: i) each firm minimizes the cost by setting the optimal mix of inputs ($C_{F,i,t}(j)$) across different countries and ii) each firm sets its price following Calvo pricing scheme with indexation. Calvo pricing in the importers implies short term deviations from the law of one price for imported goods¹⁰, therefore PPP does not hold. The price stickiness in domestic goods provides an additional reason for observing short term deviations of PPP.

i) Minimizing Cost

$$\text{Min}_{\{Y_{F,i,t}(j), i \in [0,1]\}} \int_0^1 e_{i,t} P_{F,i,t}(j) C_{F,i,t}(j) di \quad (3.28)$$

s.t.

$$C_{F,t}(j) = \left[\int_0^1 C_{F,i,t}(j)^{\frac{\gamma-1}{\gamma}} di \right]^{\frac{\gamma}{\gamma-1}} \quad (3.29)$$

Where:

¹⁰If the law of one price holds $P_{F,t}(j) = e_t P_t^*$.

γ :	Elasticity of substitution between different countries.
$e_{i,t}$:	Nominal exchange rate with country i. $e_{i,t} \equiv \left(\frac{\text{BR currency}}{\text{i currency}} \right)$
$C_{F,i,t}(j)$:	Imported consumption good variety j from country i.

The FOC imply:

$$e_{i,t} P_{F,i,t}(j) C_{F,i,t}(j)^{\frac{1}{\gamma}} = \text{mc}_{F,t} C_{F,t}^{\frac{1}{\gamma}}(j) \quad (3.30)$$

where $\text{mc}_{F,t}$ denotes the Lagrange multiplier of Equation 29 that is interpreted as the marginal cost. The real marginal cost is $\text{rmc}_{F,t} \equiv \frac{\text{mc}_{F,t}}{P_{F,t}}$.

$$\text{If } \gamma = 1 \Rightarrow e_{i,t} P_{F,i,t}(j) C_{F,i,t}(j) = \text{mc}_{F,t} C_{F,t}(j) \quad (3.31)$$

Replacing in the cost

$$\text{Cost}_t \equiv \int_0^1 e_{i,t} P_{F,i,t}(j) C_{F,i,t}(j) di \quad (3.32)$$

$$= \int_0^1 \text{mc}_{F,t} C_{F,t}(j) di = \text{mc}_{F,t} C_{F,t}(j) \quad (3.33)$$

ii) Setting Prices

The importer firm sets prices under a Calvo pricing structure with indexation described by the function below.

$$P_{F,t}(j) = \begin{cases} P_{F,t-1}(j) \left(\frac{P_{F,t-1}}{P_{F,t-2}} \right)^b, & \text{with probability } \theta_F. \\ P_{F,t}^\bullet(j) \equiv \text{optimization price,} & \text{with probability } 1 - \theta_F. \end{cases} \quad (3.34)$$

With probability $1 - \theta_F$, the importer firms solves:

$$\text{Max}_{\{P_{F,t}^\bullet(j), i \in [0,1]\}} \sum_{l=0}^{\infty} (\beta \theta_F)^{t+l} E_t \left[\left(\frac{P_{F,t+l}(j) - \text{mc}_{F,t+l}}{P_{F,t+l}} \right) C_{F,t+l}(j) \right] \quad (3.35)$$

s.t.

$$P_{F,t+l}(j) = P_{F,t}^\bullet(j) \left(\frac{P_{F,t+l-1}}{P_{F,t-1}} \right)^b \quad \forall t \quad (3.36)$$

$$C_{F,t+l}(j) = \left(\frac{P_{F,t+l}(j)}{P_{F,t+l}} \right)^{-\epsilon} C_{F,t+l} \quad \forall t \quad (3.37)$$

The FOC implies:

$$\frac{P_{F,t}^\bullet(j)}{P_{F,t-1}} = \frac{\epsilon}{\epsilon - 1} \frac{E_t \sum_{l=0}^{\infty} (\beta \theta_F)^{t+l} [\mathbf{r} \mathbf{m} \mathbf{c}_{F,t+l} C_{F,t+l}(j)]}{E_t \sum_{l=0}^{\infty} (\beta \theta_F)^{t+l} \left[\left(\frac{P_{F,t-1}}{P_{F,t}} \right)^b \left(\frac{P_{F,t-1}}{P_{F,t+l-1}} \right)^{1-b} C_{F,t+l}(j) \right]} \quad (3.38)$$

Assuming symmetry among importer firms that optimize in period t , then $P_{F,t}^\bullet(j) = P_{F,t}^\bullet(k)$, for all k . This implies that the average price of the imported good will be:

$$P_{F,t}^{1-\epsilon} = \theta_F \left(P_{F,t-1} \left(\frac{P_{F,t-1}}{P_{F,t-2}} \right)^b \right)^{1-\epsilon} + (1 - \theta_F) (P_{F,t}^\bullet)^{1-\epsilon} \quad (3.39)$$

Banks

There is a competitive banking sector that takes deposits from households (D_t) and borrows from the central bank (B_t^{CB}). Banks lend to the domestic producers. These production firms borrow in order to finance their working capital. The banks can borrow from the central bank at the rate (R_t) and pay them back at the end of the period. The banks solve:

$$Max_{\{R_t^L\}} R_t^L (1 - \Psi(R_t)) L_t - R_t (D_t + B_t^{CB}) - \kappa L_t \quad (3.40)$$

s.t.

$$L_t = D_t + B_t^{CB} \quad \forall t \quad (3.41)$$

$$L_t = \Lambda[W_t N_t] \quad \forall t \quad (3.42)$$

and

$$\Psi(R_t) = \iota R_t^2 \quad \forall t \text{ where } \iota > 0 \quad (3.43)$$

Where $\Psi(R_t)$ represents a corporate spread that represents the financial friction. Developing a theory for market frictions is beyond the goal of this chapter, therefore the financial friction is assumed to be summarized by the function $\Psi(R_t)$. This function follows Chowdhury et al. (2006) and it reflects the adverse effects of the monetary policy rate on the balance sheets of the firms.¹¹

¹¹It mirrors the financial accelerator idea similar to Bernanke, Gelter and Gilchrist (1999).

The function $\Psi(R_t)$ is required to: i) $\Psi(R_t) \in [0, 1)$ and ii) $\Psi'(R_t) \geq 0$. The idea is that when the risk free interest rate is higher, firms lean towards riskier projects under asymmetric information and debt financing. Finally κ denotes a fixed cost of processing loans and Equation 3.42 states that the banks lend as much as the firms need to finance their working capital.

The zero profit condition and the funds constraint imply:

$$R_t^L (1 - \Psi(R_t)) = R_t + \kappa \quad (3.44)$$

$$D_t + B_t^{CB} = \Lambda W_t N_t \quad (3.45)$$

Some Definitions

$$S_{i,t} \equiv \frac{P_{F,i,t}}{P_{H,t}} \quad \text{Bilateral terms of trade.} \quad (3.46)$$

$$\begin{aligned} & \text{where } P_{F,i,t}^{1-\epsilon} \equiv \int_0^1 P_{F,i,t}(j)^{1-\epsilon} dj \\ \Rightarrow S_t &= \frac{P_{F,t}}{P_{H,t}} \quad \text{Multilateral terms of trade.} \end{aligned} \quad (3.47)$$

$$\text{where } S_t^{1-\gamma} \equiv \int_0^1 S_{i,t}(j)^{1-\gamma} dj$$

$$Q_{i,t} \equiv \frac{e_{i,t} P_{i,t}^*}{P_t} \quad \text{Bilateral real exchange rate with country i.} \quad (3.48)$$

$$\Rightarrow Q_t = \left(\int_0^1 (Q_{i,t})^{1-\gamma} di \right)^{\frac{1}{1-\gamma}} \quad \text{Multilateral real exchange rate.}$$

Where:

$e_{i,t}$: Bilateral nominal exchange rate with economy i.

$P_{i,t}^*$: CPI of the foreign economy i.

P_t^* : $\equiv \left(\int_0^1 (P_{i,t}^*(j))^{1-\gamma} di \right)^{\frac{1}{1-\gamma}}$: Weighted foreign CPI.

International Risk Sharing Conditions

The FOCs of the domestic economy and foreign economy play a crucial role to determine the exchange rate. In this model it is assumed that domestic and foreign bonds are perfect substitutes, implying UIP holds as expected returns should be the same. Given this assumption and in order to simplify the model allows foreign households to buy domestic and foreign currency denominated bonds, but domestic household can only buy or sell bonds denominated in domestic currency. Modeling in this way reduces the number of variables that need to be determined for the domestic economy.

The representative household of the foreign economy i solves:

$$Max_{\{C_{i,t}^*, N_{i,t}^*, D_{i,t}^*, B_{i,t+1}^*, B_{i,t+1}, M_{i,t+1}^*\}} E_0 \left[\sum_0^{\infty} \beta^t \left(\frac{(C_{i,t}^* - H_{i,t}^*)^{1-\sigma}}{1-\sigma} - \frac{(N_{i,t}^*)^{1+\phi}}{1+\phi} \right) \right] \quad (3.49)$$

s.t. that $\forall t$:

$$\begin{aligned} P_{i,t}^* C_{i,t}^* + D_{i,t}^* + B_{i,t+1}^* + \frac{B_{i,t+1}}{e_{i,t}} + M_{i,t+1}^* &= W_{i,t}^* N_{i,t}^* + R_{i,t}^* D_{i,t}^* \\ &+ R_{i,t}^{B^*} B_{i,t}^* + \frac{R_t^B B_{i,t}}{e_{i,t}} \\ &+ M_{i,t}^* + T_{i,t}^* + \Pi_{i,t}^* \end{aligned} \quad (3.50)$$

$$P_{i,t}^* C_{i,t}^* + D_{i,t}^* = W_{i,t}^* N_{i,t}^* + M_{i,t}^* \quad (3.51)$$

In this case the bonds issued in the currency of the economy i are $B_{i,t}^*$ (foreign currency from the model perspective) and $B_{i,t}$ are the bonds in the Brazilian currency (domestic currency from the model perspective) demanded by the economy i.

The first order conditions for the economy i imply:

$$\beta \left[\frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \right]^{-\sigma} = \frac{1}{R_{i,t}^{B^*}} \frac{P_{i,t+1}^*}{P_{i,t}^*} \quad (3.52)$$

$$\beta \left[\frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \right]^{-\sigma} = \frac{1}{R_t^B} \frac{e_{i,t+1} P_{i,t+1}^*}{e_{i,t} P_{i,t}^*} \quad (3.53)$$

Combining them results in:

$$\begin{aligned} \frac{1}{R_{i,t}^{B^*}} \frac{P_{i,t+1}^*}{P_{i,t}^*} &= \frac{1}{R_t^B} \frac{e_{i,t+1}}{e_{i,t}} \frac{P_{i,t+1}^*}{P_{i,t}^*} \\ \frac{1}{R_{i,t}^{B^*}} &= \frac{1}{R_t^B} \frac{e_{i,t+1}}{e_{i,t}} \\ R_t^B &= R_{i,t}^{B^*} \frac{e_{i,t+1}}{e_{i,t}} \end{aligned} \quad (3.54)$$

Taking expectation across all states derives the UIP condition, that holds in expectation for all t . Recall state notation is omitted.

$$R_t^B = R_{i,t}^{B^*} E_t \left[\frac{e_{i,t+1}}{e_{i,t}} \right] \quad \forall t \quad (3.55)$$

Finally using the Euler equation from the foreign economy and the domestic economy, the International Risk Sharing condition is derived. UIP is implied by the the model to derive this condition.

$$\beta \left[\frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right]^{-\sigma} \frac{P_t}{P_{t+1}} = \frac{1}{R_t^B} = \beta \left[\frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \right]^{-\sigma} \frac{e_{i,t} P_{i,t}^*}{e_{i,t+1} P_{i,t+1}^*} \quad (3.56)$$

$$\begin{aligned} \left[\frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right]^{-\sigma} &= \left[\frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \right]^{-\sigma} \frac{e_{i,t} P_{i,t}^*}{e_{i,t+1} P_{i,t+1}^*} \frac{P_{t+1}}{P_t} \\ \left[\frac{C_{t+1} - H_{t+1}}{C_t - H_t} \right]^{-\sigma} &= \left[\frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \right]^{-\sigma} \left(\frac{e_{i,t} P_{i,t}^*}{P_t} \right) \left(\frac{P_{t+1}}{e_{i,t+1} P_{i,t+1}^*} \right) \\ \frac{(C_{t+1} - H_{t+1})}{C_t - H_t} &= \frac{C_{i,t+1}^* - H_{i,t+1}^*}{C_{i,t}^* - H_{i,t}^*} \left(\frac{Q_{i,t}}{Q_{i,t+1}} \right)^{-\frac{1}{\sigma}} \end{aligned}$$

Taking the expectation across all the states of the nature results in:

$$E_t \left[\frac{C_{t+1} - hC_t}{C_t - hC_{t-1}} \right] = E_t \left[\frac{C_{i,t+1}^* - hC_{i,t}^*}{C_{i,t}^* - hC_{i,t-1}^*} \left(\frac{Q_{i,t+1}}{Q_{i,t}} \right)^{\frac{1}{\sigma}} \right] \quad (3.57)$$

The consumption of the foreign economy i is denoted $C_{i,t}^*$. Assuming: i) identical initial endowments, ii) symmetry among the economies, iii) $Q_{i,0} = 1$, and then integrating across i , which indexes countries, results in¹²:

$$E[C_{t+1} - hC_t] = E_t \left[(C_{t+1}^* - hC_t^*) Q_{t+1}^{\frac{1}{\sigma}} \right] \quad (3.58)$$

$$\text{where } C_t^* \equiv \left[\int_0^1 C_{i,t}^* \frac{\gamma-1}{\gamma} di \right]^{\frac{\gamma}{\gamma-1}}$$

In open economy models it is useful to spell out if the PPP (or the law of one price) and UIP hold, as these are the key assumptions determining the exchange rate. This model will allow for short term deviation from PPP. This is attributed to the assumptions that importers follow a Calvo pricing scheme¹³. The model also implies that UIP holds, otherwise it will not be possible to write the International Risk Sharing conditions¹⁴.

¹²The continuum of foreign countries and symmetry are not strictly necessary but they help to simplify the final derivations.

¹³The stickiness of domestic prices also contribute the deviations from PPP if CPI are the price considered in PPP

¹⁴These assumptions determine that the model shows overshooting as in Dornbusch (1976). The result detailed below will not exactly follow the overshooting model for two reasons. First, as explained before, Dornbusch's model

Balance of payments

The change in the debt is identical to the trade balance because foreign households can buy domestic bonds.

$$B_t - R_{t-1}^B B_{t-1} = P_{H,t} C_{F,t}^* - P_{F,t} C_{F,t} \quad (3.59)$$

Market Clearing Conditions

$$Y_t(j) = C_{H,t}(j) + C_{F,t}^*(j) \quad \text{Equil. domestically produced good } j \quad (3.60)$$

$$N_t = \int_0^1 N_t(j) dj \quad \text{Equil. Labor Market} \quad (3.61)$$

$$0 = \int_0^1 B_{i,t} di \quad \text{Equil. Bond Market} \quad (3.62)$$

By replacing the demand of each good j , assuming $Y_t \equiv \left[\int_0^1 Y_t(j)^{\frac{1-\epsilon}{\epsilon}} dj \right]^{\frac{\epsilon}{1-\epsilon}}$ and using the International Risk Sharing condition, the domestically produced goods market clearing condition becomes:

$$Y_t = \left(\frac{P_{H,t}}{P_t} \right)^{-\eta} C_t \left[(1-\alpha) + \alpha \int_0^1 (S_{i,t} S_t^i)^{\gamma-\eta} Q_{i,t}^{\eta-\frac{1}{\sigma}} di \right] \quad (3.63)$$

Where $S_{i,t}$ represents the bilateral terms of trade between the domestic economy and country i , and S_t^i represents the weighted term of trade of country i in respect to the rest of the countries.

Monetary rule

The central bank follows an inflation targeting rule, where the nominal interest rate is the instrument. This leaves the money supply to be determined by the money demand.

$$R_t = R(\pi_t)^{(1-\phi_R)\phi_\pi} R_{t-1}^{\phi_R} e^{\xi_{R,t}} \quad \text{where } \pi_t \equiv \frac{P_t}{P_{t-1}} \quad (3.64)$$

Where $\xi_{R,t}$ is a monetary shock and R is the real and nominal interest rate in the steady state¹⁵.

assume static behavior of policy makers while in my model that behavior is dynamic. Second, Dornbusch assumed staggered prices (meaning response with lag), while in my model prices show some response to current events as they follow the Calvo pricing scheme.

¹⁵In this model the real and nominal interest rates in the steady state are equal, as zero inflation is assumed in the steady state.

Exogenous variables

Three stochastic processes are defined: one for productivity (Equation 3.65), one for the foreign output (Equation 3.66) and one for monetary shocks (Equation 3.67). Foreign prices are assumed to be constant $\log(P_t^*) = 1$.

$$\log(A_t) = \rho_a \log(A_{t-1}) + u_{a,t} \quad (3.65)$$

$$\log(Y_t^*) = (1 - \rho_{Y^*}) \log(Y^*) + \rho_{Y^*} \log(Y_{t-1}^*) + u_{Y^*,t} \quad (3.66)$$

$$\xi_{R,t} = \rho_R \xi_{R,t-1} + u_{R,t} \quad (3.67)$$

$$\begin{pmatrix} u_{a,t} \\ u_{Y^*,t} \\ u_{R,t} \end{pmatrix} \stackrel{\text{iid}}{\sim} N \left(\begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \sigma_{u_a} & \rho_{a,y^*} & 0 \\ \rho_{a,y^*} & \sigma_{u_{Y^*}} & 0 \\ 0 & 0 & \sigma_{u_R} \end{bmatrix} \right) \quad (3.68)$$

3.4 Cost Channel in Closed and Open Economies

This section focuses on contrasting the effects of working capital in open and closed economies. It describes the effects of a 100 basis point monetary shock in these environments. Subsection 3.4.1 details the parameters, subsection 3.4.2 presents the impulse responses and explains the underlying results and Subsection 3.4.3 analyzes the robustness of the results.

3.4.1 Parameters in the Simulations

The model was simulated using standard parameters in the literature. The parameters follow Gali and Moncellì (2005) but some are adjusted to reflect Brazil's economy. The details are shown in Table 3.2.

In particular the parameter α was set to 0.3, relatively similar to the ratio of openness observed in the data. The parameter θ_H was set to 0.65, consistent to adjustments two times every three quarters, and θ_F was set to 0.10, to reflect a high pass-through. The parameter $h=0.1$ is set to approximate standard preferences. The financial friction $\Psi'(\bar{R})$ is consistent with the movement

Table 3.2: Simulation Parameters

Parameter	Value	Source	Parameter	Value	Source
ϵ	1.00	GM (2005)	σ_a	0.0071	GM (2005)
γ	1.00	GM (2005)	σ_{y^*}	0.0078	GM (2005)
η	1.00	GM (2005)	σ_R	0.0625	Data Brazil
β	0.99	GM (2005)	ρ_a	0.66	GM (2005)
σ	1.50	RW (2006)	ρ_{y^*}	0.66	GM (2005)
θ_H	0.65	RW (2006)	ρ_{a,y^*}	0.30	GM (2005)
ϕ	1.00	RW (2006)	ϕ_π	1.50	GM (2005)
α	{0,0.3}	Data Brazil	$\Psi'(\bar{R})$	{0,0.5}	Data Brazil
ϕ_R	0.60	Data Brazil			
Assumed Parameters					
Λ	{0,1}		$\rho_{y^*,R}$	0.00	
ρ_R	0.00		$\rho_{a,R}$	0.00	
θ_F	0.10		h	0.10	
b	0.75				

Notes: GM (2005): Gali & Monacelli (2005)
RW (2006): Ravenna & Walsh (2006)

on the spread of lending rates from commercial banks for working capital. ϕ is set to 1, within the range in the literature¹⁶.

This model allows us to switch off the open economy effects (α), the financial frictions ($\Psi'(\bar{R})$) effects and the working capital effect (Λ). If $\alpha = 0$ the economy is closed and similarly if $\Psi'(\bar{R}) = 0$ there is no financial friction. The role of working capital can be analyzed setting $\Lambda = 0$, in such case there is no working capital channel.

3.4.2 Results

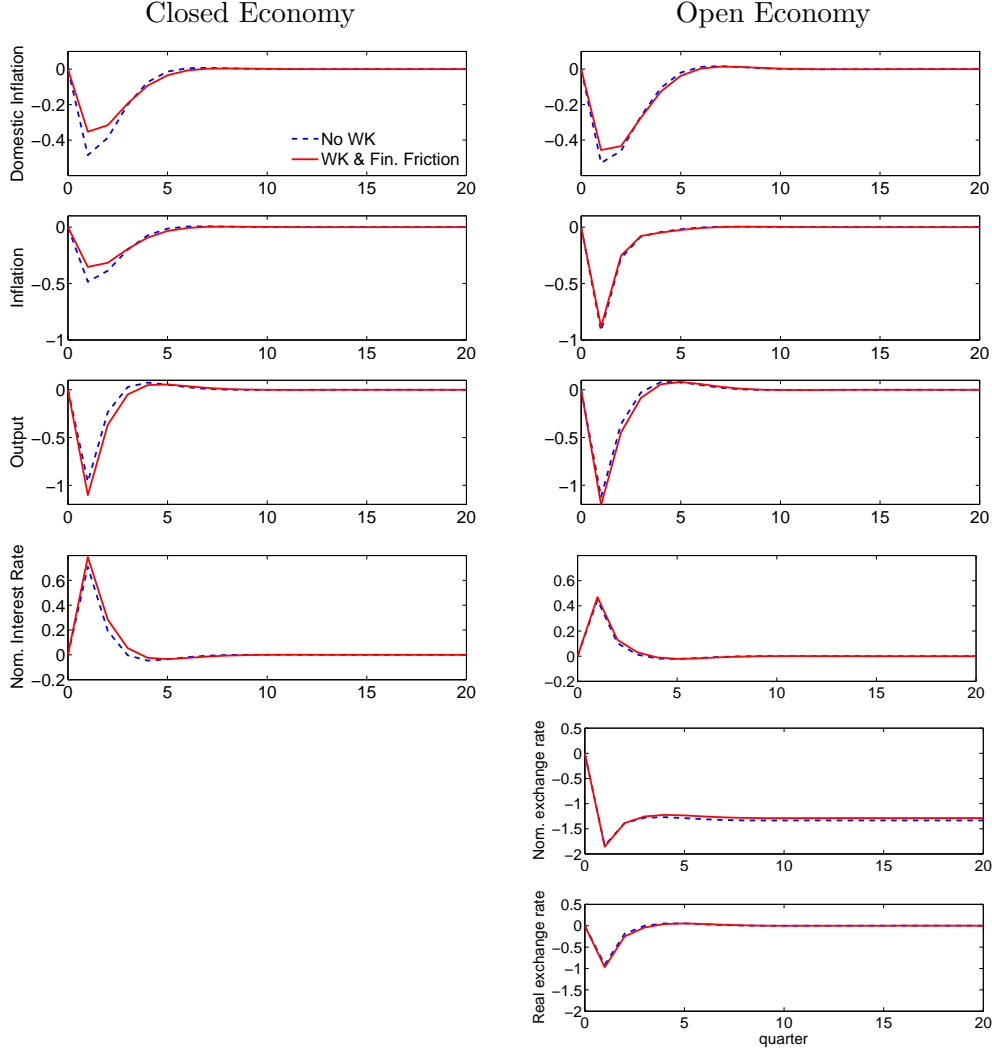
This subsection documents the effect of the working capital channel on the sensitivity of key economic variables to monetary shocks. Panel 1 displays the effect of a 100 basis points monetary shock. It shows that while the introduction of working capital and financial frictions affects the sensitivity of domestic inflation and output in a closed economy, the presence of working capital and financial frictions in an open economy has negligible effects on the sensitivity of those variables. Under working capital constraints, domestic inflation is less sensitive to the interest rate shocks, both in a closed economy and open economy. Contrary to this, output becomes more sensitive to the interest rate shock under working capital constraints, both in a closed and open economy. The higher sensitivity of output is attributed to the increase of marginal cost generated by the working capital channel.

¹⁶E.g. Castro et al. (2011), Ravenna and Walsh (2006).

Panel 1: Benchmark model

Impulse Response Function to a 100 Basis Points Monetary Shock

(Charts are in percent from steady state or initial values)



The left column of Panel 1 shows the effects in a closed economy ($\alpha = 0$) while the right column shows the effects in an open economy ($\alpha = 0.3$). Assuming a closed economy and a monetary shock of a 100 basis points, the charts in left column compare the impulse responses in an economy without working capital (dashed lines, meaning $\Lambda = 0$) to the impulse responses in an economy with working capital and financial frictions (solid lines, meaning $\Lambda = 1$ and $\Psi'(\bar{R}) = 0.5$).

The impulse responses that include working capital but without financial friction are not presented. Those impulse responses are shown in Appendix C.2 and they would have been between

the non-working capital impulse responses (dashed lines) and the working capital with financial friction impulse responses (solid lines).

A closed economy without working capital (left column of Panel 1, dashed lines): After a 100 basis points monetary shock, the interest rate rises but it raises less than the 100 basis points as the monetary rule is responding to the current level of output and inflation (4th chart in the left column). The increment in the interest rate encourages the households to shift from current consumption towards future consumption. This reduces current consumption and therefore output contracts (3rd chart in the left column). After this reduction in the demand, the firms reduce prices in order to moderate the contraction in sales (1st chart in the left column).

A closed economy with working capital and financial friction (left column of Panel 1, solid lines): In this case the demand side (households) operates as it was described in the case without working capital. The main difference arises in the supply.

After the increase in the interest rate, firms are affected by two forces that run in opposite directions. The first effect is the reduction in the demand for their product. This will lead the firms to reduce prices, but at the same time the increase in the interest rate implies an increment in the marginal cost. This second effect stimulates the firms to increase prices. The net response of the firms is to reduce prices but with less intensity than in the case without working capital (1st chart in the left column). The reason is that immediately after the monetary shock and before any other changes take place, the firms' markups are smaller than in the case without working capital (due to the higher interest rate). The different responses of the firms are reflected in the gap between the dashed line and the solid line in the 1st chart in the left column of Panel 1. Note that in the closed economy, domestic inflation and inflation (which considers domestic and foreign inflation) are identical as there is no foreign inflation (1st and 2nd charts in the left column).

An open economy without working capital (right column of Panel 1, dashed lines): After a monetary shock of a 100 basis points, the domestic interest rate rises, but less than 100 basis points as detailed above. After this shock the consumers face two kinds of incentives. First, as in the closed economy a higher interest rate reduces current consumption. In addition the exchange

rate channel will be affecting the consumers behavior. Immediately after the monetary shock, a nominal appreciation of domestic currency is observed. This is because the instantaneous return of the domestic bond is higher than the return of foreign bond at that point. This attracts capital inflows that appreciate the currency (5th chart in the right column). The model allows for an expected depreciation in the following periods, but instantaneously there is an appreciation. This appreciation induces consumers to substitute the foreign goods for the domestic goods.

This implies that in an open economy the domestic firms face a sharper contraction in their demand than in a closed economy after the same shock. Openness allows the consumer to substitute foreign for domestic consumption. Note that the right column contraction in output is larger than the left column contraction in output (dashed lines). In the open economy case, the domestic firms are forced to reduce prices more than in the closed economy as the appreciation of the domestic currency (respect to the initial level) reduces demand. Inflation responds in a sharper way in an open economy than in a closed economy (charts on the 2nd row) due to the reduction in the price of the imported goods after the nominal exchange rate appreciation.

In this model there is a transitory real exchange rate appreciation and afterwards a depreciation of the real exchange rate to return to its steady state level (6th chart in the right column, dashed line). There is a temporary appreciation of the nominal exchange rate (5th chart in the right column, dashed line). Initially the nominal exchange rate appreciates and then it starts to depreciate. The appreciation is a result of the initial interest rate increment and the later depreciation is attributed to the nominal interest rate returning to its steady state and the prices adjustment. The nominal exchange rate is not stationary as the prices are not stationary. The stationary variables are inflation and the real exchange rate.

An open economy with working capital and financial frictions (right column of Panel 1, solid lines): After a monetary shocks of 100 basis points, the interest rate rises in a similar way as in the open economy case explained above. The consumer behavior will be the same. The difference will be in the response of the firms (the supply side).

The domestic firms are encouraged to reduce prices in response to the effects of the interest rate channel and the exchange rate channel which reduce their demand. Also on the supply side, the interest rate increment raises the marginal cost of the domestic firms and encourages these firms to increase prices. The net outcome on the prices depends on the size of these effects. The model predicts that the incentive to increase prices has a minimal effect. The intuition is that openness reduces the market power of the domestic firms due to the presence of foreign goods. This can be observed as the gap between the solid line and the dashed line in the 1st chart of the right column. The gap is approximately 1/3 of the gap observed in a closed economy. In terms of inflation (which considers foreign and domestic goods) the gap is almost zero (2nd chart in the right column). This implies that the size of cost channel in an open economy is very small.

The presence of working capital in an open economy does not significantly modify the response of output to monetary shocks. This is because the output response is driven by the households' behavior, which is hardly affected by working capital channel. Both in closed and open economies working capital increases the sensitivity of output to monetary shocks, as it increases the marginal cost of the domestic firms, which reduces the aggregate supply, but the magnitudes of these changes are negligible.

For the variables shown in the open economy column, the differentials between the calibration with working capital and financial frictions over the calibration without them are too small to be of concern¹⁷. The crucial point is that working capital has very different implications in an open and closed economy. While in a closed economy it may reduce the sensitivity of inflation to the interest rate, this result nearly disappears in an open economy.

3.4.3 Robustness and Model Evaluation

This subsection aims to consider the robustness and sensitivity of the model which is an essential feature in any model. It will also evaluate the model, to determine accuracy and future extensions.

¹⁷This finding is in line with Rabanal (2007).

The results detailed above hold under a wide range of parameters as shown in Appendix C.3. The impulse responses of those robustness tests suggest that results are not highly sensitive to the indexation of the economy, smoothing of the interest rate and the pass-through, while they are sensitive to the openness of the economy. The more open the economy is, the smaller the effect of the working capital channel will be. The model results also hold even when a more realistic sequence of monetary shocks are assumed as shown in Appendix C.4.

Usually models are evaluated by considering the accuracy of the model to match actual data. For this purpose, 1000 observations were simulated using the model and then impulse responses were estimated over those 1000 observations. The estimation uses a VAR specification consistent with empirical VAR estimations (Chapter 1). Those impulse responses show a poor approximation to the impulse responses estimated on the actual data for the period 1999-2012 in Brazil (Appendix C.5). Although the comparison shows a poor approximation of the model to the empirical VAR impulse responses, the model can still be used as a qualitative tool. The poor approximation does not invalidate the results for two reasons. First the objective of this chapter is not to get an exact measure but to characterize the effects. Second, this issue can be solved in future extensions by adding variables omitted in the current model (such as capital and sticky wages) and by doing an estimation of the parameters.

The following section continues to analyze the robustness of the model, by considering the role of importer inputs in the model. Imported inputs are considered a fundamental feature in emerging economies.

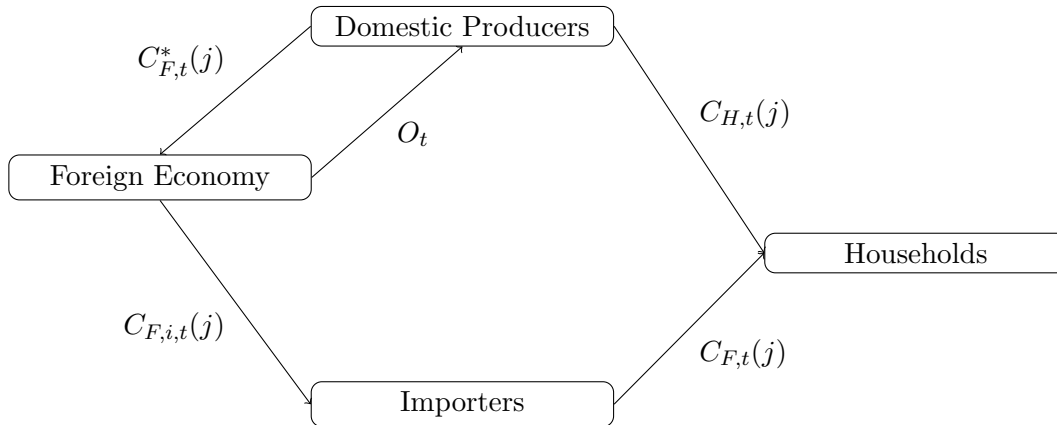
3.5 The Cost Channel in an Open Economy with Imported Inputs

This section considers how the open economy results found in the previous sections change when imported inputs are considered. In this section's model imported inputs will be represented by oil¹⁸ denoted O_t . Examining the role of imported inputs is relevant as a monetary policy tightening produces a temporary appreciation of the nominal exchange rate that reduces the price of imported

¹⁸Oil represents any basic imported inputs such as propane, coal, fertilizers, iron, etc.

inputs and therefore marginal cost. This reduction in the marginal cost will partially cancel the rise in the marginal cost resulting from higher interest rates.

Figure 3.4: Goods Flow: Extended Model



The model itself will be almost the same as the model detailed in Section 3.4, except for some minimal adjustments in the domestic producers, the balance of payments and the shocks (Figure 3.4).

3.5.1 Domestic Producer

The domestic producer environment is identical to the description in Section 3.4, except for the production function. Each firm's technology is given by $Y_t(j) = A_t N_t^{\psi_p}(j) O_t^{1-\psi_p}(j)$. A_t is the productivity, which is the same for all the firms. The firm's inputs are labor ($N_t(j)$) and oil ($O_t(j)$), and $1 - \psi_p$ is the share of imported inputs in the firm's output.

As detailed in previous sections the law of one price holds for exports but not for imports of consumption goods. In addition, in this section, it is assumed that the law of one price always holds for oil. This means that $P_t^{oil} = e_t P_t^{oil*}$ holds. The argument behind this assumption is that commodities prices (such as oil) are governed by the world prices.

Each firm j sets a mix of inputs ($N_t(j), O_t(j)$) and the price of its product ($P_{H,t}(j)$). In addition, the firms borrow from the banks to finance their working capital (The working capital in this section's model is a fraction Λ of the wage bills plus the cost of oil). The firms borrow at the gross rate R_t^L and pay back at the end of the period.

As in the previous section the problem can be split into two parts: i) finding the minimum cost subject to the technology and ii) finding the optimal price $P_{H,t}^\bullet(j)$. The only difference respect to the model shown before is the cost minimization that will be solved below:

Finding the minimum cost:

$$\text{Min}_{\{N_t(j), O_t(j)\}} (1 - \Lambda)\text{cost}_t(j) + \Lambda R_t^L \text{cost}_t(j) \quad (3.69)$$

s.t.

$$\text{cost}_t(j) \equiv W_t N_t(j) + P_t^{oil} O_t(j) \quad (3.70)$$

$$Y_t(j) = A_t N_t^{\psi_p}(j) O_t^{1-\psi_p}(j) \quad (3.71)$$

FOCs imply:

$$(1 - \Lambda + \Lambda R_t^L) W_t N_t(j) = \text{mc}_{H,t} \psi_p Y_t(j) \quad (3.72)$$

$$(1 - \Lambda + \Lambda R_t^L) P_t^{oil} O_t(j) = \text{mc}_{H,t} (1 - \psi_p) Y_t(j) \quad (3.73)$$

$$\frac{1 - \psi_p}{\psi_p} \frac{W_t}{P_t^{oil}} = \frac{O_t(j)}{N_t(j)} = \frac{O_t}{N_t} \quad (3.74)$$

The variable $\text{mc}_{H,t}$ is the multiplier of the production function, which is interpreted as the nominal marginal cost. It is independent of the amount of inputs hired due to constant returns to scale. Finally by adding Equation 3.72 and 3.73 it is possible express the cost as $(1 - \Lambda + \Lambda R_t^L)[W_t N_t(j) + P_t^{oil} O_t(j)] = \text{mc}_{H,t} Y_t(j)$.

3.5.2 Balance of payments

The change in the debt is identical to the trade balance since foreign households can buy domestic bonds.

$$B_t - R_{t-1} B_{t-1} = P_{H,t} C_{F,t}^* - P_{F,t} C_{F,t} - P_t^{oil} O_t \quad (3.75)$$

3.5.3 Exogenous variables

Four stochastic processes are defined: one for productivity (Equation 3.76), one for the foreign output (Equation 3.77), one for monetary shocks (Equation 3.78) and one for the foreign price of oil (Equation 3.79).

$$\log(A_t) = \rho_a \log(A_{t-1}) + u_{a,t} \quad (3.76)$$

$$\log(Y_t^*) = (1 - \rho_{Y^*}) \log(Y^*) + \rho_{Y^*} \log(Y_{t-1}^*) + u_{Y^*,t} \quad (3.77)$$

$$\xi_{R,t} = \rho_R \xi_{R,t-1} + u_{R,t} \quad (3.78)$$

$$\log(P_t^{oil^*}) = (1 - \rho_{po^*}) \log(P^{Oil^*}) + \rho_{po^*} \log(P_{t-1}^{oil^*}) + u_{po^*,t} \quad (3.79)$$

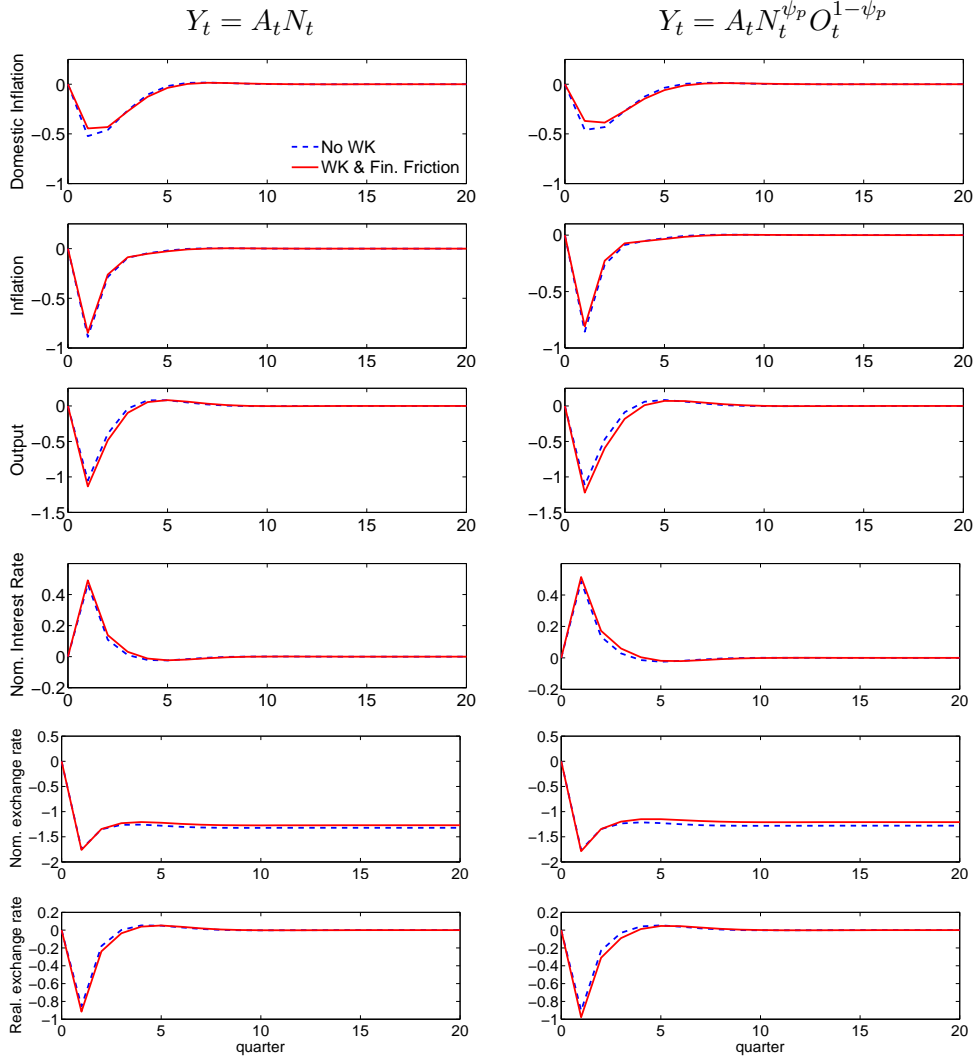
$$\begin{pmatrix} u_{a,t} \\ u_{Y^*,t} \\ u_{R,t} \\ u_{po^*,t} \end{pmatrix} \stackrel{\text{iid}}{\sim} N \left(\begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \end{pmatrix}, \begin{pmatrix} \sigma_{u_a} & \rho_{a,Y^*} & 0 & 0 \\ \rho_{a,Y^*} & \sigma_{u_{Y^*}} & 0 & 0 \\ 0 & 0 & \sigma_{u_R} & 0 \\ 0 & 0 & 0 & \sigma_{u_{po^*}} \end{pmatrix} \right) \quad (3.80)$$

Panel 2 displays the effect of a 100 basis points monetary shock in an open economy with and without imported inputs. The left column presents the model without imported inputs, which assumes that labor is the only input, while the right column presents the model with imported inputs, which assumes that the production requires labor and imported oil. The main point is that the introduction of imported inputs does not substantially modify the results found in the previous section.

Panel 2: Open Economy With Imported Inputs

Impulse Response Function to a 100 Basis Points Monetary Shock

(Charts are in percent from steady state or initial values)



Open economy with imported inputs and without working capital: (right column charts, dashed line) After a monetary shock of 100 basis points the households behave in the same way as described in the previous section. Households reduce consumption as interest rate increases and at the same time they substitute foreign goods for domestic goods in response to the exchange rate appreciation. As in the previous section, the contraction in the domestic households demand for domestic goods induces the domestic firms to reduce prices. Imported inputs imply a reduction in the marginal cost as imported inputs prices diminish after the initial appreciation in the nominal exchange rate. The model predicts that the effect of imported inputs on the marginal cost are

relatively small.

Open economy with imported inputs, working capital and financial frictions (right column charts, solid line): Introducing working capital and financial frictions in the economy with imported inputs does not modify the findings of the previous section. The model will behave in a similar way as explained before except for the firms' responses. After a monetary shock of a 100 basis points the domestic firms face a contraction in their demand, due to the exchange rate and interest rate channel. The domestic firms' costs are modified by the interest rate and also by the exchange rate. As in the case of an open economy without imported inputs, the raise in the interest rates increases the marginal cost encouraging price increments. At the same time the appreciation of the domestic currency implies a reduction in the marginal cost of the domestic firms encouraging reductions in the prices. For the domestic firms, the exchange rate channel and the working capital channel work in opposite directions. The first induces firms to reduce prices while the second stimulates the firms to increase prices. The final outcome predicted by the model is that working capital in an open economy has negligible effects. For an economy with standard parameters of the literature the effects of the working capital channel and the exchange rate channel on the supply are minimal. The intuition is that the large effects of the exchange rate channel on the aggregate demand reduces significantly the market power of the firms, while the effects of the working capital and the exchange rate channel on the aggregate supply are relatively small.

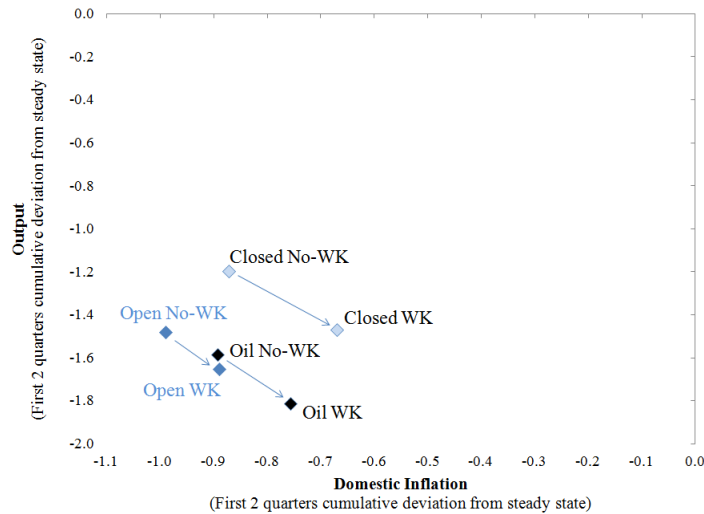
3.6 Summarizing the Models

The models presented can be analyzed by considering the deviation of the domestic inflation and output to monetary shocks. In this case the cumulative deviation will be considered. This measure will be constructed by adding the deviation from the steady state for the first two quarters. During this period the monetary shocks have the strongest effects in the model. The results are plotted in Figure 3.5.

It is possible to observe that the cumulative deviation of the domestic inflation is smaller in a model with working capital and financial friction (dots denoted WK) than in the same model without working capital. A key result is that introducing working capital reduces the response

of domestic inflation in both closed and open economies. The reduction in response of domestic inflation attributed to the introduction of working capital in an open economy is around 1/3 of the reduction in a closed economy attributed to the introduction of the working capital. Finally it is shown that in all the models the transition from an economy without working capital to an economy with working capital and financial frictions implies an increase in the response of output to monetary shocks.

Figure 3.5: Summary - Cumulative Deviations from Steady State



3.7 Conclusion

The main implication of the models we have considered is that the presence of working capital may have very different effects in an open economy compared with a closed economy. While in a closed economy the presence of working capital and financial frictions significantly modify the response of inflation and output to monetary shocks for the model considered, these results do not hold in an open economy.

In a closed economy the presence of working capital and financial frictions reduce the dampening effect of a monetary tightening on domestic inflation. The presence of working capital also increases the sensitivity of output to the interest rate as it affects the marginal cost of the firms. Although these results hold in an open economy, their magnitude is minimal. The first finding is that the presence of working capital will not have critical implications for monetary policy in an open

economy.

The intuition of the argument is that in a closed economy after a monetary shock the dampening of domestic inflation is partially canceled by the increase in the marginal cost generated by the higher cost of borrowing. These effects are very small in an open economy. In an open economy after a monetary tightening, the increase of the interest rate leads to an appreciation of the nominal exchange rate that generates a substitution of foreign goods for domestic goods. This substitution reduces the demand of the domestic firms and motivates price reductions seeking to moderate the demand contraction. The working capital channel becomes negligible, due to the effect of the exchange rate channel.

The second model we considered states that this result is robust to the inclusion of imported inputs in production. The appreciation generates a relatively large substitution in consumption that minimizes any possible effect of imported inputs. The intuition is that the openness significantly constraints the market power of the domestic firm and therefore any effect on the marginal cost has a secondary role.

The main finding is that the presence of working capital is irrelevant for the central bank of a small open economy since the sensitivity of domestic inflation and output are not significantly modified by the presence of working capital. The working capital channel has very small effects in the sensitivity of core economic variables.

A future agenda of extensions should consider the role of the following issues in order to expand the analyses to other environments: i) borrowing in foreign currency by firms, ii) risk premiums in foreign currency bonds, iii) the role of high persistence in habit, iv) physical capital and v) sticky wages.

Appendix A

Appendix - Chapter 1

A.1 Specification

Example of Matrices A and B under a Choleski or recursive identifications.

$$A_0 u_t = B e_t$$

$$\underbrace{\begin{pmatrix} * & 0 & 0 & 0 & 0 \\ * & * & 0 & 0 & 0 \\ * & * & * & 0 & 0 \\ * & * & * & * & 0 \\ * & * & * & * & * \end{pmatrix}}_{A_0} \begin{pmatrix} u_{IP,t} \\ u_{CPI,t} \\ u_{R,t} \\ u_{M1,t} \\ u_{NER,t} \end{pmatrix} = \underbrace{\begin{pmatrix} 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 1 \end{pmatrix}}_B \begin{pmatrix} e_{IP,t} \\ e_{CPI,t} \\ e_{R,t} \\ e_{M1,t} \\ e_{NER,t} \end{pmatrix}$$

This means that the reduced and structural innovations are related in the following way: The reduced innovation of the variable described in the first equation ($u_{IP,t}$) depends contemporaneously only on the structural innovations of itself ($e_{IP,t}$). The reduced innovations of the second variable ($u_{CPI,t}$) depends contemporaneously on the structural innovations of the variable in the first equation ($e_{IP,t}$) and the reduced innovation of itself ($e_{CPI,t}$). The reduced innovations of the third variable ($u_{R,t}$) depend contemporaneously on the structural innovations on the two previous equations ($e_{IP,t}, e_{CPI,t}$) and the structural innovations of itself ($e_{R,t}$), and so on.

A.2 Summary Literature VARs

Table A.1: VARs in Closed Economies

Author	Frequency & Period	Endogenous Variables	Order	# of Lags	Exogenous	Main Conclusion
Sims (1980)	Monthly 1920-41 & 1948-78	Log levels of: IP, WPI, M1 and R (not log)	Choleski R, M1, WPI, IP	12 lags	Intercept	*Money explains substantial part of IP variance. *IP response of R is stable and declines smoothly after 6 months. *IP response to R is small. *documented price puzzle.
Bernanke Blinder (1992)	Monthly 1959-1989	Log levels of: IP (6 other measure of real activity), CPI, M1, R bonds, R, FF (not log)	Choleski IP CPI M FF (also tested for IP FF CPI M)	6 lags	Intercept (also tested with trend)	*FF explains substantial part of the IP variance (not Money).
Christiano, Eichenbaum and Evans (1998)	Quarterly 1965-1995 Monthly 1965-1995	Log levels of: Y, P, Pcom (smoothed change), FF(not log), NBR, TR, M1 (or M2)	Choleski TR, FF, NBR PCOM P, Y	4 lags for Y, P, Pcom 1 lag for FF, NBR, TR, and M1.	Intercept and trend	Sustained decline in real GDP and shows hump shape Initially price responds weakly. After 1.5 years it responds negatively.
Gordon & Leeper (1999)	Monthly 1982-1992	Log levels of: TR, FF(not log), CPI, IP, U(not log), R10(not log), Pcom	Structural TR, FF, CPI, IP, U, R10, Pcom	6 lags	Intercept	Monetary tightening reduces output and prices.
Sims and Zha (1998)	Quarterly 1964-1993	Log levels of: FF (not log), M2, P, Y, W, Pim, Tbk.	Structural specification.	Not specified	Not specified	*Develops a theoretical structural model that supports the structural VAR estimation. *Monetary policy shocks have weak effects on output and strong effects on prices.
Bernanke and Mihov (1998)	Monthly 1965-1996	Log levels of: Real GDP, GDP deflator, Pcom, TR, NBR, FF	Structural TR, FF, NBR	13 Lags	Intercept	*Monetary tightening reduce output and prices *Estimates structural money supply and money demand in order to identify shocks

Notes: IP: industrial production; WPI: Wholesale Price Index; R: Short Term interest Rate; Y: real GDP; P: GDP deflator; Pcom: index of sensitive commodities (CBR); FF: Fed funds rate; TR: Total bank reserves; NBR: Banks non borrowing reserves; W: hourly wage of non farm workers; Pim: producer's price index for intermediate materials; Tbk: bankruptcy filing, personal and business

Table A.2: VARs in Open Economies

Author	Frequency & Period	Endogenous	Order	# of Lags	Exogenous	Main Conclusion
Sims (1992) (Germany, France, UK, Japan and USA)	Monthly 1957-1991	Log levels of: R (in level), M (Non SA), CPI, IP (SA), Pcom, XR.	Choleski R, XR, Pcom, M, CPI, IP, (R impacts cont. all variables, while IP impact cont, on no other variables)	14 Lags	Intercept and Seasonal Dummies	After interest innovation: *Output responds negatively. *Price puzzle. *Exchange rate puzzle. *Introducing commodity price index (proxy for expected inflation) reduces the price and exchange rate puzzles.
Kim & Roubini (1995) (Canada, France, Germany, Italy, Japan, & UK)	Monthly 1974-1992	Log levels of R (in level), M, CPI, IP, Oil Price, FF(in level), XR.	Structural specification (cont. zero restriction)	6 Lags	Intercept and Seasonal Dummies	*Solve price and exchange rate puzzle with structural identification. *Introduce oil price and FF to isolate exogenous monetary policy changes.
Cushman and Zha (1997) (Canada)	Monthly 1974-1993	XR, M1, R, CPI, IP, Exports, Imports, IP*, CPI*, FF, Wxp*	Structural specification (cont.ous zero restriction)	12 Lags	Intercept	After a contractionary monetary policy shock: *Weak effects on output. *Prices fall slowly. *Appreciation of Canadian dollars.
Gerlach & Smets (1995) (G-7 Countries)	Quarterly 1973-1993	D.Y (diff of log), D.CPI(diff of log), R (3 month T-Bills)	Structural specification (cont.ous and long run constrains)	4 Lags	Intercept	*Output falls after interest rate shock. *Prices fall after interest rate shocks for most countries, but some still observe price puzzle.
Smets (1997) (Germany, France & Italy)	Monthly 1979-1996	D.Y(diff of log), D.CPI(diff of log), R (3 month T-Bills), D.XR(diff of log)	Structural specification (cont. and long run constrains)	12 Lags	Intercept	After contractionary monetary policy shock: *Output growth falls and then recovers. *Prices falls. *Exchange rate appreciates.

Notes: IP: industrial production; R: Short Term interest Rate; Y: real GDP; P: GDP deflator; Pcom: commodities price index (not smoothed); FF: Fed funds rate, XR: nominal exchange rate.

A.3 Quarterly Estimations

Figure A.1: Structural I - Quarterly Estimation

Impulse response function in percent points and the 90% confidence interval

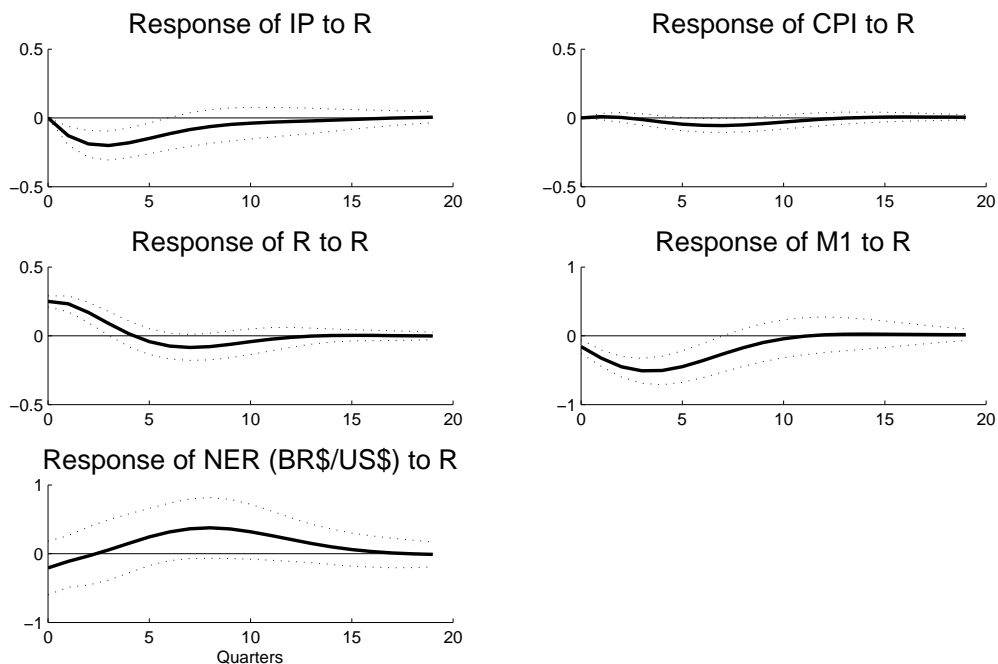


Figure A.2: Structural II - Quarterly Estimation

Impulse response function in percent points and the 90% confidence interval

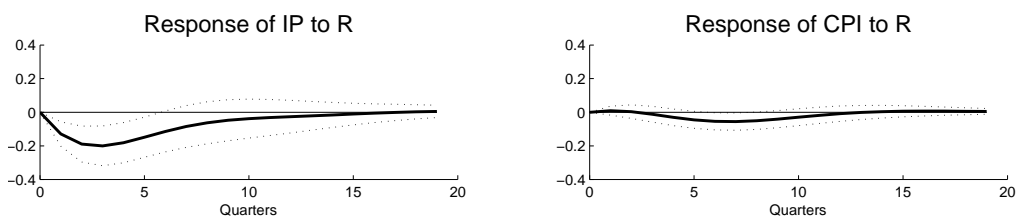


Figure A.3 shows robustness to lag structure and output measured by GDP. Panels A and B show the results of a 2 lags structure while Panels C and D show the results using GDP as output measure.

Figure A.4 shows the robustness results for price measurements. Panels A and B show the results of CPI-Free Prices and Panels C and D show the results of IGP.

Figure A.3: Recursive Specification - Quarterly - Sensitivity to Lags and Output

Impulse response function in percent points and the 90% confidence interval

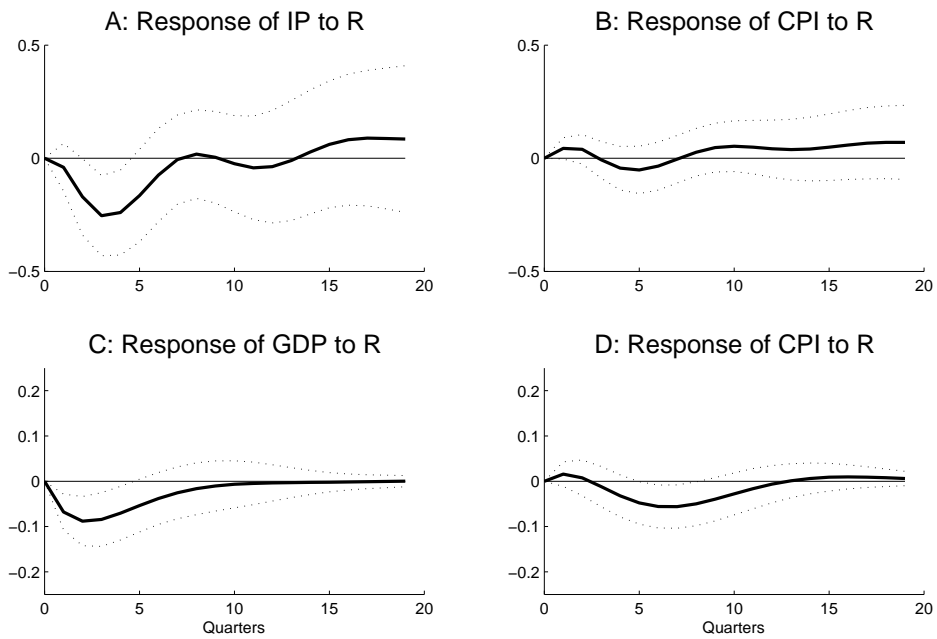


Figure A.4: Recursive Specification - Quarterly - Sensitivity to Price Measures

Impulse response function in percent points and the 90% confidence interval

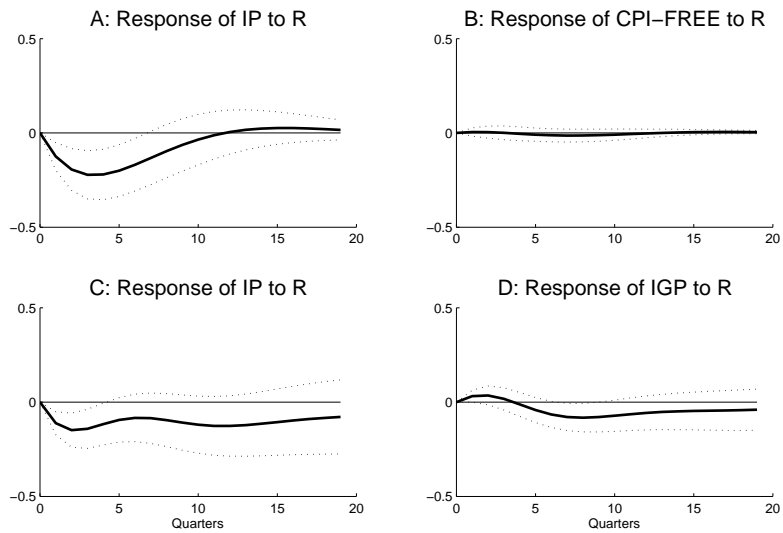
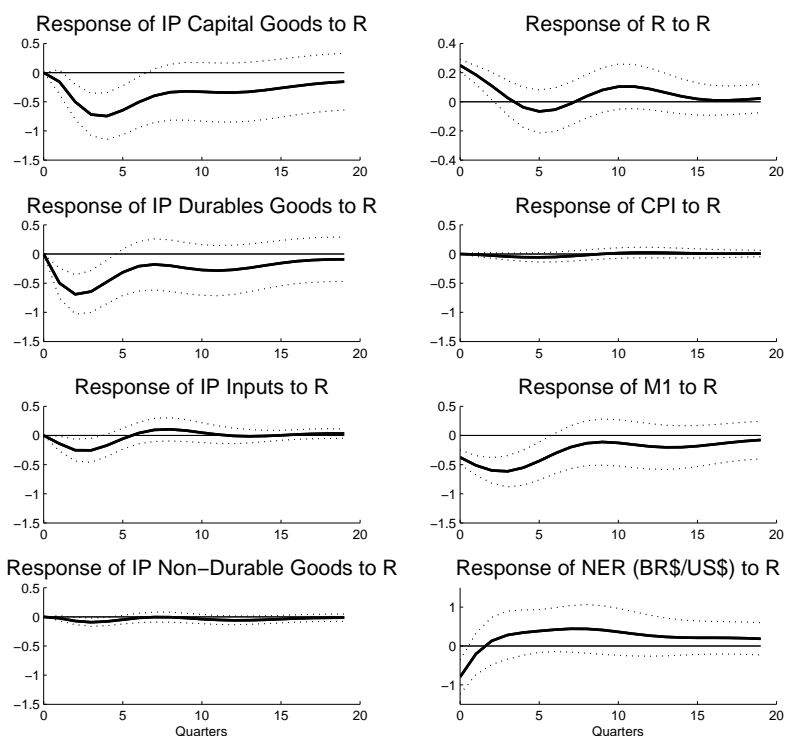


Figure A.5: Industry Effects - Quarterly - Recursive Specification

Impulse response function in percent points and the 90% confidence interval



A.4 Does Monetary Policy Affect the Retail Borrowing Rates?

The goal of this subsection is to show that the rates at which banks lend to firms and households respond to changes in the monetary policy rate. The idea is that changes in the cost of borrowing affect investment and consumption decisions.

In Brazil bank lending is mainly characterized by a low ratio of Loans/GDP and short term lending. The loans of the Brazilian financial system were around 46% of GDP in 2010, which is low compared to South Asian countries (e.g. Korea 73% of GDP). Around 16% of GDP corresponds to earmarked loans mainly provided by the national development bank (BNDES) and 30% of GDP corresponds to non-earmarked loans provided by public and private banks. Lending is mostly short term, with the average maturity of a loan being 1.3 years. The main credit lines for firms are working capital lending, which was around 57% of the loans to firms in 2010. While for households the main credit lines are personal loans and loans for vehicles acquisitions, which were around 49% and 34%, respectively, of the loans to households for 2010.

In order to assess the mentioned effects we estimate a VAR relating the changes of the interest rates of the main credit lines (borrowing rate for Working Capital, Personal Loan and Loans for Vehicles acquisitions) to the changes in the monetary policy rates. Specifically, we analyze the fixed interest rates as the floating interest rates will obviously reflect fluctuations with changes in the monetary policy rates as this is the reference for most floating rates. The sample period is February 1999 until March 2012 and focuses on monthly data to avoid high volatility observed in daily data since information corresponds to new loans. The estimated VAR is set as:

$$Y_t = C(L)Y_t + u_t \quad (\text{A.1})$$

$$Y_t = \begin{bmatrix} \Delta R_t & \Delta LR_t^i \end{bmatrix} \quad (\text{A.2})$$

ΔR_t : monthly change of the average monetary policy rate (SELIC rate)

ΔR_t^i : monthly change of the average bank lending rate

$$i \in \{\text{BRWK}, \text{BRPL}, \text{BRVA}\}$$

BRWK: average Borrowing Rate for Working Capital at a fixed rate.
(non-earmarked resources)

BRPL: average Borrowing Rate for Personal Loans at a fixed rate.
(non-earmarked resources)

BRVA: average Borrowing Rate for Vehicles Acquisition Loans at a fixed rate.
(non-earmarked resources)

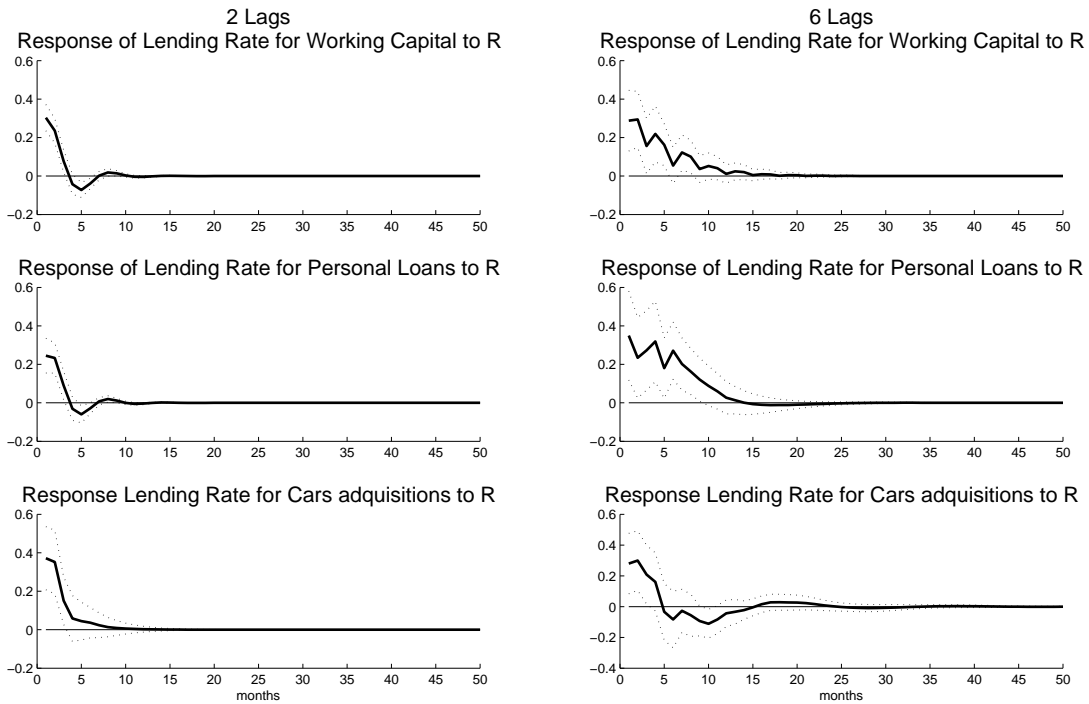
The intuition for this specification is that banks borrow funds at the monetary policy rate, and the central bank is following an inflation targeting scheme with the interest rate as the instrument. Therefore the monetary policy rate is not responding to money demand shocks that would be reflected in the rates at which banks lend.

The estimation results are displayed in Figure A.6 and show the impulse response of each borrowing rate to a 25 basis points shock in the monetary policy rate under two different lag specifications. The evidence shows that the monetary policy rate affects the borrowing rates significantly and quickly. The response is nearly one to one for working capital and vehicles acquisition, and

more than proportional in personal loans. This result is explained by the short term structure of the loans, while the more than proportional response of personal loans can be explained by the changes in probability of default of loans as a result of changes in interest rates.

Figure A.6: Response of Retail Interest Rates

Impulse response function in percent points and the 90% confidence interval



A.5 Lag Structure Tests

Table A.3: Lag structure test

Lag	LR	FPE	AIC	SC	HQ
0	...	4.54e-15	-18.83676	-18.44575	-18.67795
1	2040.552	5.86e-21	-32.39756	-31.51779	-32.04023
2	221.8554	1.70e-21	-33.63940	-32.27088*	-33.08357*
3	58.62284	1.53e-21*	-33.74680*	-31.88951	-32.99245
4	25.16512	1.75e-21	-33.61693	-31.27088	-32.66407
5	35.54424	1.84e-21	-33.57629	-30.74149	-32.42492
6	27.85668	2.05e-21	-33.48411	-30.16055	-32.13422
7	31.44644	2.20e-21	-33.43237	-29.62005	-31.88397
8	41.13318*	2.15e-21	-33.47912	-29.17804	-31.73221
9	24.50896	2.43e-21	-33.38766	-28.59782	-31.44224
10	21.39490	2.82e-21	-33.27690	-27.99831	-31.13297
11	21.10387	3.28e-21	-33.17396	-27.40660	-30.83151
12	24.69374	3.67e-21	-33.12185	-26.86574	-30.58089

* indicates lag order selected by the criterion

LR: sequential modified LR test statistic (each test at 5% level)

FPE: Final prediction error

AIC: Akaike information criterion

SC: Schwarz information criterion

HQ: Hannan-Quinn information criterion

A.6 Stationarity Tests

This appendix supports the discussion on whether the series included in the VAR are trend stationary or first difference stationary. Below I provide some standard unit root tests to determine if the processes are trend stationary or first difference stationary. It is possible to observe that the tests are sensitive to the data sample and the test applied.

Table A.4: Monthly Frequency - Unit Root Tests

	Log(IP)	Log(CPI)	R	Log(M1)	Log(NER)
ADF, Ho=Unit root - P-Value of Rejecting Ho					
1994-2012					
Level (Constant)	0.629	0.045	0.000	0.216	0.003
Level (Constant+Trend)	0.016	0.000	0.000	0.000	0.027
1st. Diff (Constant)	0.000	0.000	0.000	0.000	0.000
2000-2012					
Level (Constant)	0.518	0.572	0.317	0.733	0.333
Level (Constant+Trend)	0.122	0.838	0.019	0.385	0.267
1st. Diff (Constant)	0.000	0.001	0.001	0.000	0.000
Perron-Phillips, Ho=Unit root - P-Value of Rejecting Ho					
1994-2012					
Level (Constant)	0.630	0.000	0.000	0.000	0.000
Level (Constant+Trend)	0.029	0.000	0.000	0.000	0.000
1st. Diff (Constant)	0.000	0.000	0.000	0.000	0.000
2000-2012					
Level (Constant)	0.525	0.416	0.644	0.395	0.387
Level (Constant+Trend)	0.181	0.864	0.260	0.824	0.344
1st. Diff (Constant)	0.000	0.000	0.001	0.000	0.000

Table A.5: Quarterly Frequency - Unit Root Tests

	Log(IP)	Log(CPI)	R	Log(M1)	Log(NER)
ADF, Ho=Unit root - P-Value of Rejecting Ho					
1994-2012					
Level (Constant)	0.615	0.699	0.503	0.641	0.238
Level (Constant+Trend)	0.001	0.000	0.010	0.000	0.691
1st. Diff (Constant)	0.000	0.000	0.000	0.000	0.000
2000-2012					
Level (Constant)	0.494	0.582	0.252	0.663	0.298
Level (Constant+Trend)	0.007	0.754	0.002	0.267	0.291
1st. Diff (Constant)	0.000	0.001	0.000	0.000	0.000
Perron-Phillips, Ho=Unit root - P-Value of Rejecting Ho					
1994-2012					
Level (Constant)	0.542	0.298	0.675	0.076	0.495
Level (Constant+Trend)	0.345	0.874	0.297	0.943	0.549
1st. Diff (Constant)	0.020	0.003	0.052	0.048	0.000
2000-2012					
Level (Constant)	0.494	0.582	0.252	0.663	0.298
Level (Constant+Trend)	0.007	0.754	0.002	0.267	0.291
1st. Diff (Constant)	0.000	0.001	0.000	0.000	0.000

Appendix B

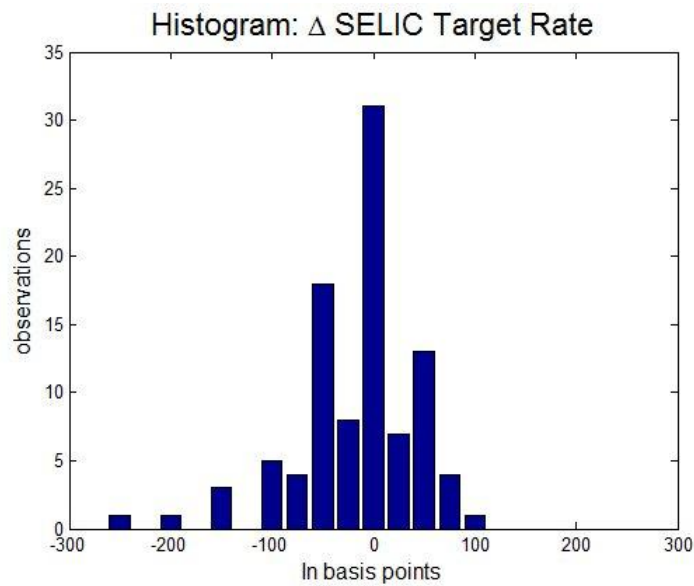
Appendix - Chapter 2

B.1 Summary Statistics

Table B.1: Main Interest Rates

In basis points	Δ Selic Target	$\Delta r(3m)$	$\Delta r(6m)$	$\Delta r(9m)$	$\Delta r(12m)$
Mean	-16.4	-0.8	-0.6	-0.2	0.3
Median	0.0	-0.8	-0.5	0.0	1.1
Std. Dev.	59.5	15.1	18.1	19.0	19.4
Min	-250.0	-58.0	-60.2	-60.3	-58.0
Max	100.0	47.0	68.0	78.0	87.0
no. observations	96	96	96	96	96

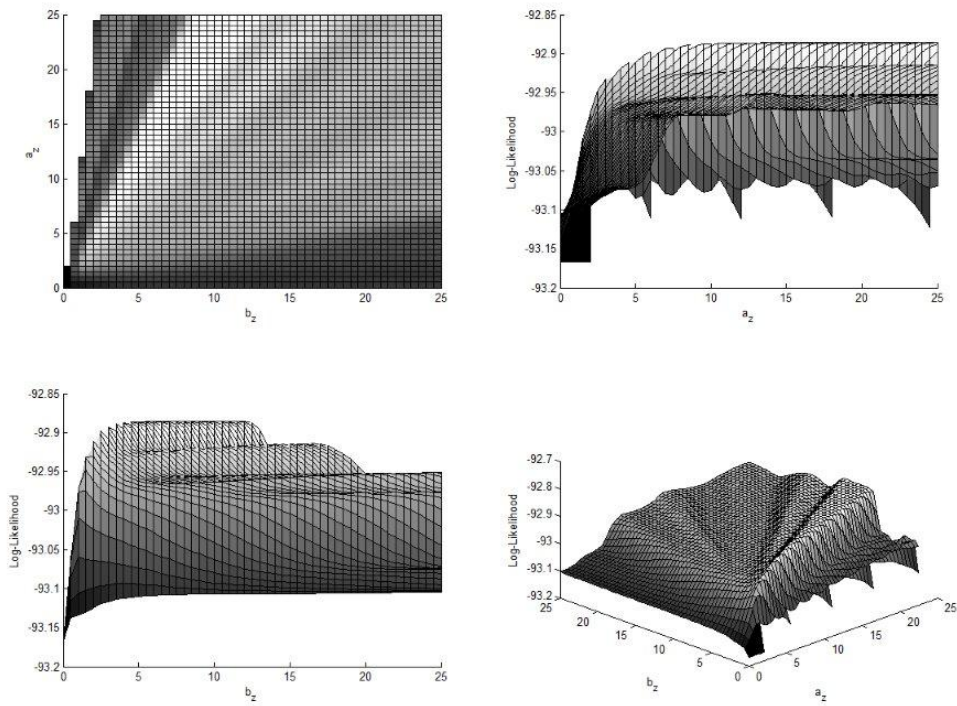
Figure B.1: Monetary Policy Rate



B.2 Log-likelihood Optimization

The log-likelihood has more than one local maximum and a set of global maximums, as shown in the plot below. The plot shows the log-likelihood for the 3 month estimation. This makes the traditional optimizations methods fail when they try to find the maximum. It was found that the estimation was sensitive to the initial values of a_z and b_z but not to the initial values of the rest of the parameters. In order to overcome this issue the estimation was completed using a grid search over the initial values of the parameter a_z and b_z to find the maximum.

Figure B.2: Log-likelihood



B.3 Estimations: Sample 2004-2013

This appendix performs a robustness test of the results by changing the market interest rate measurement and extending the maturity of the interest rates. This appendix considers as the market interest rate, the yields on the zero coupon government bonds. This allows to extend the term structure from 12 to 48 months, but constrains the sample period to January 6, 2004 until May 31, 2013. The analysis shows the robustness of the results found for 3, 6 and 12 month and that the effects of monetary policy for 24 to 48 months are smaller than the 2003-13 sample and in most of the cases nonsignificant.

In a market with low frequency issuance of government bonds like Brazil¹, constant maturity yields are estimated. The procedure consists of fitting a theoretical curve based on observed yields. For this purpose this chapter estimates the term structure of interest rate using yields on LTN and NTN-F. These bonds are issued in the domestic market, denominated in domestic currency and at fixed interest rate. They are relatively liquid in the domestic financial market and therefore reflect reference interest rates. LTN are zero coupon bonds, with maturity (in general) up to 2 years, while NTN-F are bullet bonds that pay interest coupon each semester with maturity longer than 2 years (in general). NTN-F yields have been bootstrapped to get the zero coupon yields.

The estimation of the term structure was done using a Nelson Siegel methodology for each day. The process can be summarized as given the zero coupon yields of LTN and NTN-F. Then for each day the theoretical relation between the yields and the term is estimated. Given these parameters, the constant maturity yields are computed. See Alves and others (2010) for details.

The estimation results show a good fit in general. For example the correlation between the 2 year market interest rate (from Swap DIxPRE 720 days²) and the 2 year yield estimated is 99.9%.

¹Brazil has issued NTN-F, the main medium term bond, on an average of twice a year since 2003. This number of issuance is relatively small compared to the United States where medium term issuance take place every week.

²Two year interest rate from Swap DIxPRE 720 days is a market market rate, but these contracts have only been available since September 9, 2004. The estimation of the government yields curve allows us to start the sample at January 6, 2004. Recall additional observations are very important given the small size of the sample.

The appendix follows the same approach as before. First the changes in the target monetary policy rate have been decomposed into anticipated and unanticipated monetary shocks. Then the change in the market interest rates are regressed on these anticipated and unanticipated changes. The results are presented in Table B.2.³ The first four columns show the estimation using the Swap interest rates (DlxPRE) as the market interest rates while the shaded columns show the estimations using the zero coupon yields as the market interest rate. The estimations indicate that the effects of unanticipated monetary shocks are larger than the effect of anticipated monetary shocks. The estimations using yields show similar results. Using Swaps as market interest rate, an increase of 100 basis points in the monetary policy rate, increases the 12 month interest rate by 73 basis points, while using the government yields as market interest rates the same increment on the monetary policy rate increases the 12 month interest rate by 89 basis points.

Table B.2: Estimation - 2004-2013

Anticipated and Unanticipated Monetary Policy Shocks									
	Δ Market interest rate: (Swaps)			Δ Market interest rate: (Zero coupon yields of government bonds)					
	3m	6m	12m	3m	6m	12m	24m	36m	48m
unanticipated shock	79.12 (9.50) ***	88.90 (15.34) ***	73.17 (20.16) ***	78.02 (12.95) ***	98.98 (18.01) ***	89.50 (22.46) ***	46.23 (24.79) *	25.85 (23.21)	18.67 (47.21)
anticipated shock	13.32 (2.58) ***	15.17 (3.90) ***	13.49 (4.71) ***	22.48 (3.56) ***	15.74 (3.16) ***	8.80 (3.56) **	1.75 (4.45)	-4.88 (5.62)	-11.82 (8.45)
Constant	-6.36 (1.54) ***	-5.64 (2.08) ***	-3.12 (2.53)	-7.57 (1.43) ***	-9.65 (1.66) ***	-7.93 (2.42) ***	-4.09 (3.20)	-4.78 (3.96)	-7.79 (6.11)
Observations	83	83	83	83	83	83	83	83	83
R-squared	0.60	0.44	0.26	0.56	0.48	0.31	0.08	0.03	0.02

Robust standard error in brackets

* significant at 10%; ** significant at 5%; *** significant at 1%

The second important point is that monetary shocks seem to have no effect on the 36 and 48 month interest rates. The effect of monetary policy changes diminishes as the maturity increases. The 12 month rate increases by 89 basis points after a 100 basis points in the target rate while the 48 month rate has a nonsignificant change of 18 basis points.

Finally the appendix computes the response of the shocks in the different states. The results (shown in Table B.3) considering as the market interest rates the yields of government bonds show similar results to the find in the paper. Changes in the monetary policy rate have stronger effect

³All the tables presented in this appendix corresponds to the change of t-2 days. The reason is that the prices of bonds are measured at the opening of the session and therefore do not fully reflect the effect of the monetary policy change.

during expansions. Although these results are aligned with the previous section, the results are highly sensitive to the sample when government yields are considered as market interest rates.

Table B.3: State Dependent Estimation - 2004-2013

State: Low Activity									
Anticipated and Unanticipated Monetary Policy Shocks (change t-2: Sample 2004-2012)									
	Δ Market interest rate: Swaps			Δ Market interest rate: Zero coupon yields of gov. bonds					
	3m	6m	12m	3m	6m	12m	24m	36m	48m
unanticipated shock	61.80 (11.94) ***	57.20 (18.12) ***	48.92 (25.42) *	27.39 (40.36)	21.60 (48.21)	1.06 (34.98)	8.60 (28.44)	33.70 (29.31)	45.90 (29.87)
anticipated shock	10.98 (4.08) **	11.86 (6.78) *	11.21 (10.60)	8.35 (11.84)	6.65 (10.56)	3.35 (8.67)	-3.69 (7.88)	-9.58 (7.92)	-10.50 (8.37)
Constant	-5.70 (2.53) **	-4.57 (2.43) *	-2.63 (6.17)	-16.88 (10.79)	-14.20 (11.11)	-8.07 (9.15)	-7.43 (9.82)	-11.25 (9.51)	-8.96 (9.91)
Observations	34	34	34	11	11	11	11	11	10
R-squared	0.59	0.35	0.16	0.09	0.05	0.01	0.02	0.18	0.25
Sigma ²	0.51	1.28	2.76	4.24	4.72	3.02	1.50	1.68	1.96
State: High Activity									
Anticipated and Unanticipated Monetary Policy Shocks (change t-1: Sample 2004-2012)									
	3m	6m	12m	3m	6m	12m	24m	36m	48m
	unanticipated shock	89.89 (10.80) ***	105.29 (18.12) ***	83.78 (25.69) ***	87.50 (11.63) ***	111.26 (17.51) ***	103.44 (24.68) ***	52.16 (29.10) *	23.98 (27.45)
anticipated shock	17.54 (4.57) ***	19.59 (6.78) ***	14.93 (8.18) *	23.76 (3.09) ***	15.98 (3.66) ***	9.22 (5.15) *	1.78 (6.44)	-5.84 (8.09)	-12.46 (11.70)
Constant	-7.94 (1.70) ***	-7.54 (2.43) ***	-3.96 (3.16)	-8.01 (1.35) ***	-10.32 (1.73) ***	-8.88 (2.67) ***	-4.37 (3.52)	-4.34 (4.31)	-7.38 (6.61)
Observations	49	49	49	72	72	72	72	72	73
R-squared	0.58	0.44	0.26	0.62	0.55	0.37	0.09	0.02	0.01
Sigma ²	1.24	2.90	4.13	1.12	1.89	3.27	4.81	8.17	21.90
States probability									
	3m	6m	12m	3m	6m	12m	24m	36m	48m
	IP-Gap	25.00 (0.03) ***	25.00 (0.03) ***	25.00 (0.03) ***	15.00 (0.03) ***	15.00 (0.03) ***	15.00 (0.03) ***	15.00 (0.03) ***	15.00 (0.03) ***
Const	3.50 (0.11) ***	3.50 (0.11) ***	3.50 (0.11)	25.00 (0.11) ***	25.00 (0.11) ***	25.00 (0.11) ***	25.00 (0.11)	25.00 (0.11)	25.00 (0.11)
Robust standard errors in brackets									
* significant at 10%; ** significant at 5%; *** significant at 1%									
# obs. In State Low	34	34	34	11	11	11	11	11	10
# obs. In State High	49	49	49	72	72	72	72	72	73

Appendix C

Appendix - Chapter 3

C.1 Log-Linear Model - Section 3.3

Log-linearizing around steady states, the system of equations reduces to 17 unknowns and 17 equations that define an equilibrium. The solution of the model was computed using the Blanchard Kahn Method. For any variable K_t , $k_t \equiv \log(K_t)$, \bar{K} denotes the steady state of the variable and I define $\tilde{k}_t \equiv k_t - \bar{k}_t$. After several algebraic steps and transforming some variables to turn them stationary (real wage: $wp_t \equiv \frac{W_t}{P_t}$, Gap Law of One Price $glop_t \equiv e_t + P_t^* - P_{F,t}$), the equilibrium consists of 14 endogenous variables ($\tilde{y}_t, \tilde{c}_t, \tilde{R}_t, \tilde{R}^{L_t}, \tilde{r}\tilde{m}c_{H,t}, \tilde{s}_t, \tilde{q}_t, \Delta\tilde{e}_t, \tilde{\pi}_t, \tilde{\pi}_{H,t}, \tilde{\pi}_{F,t}, \tilde{n}_t, \tilde{w}p_t, glop_t$), and 3 exogenous variables ($\tilde{a}_t, \tilde{\pi}_t^*, \tilde{y}_t^*$).

Exogenous Variables

$$\tilde{a}_t = \rho_a \tilde{a}_{t-1} + u_{a,t} \tag{C.1}$$

$$\tilde{y}_t^* = \rho_a \tilde{y}_{t-1}^* + u_{y^*,t} \tag{C.2}$$

$$\tilde{\pi}_t^* = 0 \tag{C.3}$$

Endogenous Variables

Euler Equation

$$\tilde{c} = \frac{1}{1+h} \tilde{c}_{t+1} + \frac{h}{1+h} \tilde{c}_{t-1} - \frac{1-h}{(1+h)\sigma} (\tilde{R}_t - \tilde{\pi}_t) \tag{C.4}$$

Labor-Consumption condition

$$\tilde{w}p_t = \phi\tilde{n}_t + \frac{\sigma}{(1-h)}(\tilde{c}_t - h\tilde{c}_{t-1}) \quad (\text{C.5})$$

Marginal Cost

$$\mathbf{r}\tilde{\mathbf{m}}\mathbf{c}_{H,t} = \tilde{w}p_t + (\tilde{p}_t - \tilde{p}_{H,t}) + \frac{\Lambda\bar{R}}{1-\Lambda+\Lambda\bar{R}}\tilde{R}^L_t \quad (\text{C.6})$$

Domestic Goods Phillips Curve

$$\tilde{\pi}_{H,t} = \left(\frac{b}{1+b\beta}\right)\tilde{\pi}_{H,t-1} + \left(\frac{\beta}{1+b\beta}\right)\tilde{\pi}_{H,t+1} + \left(\frac{\lambda_H}{1+b\beta}\right)\mathbf{r}\tilde{\mathbf{m}}\mathbf{c}_{H,t} \quad (\text{C.7})$$

Imported Goods Phillips Curve

$$\tilde{\pi}_{F,t} = \left(\frac{b}{1+b\beta}\right)\tilde{\pi}_{F,t-1} + \left(\frac{\beta}{1+b\beta}\right)\tilde{\pi}_{F,t+1} + \left(\frac{\lambda_F}{1+b\beta}\right)g\tilde{l}o\mathbf{p}_t \quad (\text{C.8})$$

Terms of Trade

$$\Delta\tilde{s}_t = \tilde{\pi}_{F,t} - \tilde{\pi}_{H,t} \quad (\text{C.9})$$

Real Exchange Rate

$$\tilde{q}_t = \tilde{q}_{t-1} + \Delta\tilde{e}_t + \tilde{\pi}^* - \tilde{\pi}_t \quad (\text{C.10})$$

International Risk Sharing Condition

$$\tilde{c}_t = h\tilde{c}_{t-1} + (\tilde{c}_t^* - h\tilde{c}_{t-1}^*) + \frac{1}{\sigma}\tilde{q}_t \quad (\text{C.11})$$

Production Function

$$\tilde{y}_t = \tilde{a}_t + \tilde{n}_t \quad (\text{C.12})$$

Equilibrium in the Goods Market

$$\tilde{y}_t = \tilde{c}_t + \alpha\frac{\eta-1}{\sigma}\tilde{q}_t + \alpha(\gamma-\eta)g\tilde{l}o\mathbf{p}_t \quad (\text{C.13})$$

Monetary Rule

$$\tilde{R}_t = (1 - \phi_R)\phi_\pi\tilde{\pi}_t + \phi_R\tilde{R}_{t-1} + u_{R,t} \quad (\text{C.14})$$

Lending Rate Firms

$$\tilde{R}_t^L = (1 + \Psi(\bar{R}))\tilde{R}_t \quad (\text{C.15})$$

Link CPI-Terms of Trade

$$\tilde{\pi} = \tilde{\pi}_{H,t} + \alpha\Delta\tilde{s}_t \quad (\text{C.16})$$

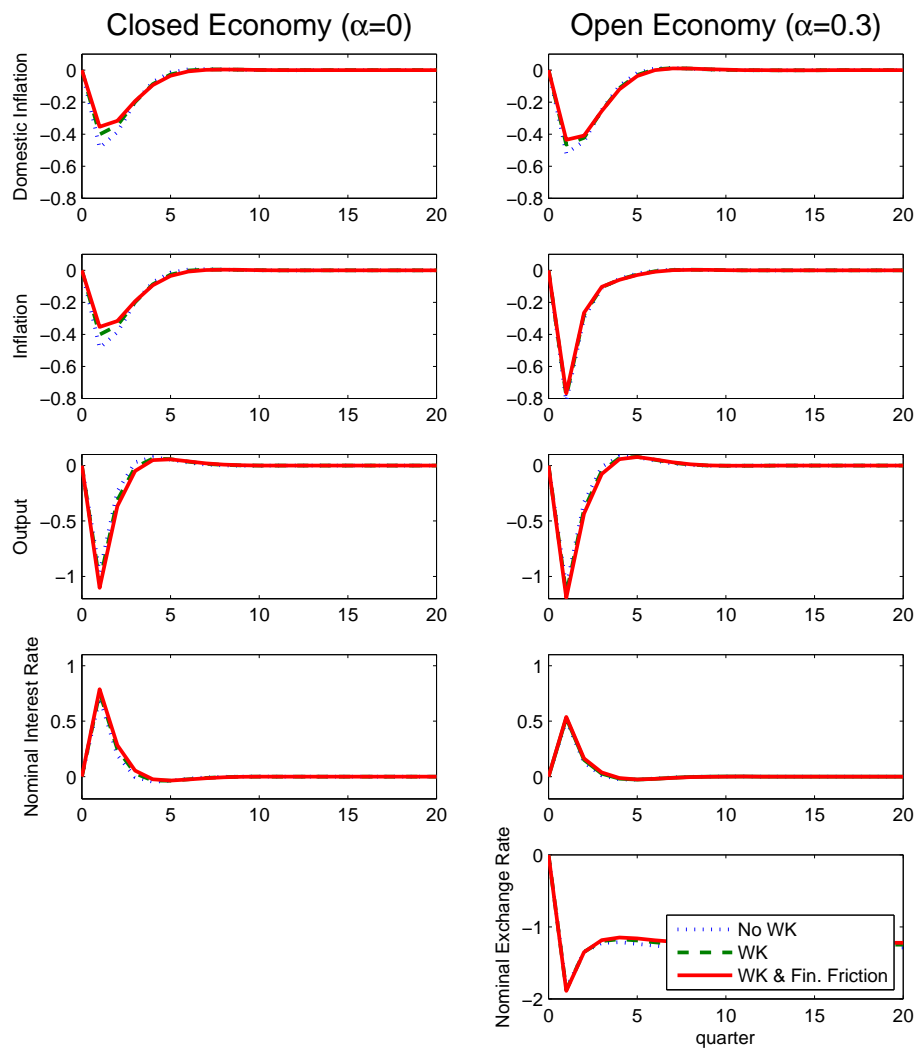
Foreign Economy

$$\tilde{c}_t^* = \tilde{y}_t^* \quad (\text{C.17})$$

C.2 Working Capital Without Financial Frictions

Figure C.1: The Effect of Financial Frictions

Impulse response function to 100 basis points Monetary Shock



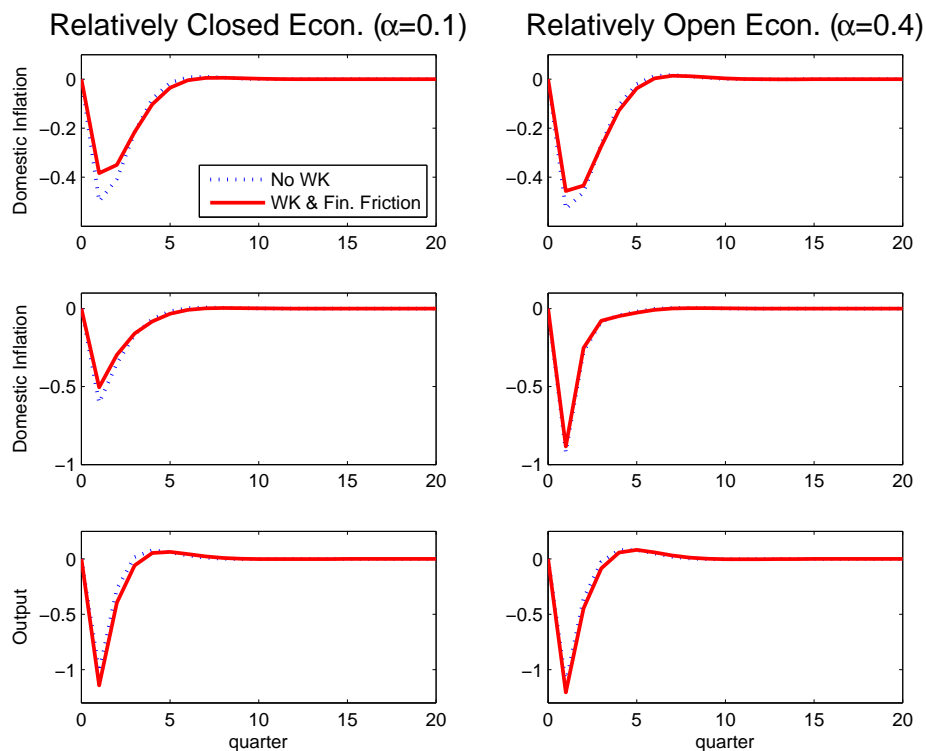
C.3 Sensitivity Analysis

C.3.1 Openness

This appendix inquires about the sensitivity of the results to structural parameters of the economy. It asks how robust are the results found in Section 3.4 to other parameter specifications. For this reason four dimensions are analyzed. This includes the robustness to the openness, degree of pass-through, degree of indexation of the economy and smoothing of monetary policy rule. The results signal that only openness significantly affect the results detailed in Section 3.4.

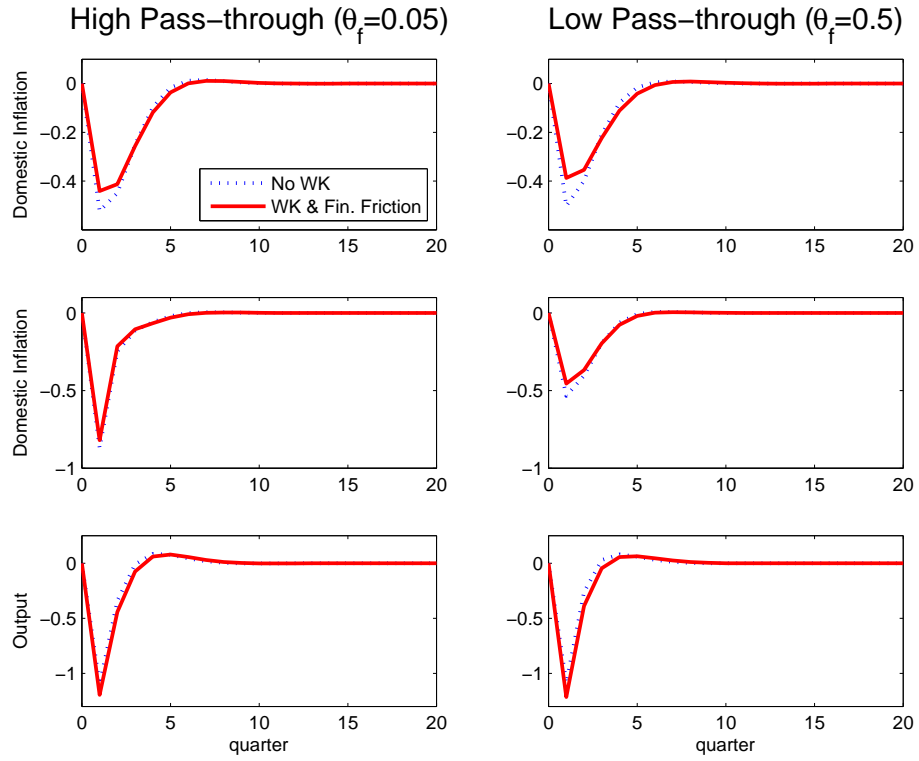
Figure C.2: Sensitivity to Openness Degree

Impulse response function to 100 basis points Monetary Shock



C.3.2 Pass-through

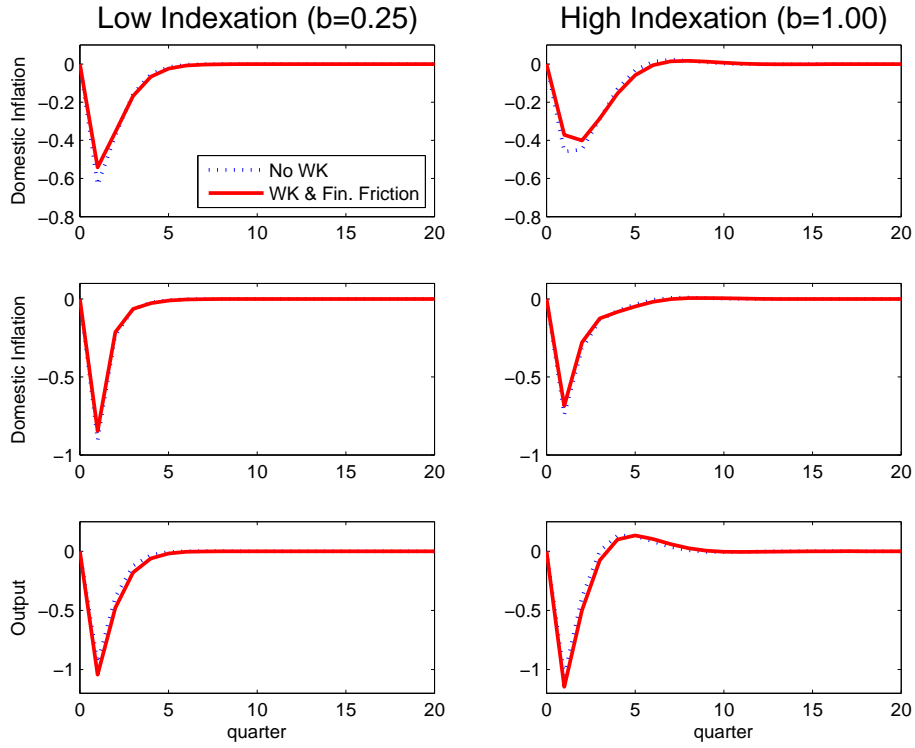
Figure C.3: Sensitivity to Pass-through in Exchange Rate
Impulse response function to 100 basis points Monetary Shock



C.3.3 Indexation

Figure C.4: Sensitivity to Indexation

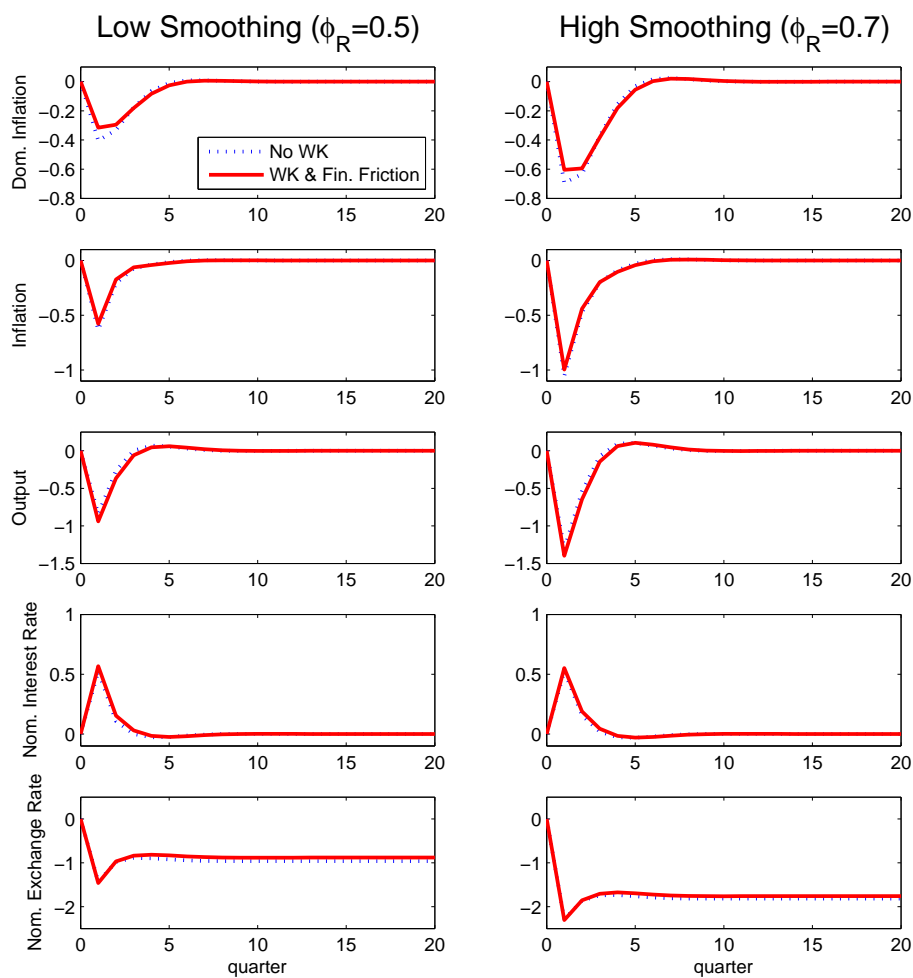
Impulse response function to 100 basis points Monetary Shock



C.3.4 Monetary Rule Interest Rate Smoothing

Figure C.5: Sensitivity to Smoothing of Interest Rate in the Monetary Rule

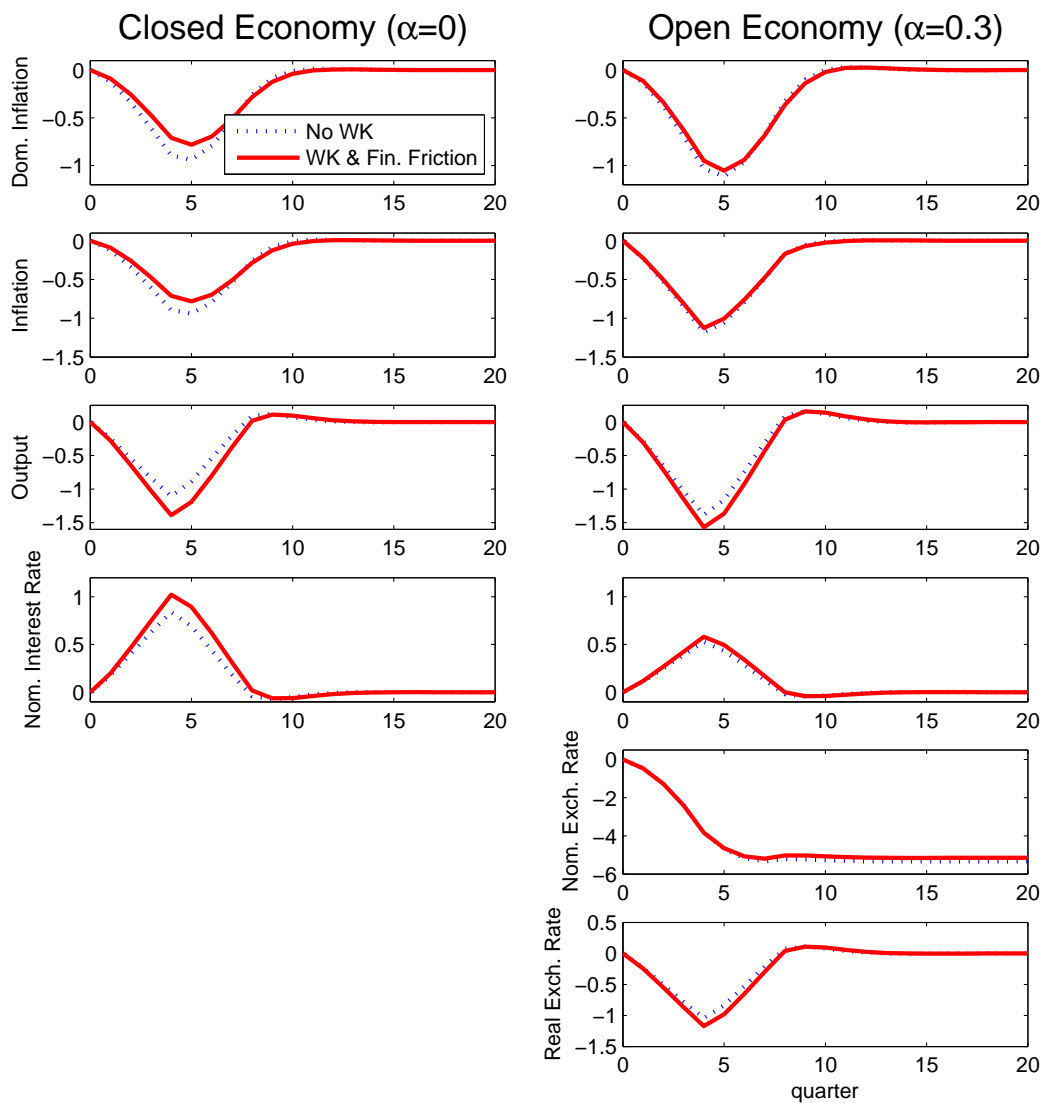
Impulse response function to 100 basis points Monetary Shock



C.3.5 Alternative Monetary Shocks

Figure C.6: Effect of Consecutive Shocks

Impulse response function to a 25, 50, 75, 100, 75, 50, 25 basis points sequence of monetary shock



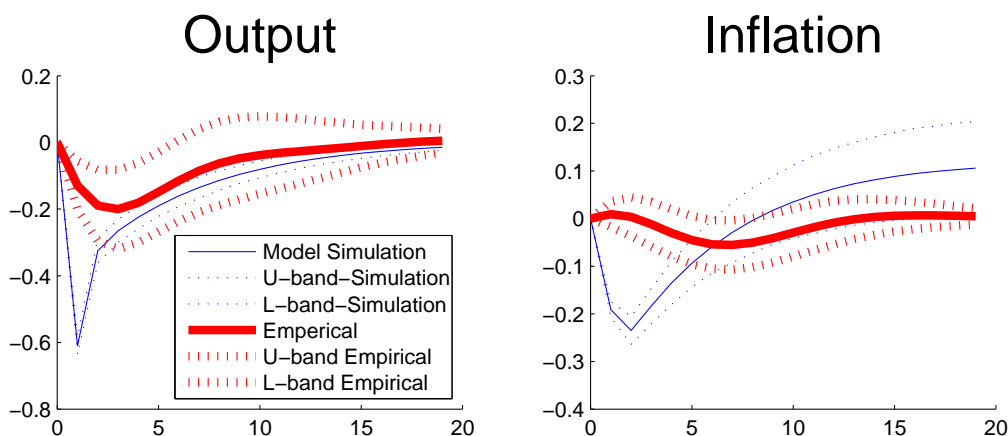
C.3.6 Accuracy of the Model

In this appendix I provide a glance of the accuracy of the model by comparing it with empirical impulse responses found in chapter 1. I simulate the model for 1000 periods and I compare with the impulse responses estimated from a VAR. The accuracy of the model is not high and that is explained by several factors. First of which is the simplifying assumptions used. The model does not include rigidities in nominal wages which will smooth the response of the output. The second reason for the low fitting is the omission of variables in the VAR estimation. E.g. Productivity is not directly observed and therefore it is not included in the VAR estimation.

Although the model does not accurately approximate the empirical VAR impulse responses, the qualitative and relative magnitude of the impulse responses signal that the model contains some of the key features that drive these variables.

Figure C.7: Empirical Results Vs Simulation Estimation

Impulse response function to 100 basis points Monetary Shock



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