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# **Towards a “New” Inflation Targeting Framework:**

## **The Case of Uruguay**

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**Inter-American Development Bank**  
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## Abstract<sup>1</sup>

Using a dynamic stochastic general equilibrium model with financial frictions, this paper evaluates the effects of a rule that incorporates not only the interest rate but also the legal reserve requirements as instruments of monetary policy. It is found that reserve requirements can be used to achieve the Central Bank's inflation objectives. The use of this instrument, however, produces a real appreciation of the Uruguayan peso. When the Central Bank uses the monetary policy rate as an instrument, the effect of an increase in reserve requirements is to contribute to reducing the negative impact on consumption, investment and output. Nevertheless, the quantitative results in terms of inflation reduction are rather poor. The policy rate becomes more effective in reducing inflation when the reserve requirement instrument is solely directed at achieving financial stability. The paper's main policy conclusion is that a well-targeted non-conventional policy instrument can help to effectively control inflation.

**JEL classification:** C61, C68, E52, E58

**Keywords:** Inflation targeting, Dynamic general equilibrium models, Monetary policy, Non-conventional instruments, Reserve requirements

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# 1 Introduction

The popularity of inflation targeting policies may be attributed to the fact that many empirical studies in the late 1980s suggested that monetary policy may have significant influence on the short-run dynamics of the real economy. On the other hand, theoretical and empirical work support the idea that, in the long run, monetary policy can only systematically affect the levels of nominal variables but not those of the real variables.

Recent developments in monetary economics provide a theoretical framework for the implementation of policy rules. For example, Taylor (1993) recommends the use of a simple interest rate rule that is a function of inflation and the output gap. Since that recommendation, it has become standard to use dynamic stochastic general equilibrium (DSGE) and new Keynesian models which typically propose the use of augmented rules to characterize Federal Reserve policy. The evaluation of the success of the alternative policy rules is usually assessed in terms of the short-run dynamics of the relevant macroeconomic variables.

Recently, several Central Banks in Latin America have adopted inflation targeting policies which have been relatively successful in reducing inflation without generating negative effects on real activity. Nevertheless, the short-run effects of these policies are not obvious since there are multiple ways to conduct monetary policies which differ on, among other things, the instruments chosen to achieve the target and on the type of target itself. Hence, in order to evaluate the costs of alternative policies under inflation targeting, it is important to understand the dynamics of the economy for the different possible specifications of the policy rule.

Using a relatively standard small open economy model with sticky prices, financial frictions and, a banking sector that is subject to legal reserve requirements this paper explores the impact on the Uruguayan economy of using conventional and non-conventional tools to meet inflation and/or financial stability objectives. Analyzing the costs and benefits of these policies is particularly interesting for Uruguay, whose Central Bank engineered one of the most successful recoveries from a financial crisis in the past 20 years.

Uruguay had a major crisis in 2002 that began in the financial sector and was largely caused by external factors - primarily a financial crisis in neighboring Argentina, during which Argentines withdrew a large portion of their deposits from Uruguayan banks. To help maintain monetary control with the onset of a new floating exchange rate regime, Uruguay implemented an inflation targeting policy in 2002. Over the next 10 years the central bank of Uruguay used different instruments to achieve financial and economic stability for an economy highly dollarized and vulnerable to the effects of external shocks, like the recent global financial crisis of 2008. This context provides a unique opportunity to study not only the evolution of the Uruguayan economy, but also to empirically evaluate the effectiveness of the different policy tools and their implications depending on the nature of shocks. In this line of thinking, this paper introduces a theoretical model that can

be used to compute costs and benefits of the alternative policies implementing inflation targeting (IT). Based on our results, we are able to make specific policy recommendations for the Uruguayan economy.

The rest of the paper is organized as follows. The next section describes the monetary policy implemented in Uruguay from 2002 to 2012 and studies the evolution of the main macroeconomic variables. Section 3 describes the theoretical framework used to evaluate the impact on the economy of the different policy tools the Central Bank of Uruguay used to achieve its inflation, outcome and financial stability objectives. This section describes the data used, the calibrating parameters and the Bayesian estimation strategy. Section 4 describes the impulse response analysis. The main findings are the following. First, reserve requirements can be used to achieve the inflation objectives of the Central Bank. However, reducing inflation using this instrument also produces a real appreciation of the Uruguayan peso. Second, when the Central Bank uses the monetary policy rate as an instrument, the effect of the reserve requirements is to contribute to reducing the negative impact on consumption, investment and output of an eventual increase in this rate. Nevertheless, the quantitative results in terms of inflation reduction are rather poor. Third, the monetary policy rate becomes more effective in reducing inflation when the reserve requirement instrument is solely directed at achieving financial stability and the monetary policy rate is used to achieve the inflationary target. Section 5 concludes the paper, describing our policy recommendations. The main policy conclusion of the paper is that having a non-conventional policy instrument, when well targeted, can help effectively inflation control. Moving reserve requirements can also be instrumental in offsetting the impact of monetary policy on the real exchange rate. The paper includes several technical appendices presenting formally the theoretical model, its calibration and estimation, prior and posterior distributions of the estimated parameters and some impulse response functions not described in the main text.

## **2 Inflation Targeting in Uruguay**

In this section we analyze the evolution of monetary policy and the main macroeconomic variables in Uruguay since 2002.

### **2.1 Monetary Policy**

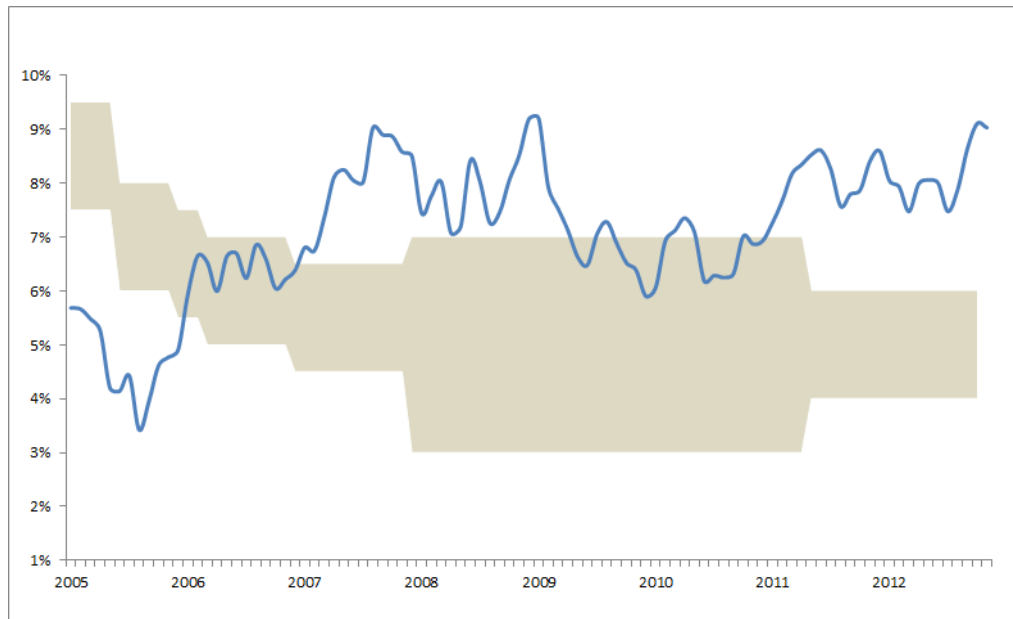
In 2001-2002 a huge economic crisis in neighboring Argentina dramatically affected the Uruguayan economy. The crisis had real effects on the economy, reflected in a drastic reduction of exports to Argentina. Deposits of foreign currency in the financial sector decreased significantly as a consequence of spillover effects of the bank run in Argentina. To help maintain monetary control with the onset of a new floating exchange rate regime, Uruguay began the implementation of an inflation targeting policy in 2002.

In June 2002 Uruguay abandoned an exchange rate peg and started to use the monetary base as the nominal anchor for the economy. Since that time the country has pursued important monetary and financial reforms. It improved financial prudential norms and supervision of the banking system, and it accumulated significant Central Bank reserves. With these reforms in place, the dollarization of the banking system declined slightly and Uruguay began to change the way it conducts monetary policy. It moved gradually towards an inflation targeting regime in which the Central Bank's goal was to keep overall price increases within a target range.

Starting in 2004 the Central Bank showed a stronger commitment to keeping an inflation target, moving from a point target for the monetary base to a band, with the objective of fulfilling the inflation targets. In November of 2004 the Central Bank announced a targeted inflation range of 6 to 8 percent by September 2005 (see Figure 1). In 2005, the Central Bank abandoned the monetary base target, keeping the inflation target as the only target of the monetary policy. The Central Bank moved to a policy rate instrument in September 2007. Since then, the main inflation targeting tool in Uruguay has been the short-run interest rate. There is some evidence (International Monetary Fund, 2011) that, after the introduction of this policy rate as the main monetary policy instrument, the credibility of the inflation target increased significantly, and there has been significant pass-through from the policy rate to both lending and deposit rates. An inflation targeting regime implies that monetary policy decisions are initially transmitted to the rest of the economy through the effect of the policy rate on the money market rate, and changes in the money market rate are in turn transmitted to deposit and lending rates, thus affecting the consumption and saving decisions of individuals and firms, and hence aggregate demand and inflation. Moreover, as domestic and foreign interest rates in Uruguay differ for comparable assets, arbitrage between them gives rise to nominal exchange rate fluctuations, which in turn affect inflation and economic activity through the so-called exchange rate channel.

The country was able to introduce and maintain a full-fledged inflation targeting regime in a framework of greater prudential norms and supervision of the banking sector, greater transparency of the monetary policy and greater Central Bank credibility. Inflation, which at first fell from 9.6 percent (year to year change) in September 2004 to almost 4 percent in September 2005 had begun to display an increasing pattern, reaching around 9 percent in September 2007 (see Figure 1). A Macroeconomic Coordination Committee (Comité de Coordinación Macroeconómica) was created to set the inflation targets. The committee is composed of three Central Bank board members plus the Minister of Finance and two representatives of the Ministry of Finance. The Monetary Policy Committee (Comité de Política Monetaria, COPOM), composed of six Central Bank members (three board and three staff members), is in charge of setting the parameters of the monetary policy in Uruguay to meet inflation targets. As mentioned above, this committee began setting the monetary policy rate (the daily interbank market rate) in early September 2007 at 5

**Figure 1. Annual Inflation and Inflation Target Zone**



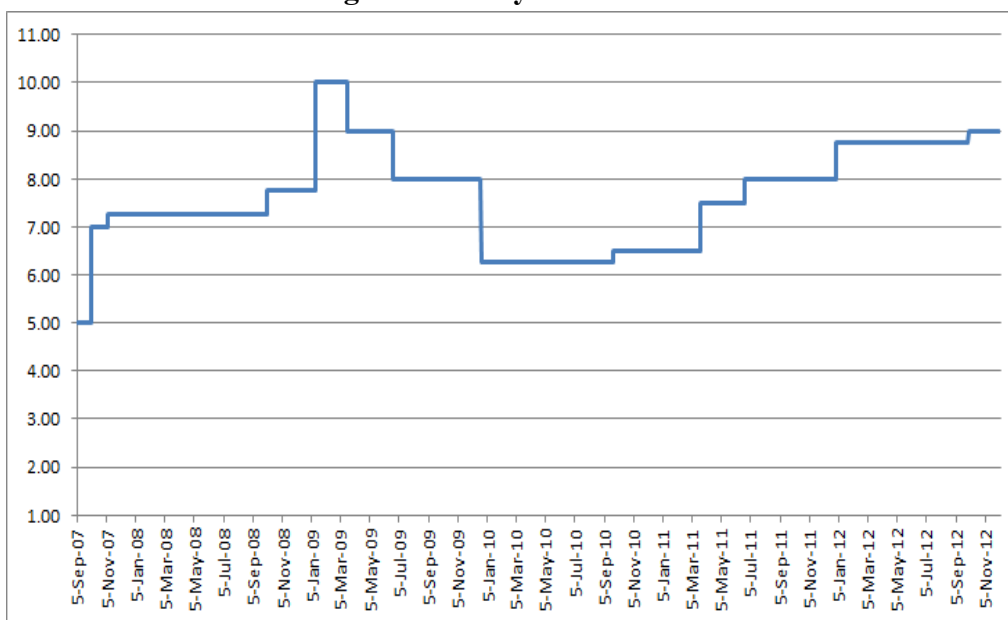
*Source:* Authors' calculations using data from the Central Bank of Uruguay.

percentage points through October 3, when this policy rate was raised to 7 percentage points. The policy rate was increased by 0.25 in early November 2007 and maintained at 7.25 percent through the first days of October 2008 (see Figure 2).

In this context, in January 2008, the Macroeconomic Coordination Committee decided to change the inflation target from a range of 4 to 6 percent to a wider range of 3 to 7 percent. According to the committee, the reasons behind this change were high volatility in international financial markets, mainly due to the Lehman Brothers' crisis, and the vulnerability of the Uruguayan economy to external shocks (see Comunicados del COPOM (2007-2012)). In July of that year the committee withheld the inflation range of 3 to 7 percent for the next 18 months. In the first days of October 2008, the Monetary Policy Committee raised the policy interest rate from 7.25 to 7.75 percent (see Figures 1 and 2). At the same time, the Central Bank began to use a non-conventional tool, reserve requirements, as a monetary policy instrument to complement the setting of the policy rate. In June 2008, the Central Bank increased to 25 percent the reserve requirements for deposits in domestic currency and to 35 percent for deposits in foreign currency. For public sector deposits in the Banco de la República Oriental del Uruguay (BROU) the reserve requirements were set at 100 percent. Moreover, the Central Bank decided to eliminate reserves remuneration, and it established penalties for banks not fulfilling the reserve requirements. The Central Bank President at that time, Walter Cancela, explained that the objective of the increase in reserve requirements



**Figure 2. Policy Interest Rate**



Source: Central Bank of Uruguay.

was twofold: first to contain inflation and second to de-dollarize the economy (see Archivos de la Presidencia de la República Oriental del Uruguay (2002-2011)).

Since the beginning of 2008 the inflationary situation had improved despite the fact that the core inflation measures were still above the inflation target. In January 2009, in spite of the negative external scenario, with the inflation rate peaking at around 9 percent, the Monetary Policy Committee decided to increase the policy rate from 7.75 percent to 10 percent. In March 2009 the Central Bank reversed its strategy, changing the policy interest rate from 10 to 9 percent while keeping its contractionary monetary policy. By June 2009 the inflation rate was within the target zone, and the Central Bank decided to cut the policy rate from 9 to 8 percent. In December 2009, the Macroeconomic Coordination Committee reduced the inflation target zone from 3 to 7 percent to 4 to 6 percent, and the Central Bank reduced the policy rate to 6.25 percent (see figures 1 and 2). In addition to these cuts in the policy rate, the Central Bank began a policy of reduction of reserve requirements. In September 2009, the Central Bank reduced to 20 percent the reserve requirements for deposits in domestic currency and to 30 percent the reserve requirements for deposits in foreign currency. Furthermore, since January 2010 the reserve requirements for deposits in domestic currency was cut from 20 to 12 percent, and since July 2010 the reserve requirement for deposits in foreign currency (of maturity less than 180 days) was set at 15 percent, and for deposits of longer maturity at 9 percent. At the beginning of 2010 the inflationary situation worsened and the possibility that inflation would be above the target zone began to emerge. In

response to this situation, in September 2010 the Central Bank increased the policy rate to 6.50 percent and kept it at that level until March 2011. By that time it was clear that inflation was not under control, and inflation expectations were above the inflation target range. In this scenario the Central Bank raised the policy interest rate to 7.5 percent. Because of the inflation situation in mid-year 2011, the Central Bank of Uruguay decided to strengthen monetary policy and raised the average reserve requirements on deposits. This pushed the marginal reserve requirement up sharply, with different ranges for pesos and foreign currency. Marginal reserve requirements were created for domestic and foreign currency deposits. Table 1 shows the reserve requirement ranges for domestic and foreign currency deposits.

**Table 1. Reserve Requirements Rates for Deposits in Domestic and Foreign Currency**

	Deposits in Domestic Currency			
Maturity	Old	New	Marginal	Total Requirement
less than 30 days	12	15	15	30
30 to 90 days	9	9	15	24
90 to 180 days	6	6	15	21
180 to 365 days	4	4	15	19
more than 1 year	0	0	15	15
	Deposits in Foreign Currency			
Maturity	Old	New	Marginal	Total Requirement
less than 180 days	15	18	27	45
more than 180 days	9	14	27	41

*Source:* Central Bank of Uruguay

Marginal reserve requirements were created for banks holding deposits in excess of average deposits in April 2011. The marginal reserve requirement was set at 15 and 27 percent for deposits in domestic and foreign currency, respectively. The Central Bank also changed the remuneration rates for reserve requirements. Table 2 shows the old and new remuneration rates.

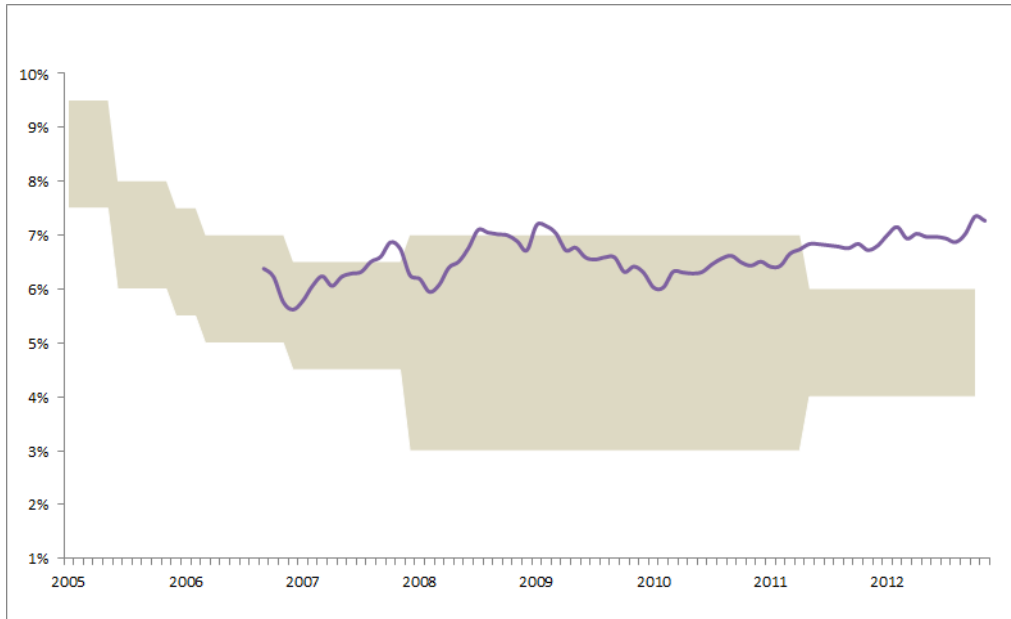
**Table 2. Reserve Requirement Remuneration Rates**

	Reserve Requirements Remuneration		
Currency	Old Rate	Average Rate	Marginal Rate
Pesos	2%	5%	2.50%
US Dollars	Federal Reserve rate	0.15%	0.15%
Euros	0.25%	0.25%	0.25%

*Source:* Central Bank of Uruguay

As shown in the table, the Central Bank raised the remuneration for the average reserve requirements from 2 to 5 percent and established a remuneration rate of 2.5 percent for marginal reserve requirements in domestic currency. The Central Bank also established remuneration rates

**Figure 3. Inflation Expectations (18-month horizon) and Inflation Target Zone**

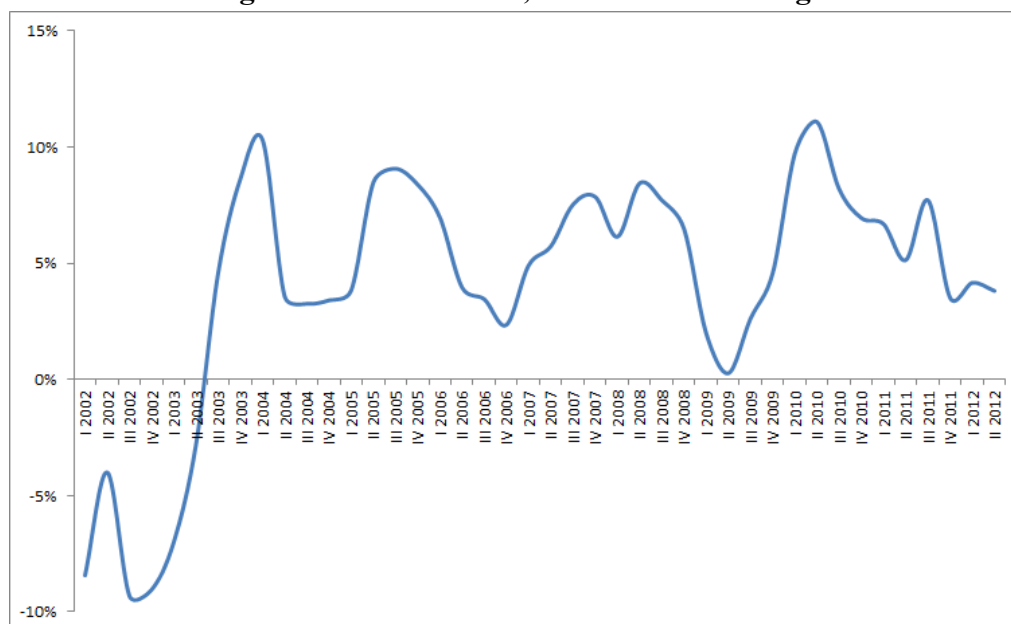


*Source:* Authors' calculations using data from the Central Bank of Uruguay.

of 0.15 and 0.25 percent for marginal reserve requirements in US dollars and Euros, respectively. The Central Bank's idea behind these measures was to increase the cost of funding and through this mechanism to reinforce the monetary policy channel. In September 2011 the Central Bank continued with its contractionary monetary policy and increased the policy rate from 7.5 to 8 percent. In spite of these policies the inflation rate was well over the inflation target zone during all of 2011. This situation prompted the Central Bank to raise again the policy rate by the last day of December 2011. The new policy rate was set at 8.75 percent. By August 2012 the inflation rate still was two points above its target zone, and the Central Bank, continuing its contractionary monetary policy, decided to increase by 20 and 40 percent the marginal reserve requirements for deposits in domestic and foreign currency, respectively. In early October 2012 the Monetary Policy Committee decided to raise the policy interest rate from 8.75 to 9 percent. Even with these changes the inflation rate was over its target zone for all of 2012 (see Figure 1).

Overall, it seems that at the beginning of the implementation of the inflationary targeting regime the Central Bank was able to keep inflation within its target zone, but from the end of 2010 to early 2011 the inflation rate was well over its target zone. During the same period, the central bank had more success with inflation expectations. As it can be seen in Figure 3, these expectations were mostly within the target bands. From October 2010, following the inflation rate, inflation expectations began to be above the target zone for inflation.

**Figure 4. GDP Growth, Year-to-Year Change**



Source: Authors' calculations using data from the Central Bank of Uruguay.

## **2.2 Economic Activity**

In 2002, in the midst of a serious economic and financial crisis, economic activity dropped sharply. Gross domestic product (GDP) fell by 12 percent (see Figure 4). After the 2002 crisis, however, economic activity recovered quickly. In mid-2003, the financial and economic situation was showing some signs of a recovery, mainly thanks to increased exports and production in import-substitution sectors. As a result, GDP grew by 2.5 percent, led by the recovery of the agricultural sector. This performance far exceeded the expectations formed at the start of the year and was mainly driven by an expansion in exports. In the first quarter of 2004, GDP grew by 10.3 percent in relation to the first quarter of 2003 and by around 1.7 percent on a seasonally adjusted basis relative to the fourth quarter of 2003. In 2004 the Uruguayan economy recorded average GDP growth of 5 percent. Unlike 2003, growth in 2004 was led by manufacturing, which was fueled by domestic demand and the expansion of external demand. Production was up in all the sectors of the industry, with the most dynamic branches being foodstuffs, beverages, tobacco, chemicals and metal products, specifically machinery and equipment. In 2005 the Uruguayan economy regained the levels of production experienced prior to the crisis that began in 1999. The manufacturing industry continued to expand at a rapid rate, together with the commerce and services sectors.

The country's economic growth in 2006, and annual average rate of 4.2 percent, was attributable to the robust performance of all sectors of the economy, especially manufacturing, construction, transport and communications and the agricultural sector. The Uruguayan economy

continued to expand rapidly in 2007, with a GDP average annual growth rate of 6.5 percent. This performance was led by transport, storage and communications, commerce, restaurants and hotels and manufacturing industry. This rise in output was stimulated by growing external demand and domestic consumption, which was 7.2 percent higher than in 2006. With a GDP annual average growth rate of 7.2 percent in 2008, the Uruguayan economy achieved strong expansion for the fifth consecutive year. The growth of the economy was driven by a rise in internal and external demand, causing high levels of growth in investment and consumption. However, in the fourth quarter Uruguay's economy began to feel the impact of the international crisis. GDP, which had grown 8.4 and 7.7 percent in the second and third quarter of 2008, respectively, fell to 6.5 percent in the last quarter of the year (see Figure 4). The economy quickly felt the effects of the global financial crisis in 2009. It grew only 2.0 percent, average annual rate, in the first quarter of 2009 and contracted 2.33 percent with respect to the last quarter of 2008 in seasonally adjusted terms. Nevertheless, Uruguay posted a 2.4 average annual percent increase in GDP in 2009, making it one of the few economies in the region to remain on a growth path despite the international financial crisis. This growth was driven by private and public consumption, public investment and external demand, which offset the steep drop in private investment. The economy recovered rapidly from the mild recession in 2009 to impressive GDP growth of 9 percent in average annual terms. This rise in economic activity was a result of higher domestic consumption. The manufacturing sector managed only to recover from the sharp decline in 2009. In 2011, the Uruguayan economy grew by 9 percent, in annual terms, driven primarily by private consumption. However, the recession in Europe began to drag down economic activity in the second half of 2011. After achieving a GDP annual growth of 9.7 and 11.1 percent in the first and second quarter of 2011, respectively, output began to slow down in the second semester growing by about 8 and 7 percent in the third and fourth quarters of the year. GDP contracted by 2.41 percent during the fourth quarter of 2011, in seasonally adjusted terms, with respect to the third quarter of the year. The slowdown in economic growth experienced by Uruguay in the second part of 2011 continued through the first half of 2012.

Summarizing the facts analyzed in this section, the performance of the economic activity between 2004 and the first semester of 2012 was very impressive. The output growth during the last years prompted a high-ranking officer of the Central Bank of Uruguay to say that "you don't have to always hit the duck"<sup>2</sup> in reference to the evolution of inflation rate outside its target zone.

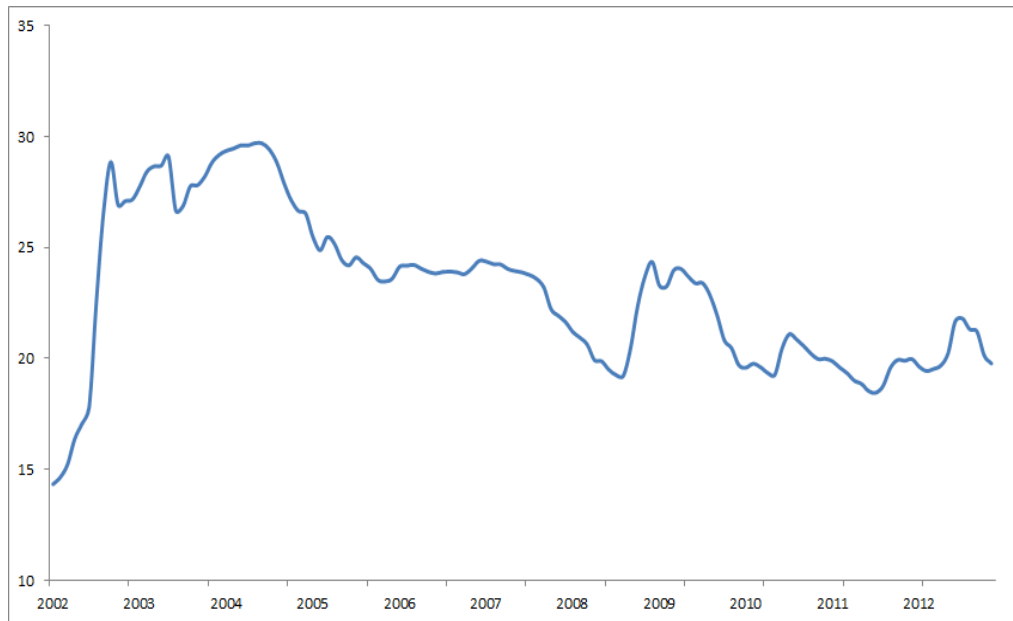
### ***2.3 Exchange Rate***

During the crisis of 2001 in neighboring Argentina, there was a huge depreciation of the Argentine peso affecting the Uruguayan economy during the first half of 2002. Economic authorities increased the monthly rate of devaluation to 2.4 percent and the width of the exchange rate band

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<sup>2</sup>This makes reference to a popular carnival game involving a player using a small caliber rifle or air gun to knock down moving targets. Quite often these targets are in the shape of ducks.

**Figure 5. Nominal Exchange Rate**



*Source:* Authors' calculations using data from the Central Bank of Uruguay.

to 12 percent in January 2002. By June the authorities began to float the exchange rate after 12 years under a sliding band system. As a consequence, the price of the dollar shot up in the volatile financial market of the third quarter of 2002. Towards the end of the year, however, strict monetary and public expenditure policies slowed the depreciation of the Uruguayan peso. The exchange rate stabilized at around 28 pesos per dollar (see Figure 5). In mid 2003, as the Argentine and Brazilian currencies appreciated in relation to the dollar, the Uruguayan peso's exchange rate was more than 80 percent higher than at the beginning of 2002. In this context, the Central Bank proposed the creation of a forward market to facilitate the management of foreign exchange risk. The currency float continued during 2004. Nevertheless, the Uruguayan peso appreciated by 9 percent against the US dollar (December 2004 against December 2003), with a competitiveness loss of 10 percent in relation to Argentina and Brazil. Appreciation pressures continued during 2005. The Uruguayan peso appreciated against the dollar by 11 percent in 2005. The Central Bank made significant exchange rate interventions that were not sterilized and that generated a significant increase in money supply growth.

In real terms, the local currency appreciated by 8.9 percent in 2005 (see Figure 6). In 2006, the Uruguayan peso appreciated, on average, by 1.7 percent in nominal terms against the US dollar, which as an annual average resulted in a real appreciation of 1.1 percent. In 2007 foreign exchange purchases were mainly undertaken by the government to meet its foreign currency needs. Public-sector banks conducted open-market operations to purchase foreign exchange in order to cover the

public sector's requirements and to sustain the nominal exchange rate. However, by mid 2007, the exchange rate appreciated significantly, from 24 pesos per dollar in May 2007 to 19 pesos per dollar in August 2008. This appreciation of the exchange rate occurred despite a 10 percent of GDP increase in international reserves due to exchange rate interventions. In this period the Central Bank began sterilizing exchange rate interventions. The Uruguayan peso appreciated by 11.3 percent against the dollar in 2007, and the real exchange rate showed an annual fall of 7 percent (see figures 5 and 6) mainly due to inflows of foreign capital, rising income from exports and the worldwide fall of the dollar. By August 2008 the dollar had an additional appreciation of around 9 percent consistent with heavy inflows of foreign exchange from exports. This trend reversed beginning in September 2008, and the Uruguayan peso depreciated by nearly 27 percent in the last four months of 2008. The revaluation of the dollar in the Uruguayan market was a consequence of the external shock produced by the Lehman Brothers crisis. As a result, in 2008 the local currency dropped 12.5 percent against the dollar in nominal terms. During 2009, the government actively intervened in the currency market to stabilize the exchange rate. An exchange rate of about 24 pesos remained unchanged until April. Thereafter, however, the peso strengthened against the dollar before broadly stabilizing, ending the year at a rate of some 19.50 on 31 December. This situation produced an appreciation of the Uruguayan peso of around 20 percent in 2009. Exchange rate interventions continued during 2010 and the nominal exchange rate remained stable for the first part of 2010. The downward trend resumed in August 2010 and continued throughout the first four months of 2011. In nominal terms, the local currency depreciated by 1.4 percent against the dollar in 2010, while it appreciated by 5 percent in the first four months of 2011. The real exchange rate indicator (Figure 6) fell by almost 7 percent in 2011 compared with the previous year, evidencing the strengthening of the local currency in the second half of the year. This decline in the index reflected a loss of competitiveness in relation to Argentina and to a lesser extent Brazil. The Uruguayan peso continued depreciating during the first semester of 2012 amid foreign exchange purchases by the Central Bank. In the first seven months of 2012 the nominal exchange rate depreciated around 11 percent. However, in the last five months of the year the Uruguayan peso appreciated by 9 percent, finishing the year with a nominal exchange rate of 19.8, which is a value almost equal to that in December 2011.

Looking at the big picture, in the period analyzed here the Uruguayan peso appreciated almost continuously against the US dollar, with shorter periods of depreciation. In this context, the use of non-conventional tools, like reserve requirements, increases in importance because it can make monetary policy more restrictive without undesirable effects on the exchange rate.

**Figure 6. Real Exchange Rate Index (2000=100)**



*Source:* Authors' calculations using data from the Central Bank of Uruguay.

### **3 Theoretical Framework**

In this section we describe the theoretical framework proposed to evaluate whether the different policy tools used in Uruguay since 2002 have allowed for greater countercyclicality and improved the country's ability to reduce economic volatility. The short-run dynamic of the implemented policies crucially depends on the parameters of the model. The methodology proposed here will allow us to analyze the impact of conventional and non-conventional monetary policies. In what follows, we describe in more detail the functioning of this economy.

#### **3.1 The Economy**

The theoretical framework of this paper relies on the dynamic stochastic general equilibrium model presented in Christiano, Trabandt and Walentin (2011), and it is extended to include financial frictions, a more complex banking sector and a monetary policy administration that incorporates not only the interest rate but also legal reserve requirements as instruments of monetary policy. In what follows, we present a brief summary of the main characteristics of the model introduced by these authors and our main departures from their framework. The complete model description and its equations can be found in a technical appendix (Appendix A).

The model presented in Christiano, Trabandt and Walentin (2011) extends the standard new Keynesian framework with price rigidities à la Calvo in different dimensions. First, the standard theoretical framework is changed in order to incorporate a small open economy structure. In



this open economy approach commercial flows play an important role in the economy. On the one hand, exports involve a continuum of exporters in which each is a monopolist in the production of a specialized export good. This specialized good is then sold to foreign competitive retailers, which create a homogeneous good that is sold to foreign citizens. On the other hand, imports consists of a homogeneous foreign good that is bought by specialized domestic importers. These specialized importers transform this homogeneous good into a specialized input that is sold to domestic retailers in order to create homogeneous goods used as inputs in the production of investment goods, consumption goods and specialized exports goods. Additionally, the interaction between the external sector and the domestic economy also allows for trade of risk-free bonds. The output, foreign inflation, interest rate and technology shocks are assumed to follow a VAR(1).

Second, financial frictions in the accumulation and management of capital are also incorporated, following the seminal work of Bernanke et al. (1999). Financial frictions are introduced as a result of differentiation between borrowers and lenders in the economy. Borrowers, referred to as entrepreneurs in the model, have the ability to manage physical capital, but they do not have enough resources for the optimal capital requirement. Since individual entrepreneurs are subject to an idiosyncratic shock, the management of capital turns out to be risky, which implies that the relationship between borrowers and lending banks has to be ruled by a special kind of debt contract. In fact, asymmetric information between borrowers and lending banks (who cannot see the idiosyncratic shock up to a monitoring cost) provides incentives to entrepreneurs to under-report their earnings, which justifies the existence of a external finance premium in addition to the risk-free interest rate. As can be noticed, monitoring cost and asymmetric information introduces a financial accelerator mechanism that is responsible for the financial frictions in the model.

Although we abstract from the labor market set-up proposed in Christiano, Trabandt and Walentin (2011) (the third dimension in which they extend the standard new Keynesian framework), our model extends their theoretical model in two ways. On the one hand, we include a more complex structure in the banking sector. This new structure splits bank activities into different bank units. Banks attract funds from households and lend them to entrepreneurs. Instead of using only one banking unit doing both the funding and lending, we analyze these tasks separately, following Glocker and Towbin (2012). Therefore, the banking sector includes deposit units and lending units.

Deposit units operate in perfectly competitive input and output markets. They collect deposits from households and lend a fraction of them to the lending units at the interbank market rate, while keeping the rest of the deposits as reserves in the Central Bank.

The profit maximization problem of a deposit bank is:

$$\max_{\{\zeta_t(j), D_t(j)\}} Div_t^S(j)$$

s.t.

$$G_t^\zeta(j) = \psi_1 (\zeta_t(j) - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t(j) - \zeta_t^{MP})^2$$

where:

$$Div_t^S(j) = \left[ (1 - \zeta_t(j)) i_t^{IB} + \zeta_t(j) i_t^R - i_t(j)^D - G_t^\zeta(j) \right] D_t(j)$$

where  $\zeta_t(j)$  represents the fraction of deposits that deposit unit  $j$  puts into an account in the Central Bank and  $\zeta_t^{MP}$  is the legal required reserve ratio.  $G_t^\zeta(j)$  represents a convex function that determines the cost of holding reserves. The linear term is associated with the Central Bank imposing a penalty for not fulfilling the reserve requirement (parameter  $\psi_1 < 0$ ). The quadratic term is associated with the Central Bank punishing large deviations from its reserve requirement target (parameter  $\psi_2 > 0$ ). Deposit units benefits come from i) the proportion of deposits they can lend,  $(1 - \zeta_t(j)) D_t(j)$ , which are remunerated at the interbank market rate  $i_t^{IB}$ , and ii) the fraction of deposits they deposit in Central Bank accounts as reserves,  $\zeta_t(j) D_t(j)$ , which are remunerated at the reserve rate  $i_t^R$ . The costs are represented by interest paid on deposits  $i_t(j)^D D_t(j)$ , and the cost function described before.

On the other hand, lending units do not interact with households. They are not subject to reserve requirements and finance themselves through the interbank market, which means that they do not hold any deposits from households. Like deposit units, lending units operate in perfectly competitive input and output markets. They obtain funds from deposit units at the cost of the interbank rate and supply loans to entrepreneurs at the lending rate. Lending units also fulfil the financial needs of domestic intermediate goods producers in terms of the working capital they need to pay either for a fraction of the wage bill or for the resources they need to produce export goods, charging them the interbank rate. The amount of interbank lending always equals the stock of loans supplied to both risky entrepreneurs and non-risky domestic intermediate goods producers.

The second extension of our model with respect to that of Christiano, Trabandt and Walentin (2011) is related to monetary policy administration. Specifically, we use a bank structure which allows to incorporate legal reserve requirements as an instrument of monetary policy.

Christiano, Trabandt and Walentin (2011) describes a monetary policy specified in terms of a Taylor rule that sets the level of the monetary policy interest rate as a function of its past value, the targeted and actual inflation, and output:

$$\log \left( \frac{R_t}{R} \right) = \rho_R \log \left( \frac{R_{t-1}}{R} \right) + (1 - \rho_R) \left[ \log \left( \frac{\bar{\pi}_t^c}{\bar{\pi}^c} \right) + r_\pi \log \left( \frac{\pi_t^c}{\bar{\pi}_t^c} \right) + r_y \log \left( \frac{gdp_t}{gdp} \right) \right] + \varepsilon_t^R \quad (1)$$

In this baseline model reserve requirements are non-existent, there are no financial frictions and the bank structure is the one specified in Christiano, Trabandt and Walentin (2011), which means that there is only one bank unit that accounts for both borrowing and lending activities.

In our model, the Central Bank has two different instruments to conduct its monetary policy: interest rate and reserve requirements. On the one hand, this institution can modify the risk-free interest rate  $R_t$ . On the other hand, it can also make use of reserve requirements, changing in this way the amount of available credit in the economy. We keep the Taylor rule approach and assume that both instruments depend on their immediately previous value as well as on four measures of economic activity and inflation: i) the relationship between the current value of the inflation target and its steady state level, ii) the relationship between the value of current inflation and the current value of the inflation target, iii) the relationship between the current level of GDP and its steady state level, and iv) the relationship between the current value of risky entrepreneurial loans and its steady state value. Since it is in our interest to analyze the effects of the coexistence of these instruments on macro and financial variables, we decided to extend the objectives described in the approach of Christiano, Trabandt and Walentin (2011) by incorporating the stock of risky entrepreneurial loans ( $B$ ) as a determinant of both instruments. Thus, the monetary policy rules used in our model can be expressed as:

$$\begin{aligned} \log\left(\frac{R_t}{R}\right) &= \rho_R \log\left(\frac{R_{t-1}}{R}\right) + (1 - \rho_R) \left[ \log\left(\frac{\bar{\pi}_t^c}{\bar{\pi}^c}\right) + r_\pi \log\left(\frac{\pi_t^c}{\bar{\pi}_t^c}\right) + r_y \log\left(\frac{gdp_t}{gdp}\right) + r_L \log\left(\frac{B_{t+1}}{B}\right) \right] + \varepsilon_t^R \\ \log\left(\frac{\zeta_t^{MP}}{\zeta^{MP}}\right) &= \rho_\zeta \log\left(\frac{\zeta_{t-1}^{MP}}{\zeta^{MP}}\right) + (1 - \rho_\zeta) \left[ \log\left(\frac{\bar{\pi}_t^c}{\bar{\pi}^c}\right) + \zeta_\pi \log\left(\frac{\pi_t^c}{\bar{\pi}_t^c}\right) + \zeta_y \log\left(\frac{gdp_t}{gdp}\right) + \zeta_L \log\left(\frac{B_{t+1}}{B}\right) \right] + \varepsilon_t^\zeta \end{aligned} \quad (2)$$

where  $\varepsilon_t^R$  and  $\varepsilon_t^\zeta$  are monetary policy shocks and the parameters are taken as unknowns to be estimated. In these policy rules,  $gdp$  denotes measured GDP in the data, which might differ from the output measure of the model because of the costs functions that characterize the behavior of capital accumulation, monitoring and reserves holding. In the previously stated policy rules,  $\bar{\pi}_t^c$  is an exogenous process that characterizes the Central Bank's consumer price index inflation target and its steady state value corresponds to the steady state of actual inflation.

This general monetary policy rules also allows us to evaluate a situation where tasks are separated in terms of monetary policy and Central Bank objectives. In this particular situation, reserve requirements only respond to deviations in the stock of entrepreneurial loans, and interest rates react to changes in both output and inflation. Under this scenario:

$$\begin{aligned}
\log\left(\frac{R_t}{R}\right) &= \rho_R \log\left(\frac{R_{t-1}}{R}\right) + (1 - \rho_R) \left[ \log\left(\frac{\bar{\pi}_t^c}{\bar{\pi}^c}\right) + r_\pi \log\left(\frac{\pi_t^c}{\bar{\pi}_t^c}\right) + r_y \log\left(\frac{gdp_t}{gdp}\right) \right] + \varepsilon_t^R \\
\log\left(\frac{\zeta_t^{MP}}{\zeta^{MP}}\right) &= \rho_\zeta \log\left(\frac{\zeta_{t-1}^{MP}}{\zeta^{MP}}\right) + (1 - \rho_\zeta) \left[ \zeta_L \log\left(\frac{B_{t+1}}{B}\right) \right] + \varepsilon_t^\zeta
\end{aligned} \tag{3}$$

A comparison between the impulse response functions that result from these three different approaches allows us to assess the role of reserve requirements in different economic environments and evaluate their convenience in terms of the objectives defined by the Central Bank.

The interaction between the two instruments could help us to assess the relative effectiveness of the different rules. Intuitively, an interest rate rule focused on inflation and output and a reserve requirements rule focused on the financial stability of the economy (measured as deviations in the stock of entrepreneurial loans) should deliver more intense reactions in macro variables (inflation, output, investment and consumption) than the ones observed when the two instruments respond to changes in all variables. For instance, it seems intuitive that a positive shock in the interest rate should lead to a decrease in aggregate demand by raising all interest rates, discouraging in this way consumption and investment. In principle, this should lower inflation pressures. However, this monetary policy tightening would also trigger a contraction in reserve requirements since the real and the financial side of the economy negatively reacts to the interest rate shock. The drop in reserve requirements could translate into a small fraction of deposits being held as reserves and contribute to avoiding a larger fall in the real stock of entrepreneurial loans, avoiding in this way a larger fall in investment and possibly output. Depending on the strength of these effects, the ability of the monetary policy interest rate to deliver significant changes in inflation will vary, making it necessary for the monetary authority to clearly define its objectives in terms of output, inflation and financial stability.

Finally, since reserves are remunerated, we also add a rule by which the Central Bank sets the interest rate paid to the reserves held by deposit banks. In our model we will assume the following interest rate relationship:

$$R_t^R = R_t - \Theta + \varepsilon_{\Theta,t}$$

where  $\Theta$  is a parameter that reflects the steady state interest rate spread between the reserves rate and the monetary policy rate. Additionally,  $\varepsilon_{\Theta,t}$  represents a shock to the mentioned spread.

### **3.2 Data**

Firstly we calibrate our model and then we estimate a subset of its parameters based on Uruguayan data for the period 2007Q1 - 2012Q4.<sup>3</sup> The time unit in our model is a quarter, so we collect quarterly data for the Uruguayan economy. Table 3 summarizes our data series and their respective sources. Since calculation of foreign sector-related variables (foreign inflation, output and interest rate, as well as the real effective exchange rate index) required a special effort, we explain their construction in Appendix D.

All real quantities are expressed in per capita terms (using constant Uruguayan pesos of 2005). We take logs and first differences for GDP, consumption, investment, exports, imports, government expenditures, real wages, real exchange rate, real stock value, corporate interest rate spread, unemployment rate and foreign GDP. Following Christiano, Trabandt and Walentin (2011), we remove the mean from each of the first differenced time series because most of these variables' trend growth differs substantially in the data. Additionally, we match the levels of nominal interest rate, deposit interest rate, reserves interest rate, reserve requirements, domestic inflation, CPI inflation, investment inflation, foreign inflation and foreign nominal interest rate. For total hours worked we match the deviation from steady state. Figure 7 presents the data employed in the estimation.

### **3.3 Calibration and Estimation**

We calibrate several of the parameters of the model using data from Uruguay and estimated the rest of the parameters using a random walk Metropolis-Hastings chain. Using Bayesian techniques we estimate a subset of 72 model parameters that includes 19 shock standard deviations, 16 VAR parameters for the foreign economy, 29 structural parameters and 8 AR(1) coefficients for the exogenous processes. The model comprises 23 stochastic variables that are used to generate the impulse response functions discussed below. The complete description of our calibration and estimation procedure is presented in Appendix A.

## **4 Impulse Response Function Analysis**

Selected five-year-horizon impulse response functions (IRF) for the shocks of the model are analyzed here.<sup>4</sup> For comparison purposes and to quantify the importance of different policies and economic environments we also plot the impulse response functions for the same fixed parameter vector for restricted versions of our model.

As explained above, we consider a baseline model without financial frictions and a monetary policy rule specifying the level of the interest rate following a stabilization goal, only taking

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<sup>3</sup>Notice that 2007 is the earliest year for our analysis due to the fact that Uruguay did not use the reserve requirement instrument before that year.

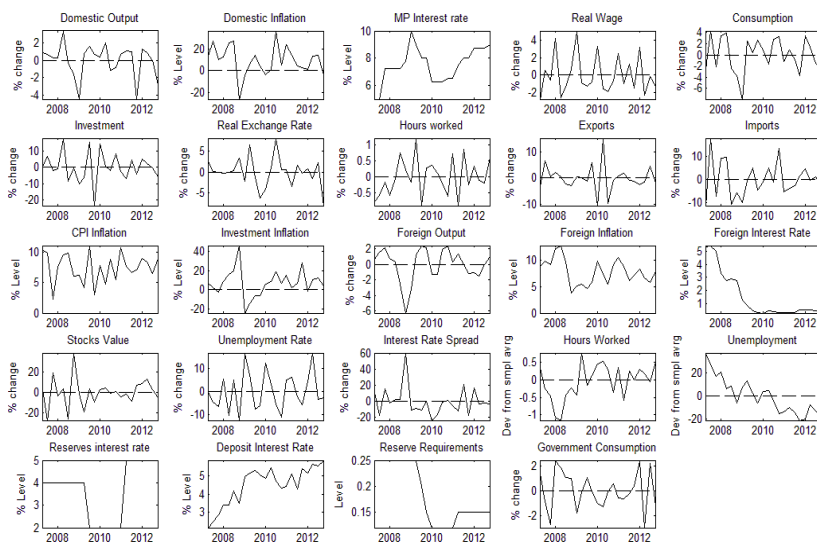
<sup>4</sup>See Appendix F for the rest of the impulse response functions.

**Table 3. Data series and data sources**

Data series	Source
Working Hours: average number of hours worked	National Institute of Statistics (INE)
Unemployment: unemployment rate	INE
Real wage: real wage index converted to actual real wages using the Uruguayan average wage for 2011Q4	INE
CPI Inflation: annualized gross CPI inflation	INE
Domestic Inflation: annualized gross National Producer Price Index (IPPN)	INE
Investment Inflation: weighted average of Construction Cost Index (40%) and investment-related categories in the IPPN (60%)	INE
Nominal Interest Rate: monetary policy interest rate	Central bank of Uruguay (BCU)
Nominal Deposit Interest Rate: annualized deposit rate for deposits in national currency in the Uruguayan banking system (91 > days)	BCU
Nominal reserves interest rate: remuneration to reserves at the Central Bank	BCU
Reserve Requirements: legal reserve requirements on local currency deposits	BCU
Corporate Interest Rate Spread: difference between annualized loan interest rates for entrepreneurial loans (> 30 days and < 365 days) and annualized deposit interest rate	BCU
Real Exchange Rate: weighted real effective exchange rate	See Appendix D
Foreign output	See Appendix D
Foreign Inflation	See Appendix D
Foreign Interest Rate: 3-months US dollar LIBOR	British Banking Association
Output: deseasonalized real GDP	BCU
Consumption: deseasonalized real consumption	BCU
Investment: deseasonalized real investment	BCU
Exports: deseasonalized real exports	BCU
Imports: deseasonalized real imports	BCU
Government consumption: deseasonalized real government consumption	BCU
Stocks value: stock value of private companies in the Montevideo Stock Market	BCU

Source: Authors elaboration.

**Figure 7. Data Used in the Estimation**



*Source:* Authors' calculations using data from the Central Bank (CBU) and the National Institute of Statistics (INE) of Uruguay and International Financial Statistics database.

into account inflation and output deviations from their target/steady state levels (see equation (1)). In this baseline model reserve requirements are non-existent and the bank structure is the same as described in Christiano, Trabandt and Walentin (2011). Hereafter, we will refer to this baseline model as Model 1.

The specification with financial frictions and a monetary policy rule with both the policy rate and the reserve requirements rate depending on their immediately previous value as well as on four measures of economic activity and inflation will be called Model 2. This is our general specification in equations (2) above.

Finally, we consider a third model using a monetary policy rule where instruments' tasks are separated: while reserve requirements only respond to deviations in the stock of entrepreneurial loans, the monetary policy interest rate accounts only for changes in both output and inflation (see equation (3)). This will be called Model 3.

The comparison between the IRF that result from these three models allows us to assess the role of reserve requirements in different economic environments and evaluate its convenience in terms of the objectives defined by the Central Bank.

In the following figures, almost all units on the y-axis are in terms of percentage deviation from steady state levels. Interest rates, spreads and inflation are measured in terms of annualized

basis points deviations. The impulse-response functions not discussed below are presented in a separate appendix.

#### *4.0.1 An Interest Rate Shock*

Figure 8 presents the reaction of macro and financial variables to a 100 basis point increase in the interest rate. For the case of Model 2, it is possible to notice a mild contraction in consumer inflation (around 0.2 percent). The increase in the policy rate translates into rises in both deposit interest rates and lending rates, which is observed through the increase in the interest rate spread due to increased default risk.

The effect of the rise in the interest rates on the real economy are standard. On the one hand, consumers reduce private consumption, since financial assets have become more appealing. On the other hand, increasing lending rates discourage investment. It is important to notice that the moderate amplification of interest rate shocks over investment responds to, as Christiano, Trabandt and Walentin (2011) mention, a moderate estimated value for the investment adjustment cost parameter  $S''$  (moderated with respect to the findings in the literature). This moderate value implies that the price of capital moderately respond to demand shocks, thus resulting in a modest change in entrepreneurs' net worth in response to the monetary policy shock. The negative deviations of both private consumption and investment explain the contraction of output.

In addition, entrepreneurs' net wealth decreases as a result of three mechanisms: first, the increase in lending rates makes it more expensive for entrepreneurs to pay their existing debts; second, the price of capital falls; and third, the surprise disinflation increases the real value of nominal debts. The contraction in entrepreneurs' net wealth also helps to explain the fall in investment.

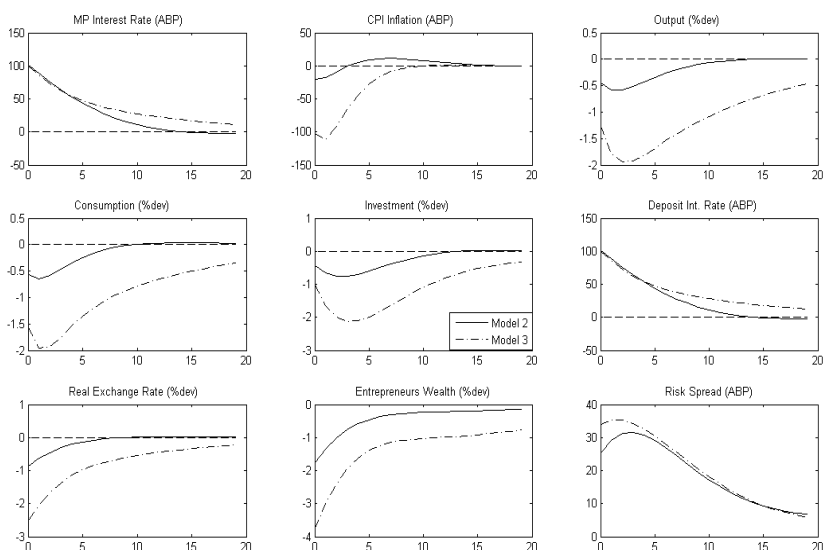
Continuing with the IRF analysis of Model 2, in order to lessen the impact of the tightening in monetary policy, the Central Bank reduces the required reserves as a reaction to the fall in output, inflation and the real stock of entrepreneurial loans. As can be seen in Figure 9, this contraction translates into a small fraction of deposits being held as reserves and contributes to avoiding a larger fall in the real stock of entrepreneurial loans. The contractions in both entrepreneurs' net wealth and entrepreneurial loans are smaller than the ones experienced in Model 3. The fall in reserve requirements also contributes to avoiding a larger interest rate spread in Model 2.

Figures 8 and 9 also show the effects of the monetary policy tightening on the external sector. The increase in interest rates attracts funds from the rest of the world and, as a consequence, domestic currency appreciates and both nominal and real exchange rates fall. Although net exports fall, the contraction experienced by domestic output is proportionally bigger so net exports increase when expressed as a fraction of local output.

Overall, the impact of a monetary policy interest rate increase in the context of Model 2 is attenuated by the existence of a reserve requirement rule that reacts to changes in inflation, output and entrepreneurial loans. As shown in the comparison with the two other models, inflation does



**Figure 8. Interest Rate Shock (1)  
IRF for Models 2 and 3**



*Source:* Authors' estimations.

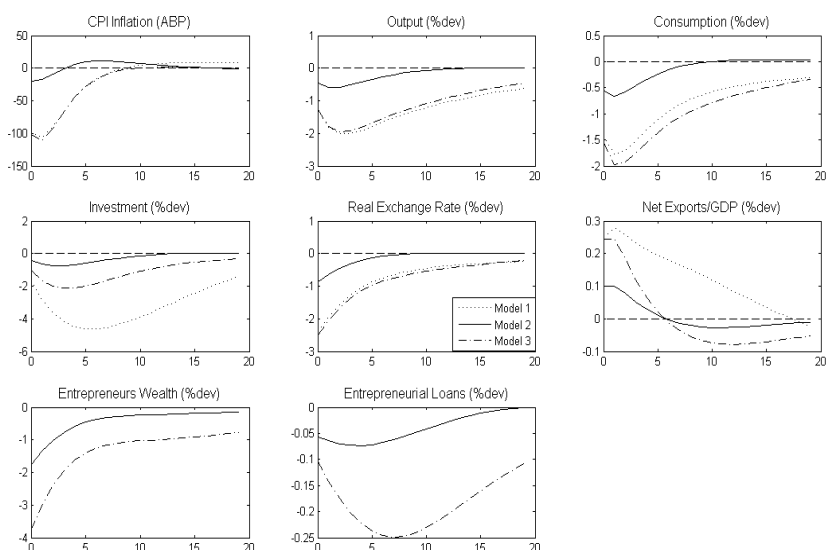
*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

not react as much as to an increase in the interest rate. In fact, the impact on inflation of a 1 percent increase in the interest rate is five times larger in Model 3, where reserve requirements only assume a financial stability objective. On the other hand, the negative impact of the interest rate increase on output, private consumption and investment is smaller in Model 2 than it is in the other two models. This rule seems to be geared to achieving the disinflation objective without paying a big cost in terms of economic activity.

Although Models 1 and 2 seem to have similar reactions to this shock, real investment exhibits a milder reaction under the existence of a reserve requirement rule. Since reserve requirements adjust to stabilize the financial side of the economy, real investment does not fall as much as it would if the mentioned rule and financial frictions were absent (Model 1).

As we calibrated the parameter that describes the importance of the financial accelerator mechanism, it is important to evaluate the performance of the model when the degree of financial friction varies. Figure 10 presents the impact of the same positive interest rate shock in Model 2, on key macro variables for the case in which banks' monitoring costs imply a loss of 15 percent, 40 percent and 70 percent, respectively, of bankrupted entrepreneurs' assets. As shown in the figure, the differences in terms of the impact of this shock on macro variables (consumption, output and inflation) are practically negligible. However, as financial frictions increase (bigger value of

**Figure 9. Interest Rate Shock (2)  
IRF for Models 1, 2 and 3**



*Source:* Authors estimations.

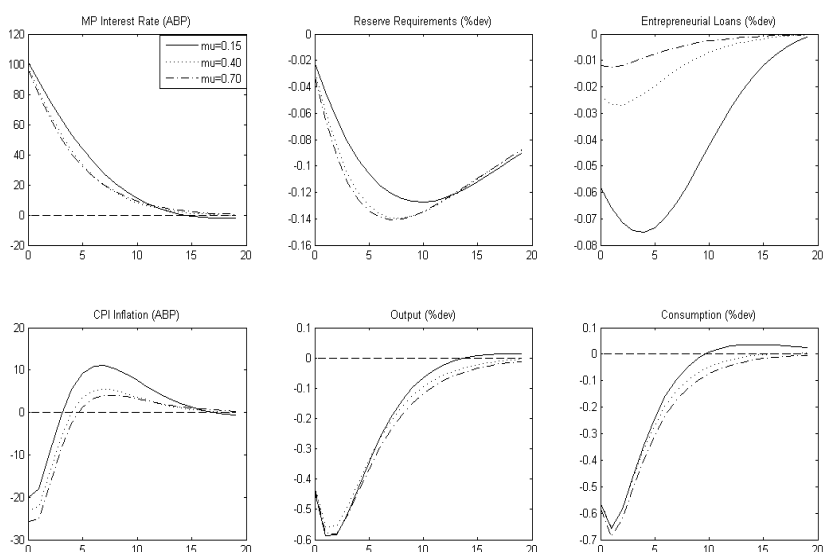
*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

the parameter  $\mu$ ), the importance of reserve requirements as an instrument to achieve financial stabilization increases. The reserve requirements reduction prevents a larger effect on the real stock of entrepreneurial loans.

#### 4.0.2 A Reserve Requirement Shock

Figure 11 presents macro and financial reactions to a 25 percent increase in the reserve requirements for Models 2 and 3. As predicted, the raise in reserve requirements increases the opportunity cost for deposit banks. Reserves holdings increase in order to avoid paying the cost for not fulfilling the monetary authority mandate. The increase in the reserve requirements acts as a tax on the banking sector (since we assumed that the interest rate paid on reserves is lower than the interbank rate), which is passed to households through an initial reduction in deposit rates. Notice that in this situation, an increase in reserve holdings, banks would want to increase the lending rate, but since this rate equals the reference rate they can only reduce the deposit rate. As deposits become less attractive, consumers substitute consumption for financial assets, which explains the rise in private consumption spending. After this initial impact, deposit rates increase and private consumption decreases.

**Figure 10. Interest Rate Shock (3)  
IRF for Models 1, 2 and 3**



*Source:* Authors' estimations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP)

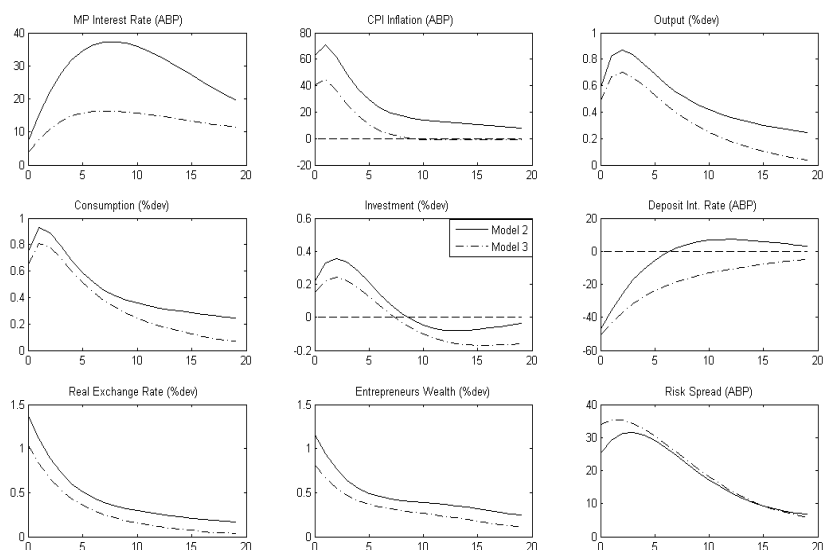
The initial increase in inflation caused by this shock, a result also found by Glocker and Towbin (2012), could be explained in terms of increasing overall production costs that exert upward pressures on the overall price level.

The increase in reserve requirements initially reduces the deposit interest rate, which triggers a real depreciation of the domestic currency. After this initial effect the real exchange rate begins to appreciate. This initial effect also contributes to explaining the increase in inflation since the cost of imported inputs goes up.

In addition, changes in the required reserves ratio also affect the real side of the economy through the loan market. This increase in the ratio reduces the amount of money available to lend, and as a result reduces investment. However, our estimations suggest that it has a mild positive effect on real investments. This initial positive impact could be the result of an increasing inflation rate that, on the one hand reduces real interest rates and, on the other hand, increases entrepreneurs' net wealth via a reduction in the real value of nominal debts. Due to the existence of a monetary policy interest rule that takes these deviations into account, this initial effect on investment is offset after no more than 10 quarters in Model 2.

The qualitative reactions to this shock in Model 3 are similar to those observed for Model 2. However, they are quantitatively smaller.

**Figure 11. Reserve Requirements Shock  
IRF for Models 2 and 3**



*Source:* Authors' estimations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

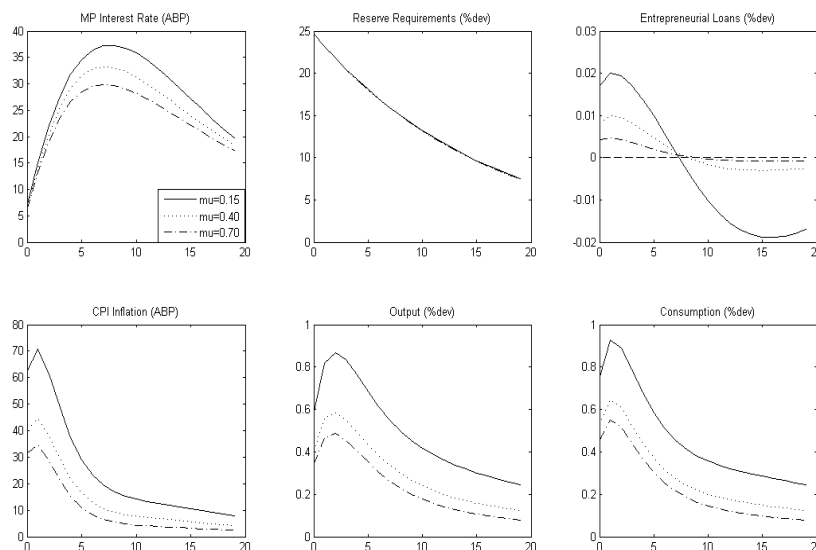
Figure 12 presents the responses of Model 2 to a reserve requirement shock, for different values of the parameter that describes the importance of the financial accelerator mechanism. The impact of an increase in reserve requirements on macro variables such as consumption, output and inflation is similar under the assumption of a 40 percent and a 70 percent loss due to the monitoring costs faced by lending banks. Those responses seems to be slightly stronger as financial frictions become less relevant.

#### 4.0.3 A Transitory Technological Shock

For a positive transitory technology shock in Model 2, we see that inflation decreases while real output increases for several periods. Despite this, there is first a reduction and then a longer-lasting increase in consumption. The immediate response of consumption is a result of both an almost negligible immediate wealth effect (domestic output tends to react slowly to the shock) and the increase observed in real interest rates: the response of CPI inflation to the shock is bigger than the response of interest rates (not graphed). As a result of more attractive real interest rates, domestic consumers postpone consumption for the future.

In the following periods the wealth effect induced by the rise in output starts to dominate and private consumption increases. This increase in output can be explained by the values of the estimated coefficients for the monetary policy rules. Those coefficients show a larger weight on

**Figure 12. Reserve Requirements Shock  
IRF for Model 2**



*Source:* Authors' estimations.

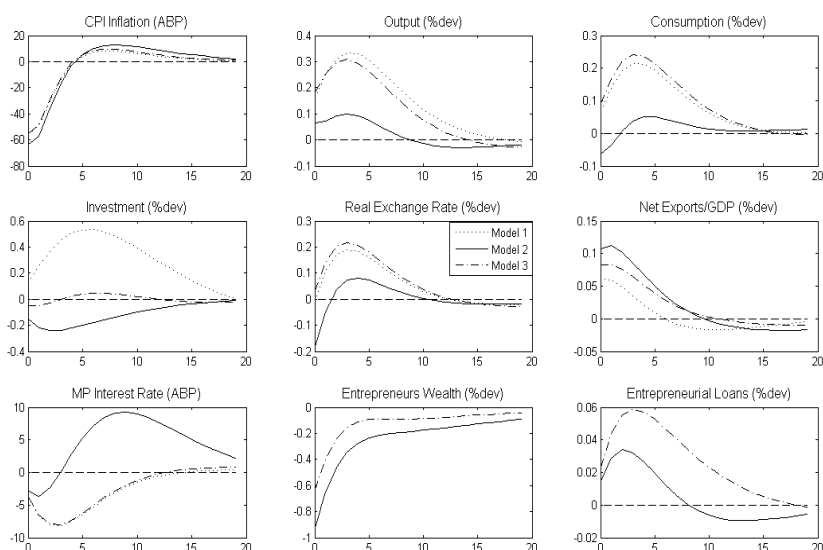
*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

inflation, which falls as a consequence of this shock. Then, both the interest rate and reserve requirements fall, fostering in this way the expansion of the economy. As more money is available in the economy, loans expand.

The initial negative response of investment is different in Model 2 from that expected in Model 1. Two different channels might explain this negative reaction: i) changes in real interest rates and ii) the type of financial frictions that govern this model. Despite the fall in nominal interest rates, inflation falls even more, which results in an increase in real interest rates that discourages investment. This effect is also reinforced by a reduction in entrepreneurs' net wealth originating in the presence of nominal debt contracts that, as a result of unexpected inflation, introduce a Fisher debt deflation mechanism.

Model 3 exhibits more conventional reactions to this shock. Output and private consumption react quantitatively more than in Model 2. A reduction in the interest rate stimulates the real side of the economy. Since reserve requirements only respond to deviations in loans and they are stimulated by a growing economy, the required rate of reserves increases to stabilize the financial side of the economy. However, these effects are quantitatively negligible.

**Figure 13. Transitory Technological Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' estimations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

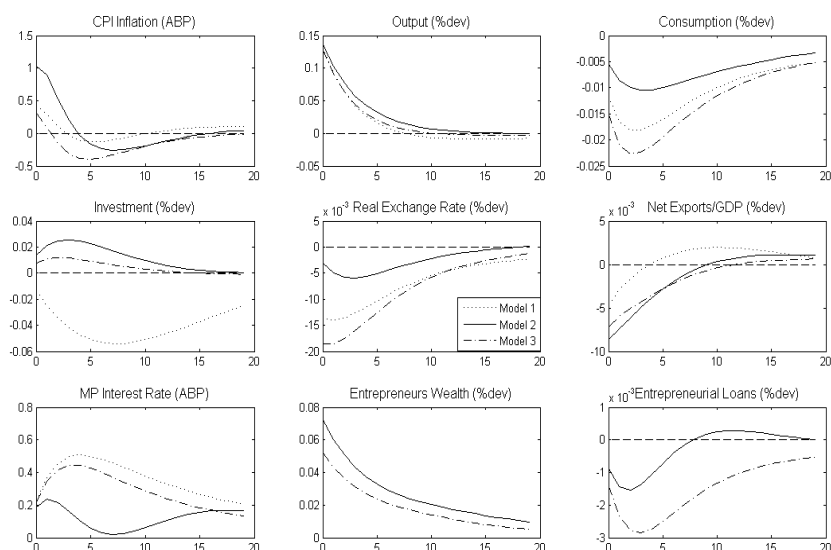
#### 4.0.4 A Government Consumption Shock

The results of a government consumption shock seem to be standard. A 1.25 percent increase in government expenditure initially expands both output and CPI inflation. Both effects trigger the Taylor rule mechanisms, so the monetary authority increases both the policy rate and the reserve requirement. Although increasing public consumption crowds out private consumption, the reaction of the latter variable is mild. The fall in real interest rates provides incentives to both private consumers and entrepreneurs to increase spending. In fact, almost all reactions are practically negligible.

#### 4.0.5 A Foreign Interest Rate Shock

Figure 15 presents the impulse response functions for a positive shock to the foreign interest rate. In Model 2, as expected, external financial assets initially become more attractive to domestic consumers and the domestic currency depreciates both in nominal and real terms, which also implies an increase in net exports. That is, consumers demand more dollars due to the increase in demand for external financial assets, and this induces an increase in the price of the foreign currency with respect to the domestic one.

**Figure 14. Government Consumption Shock  
IRF for Models 1, 2 and 3**



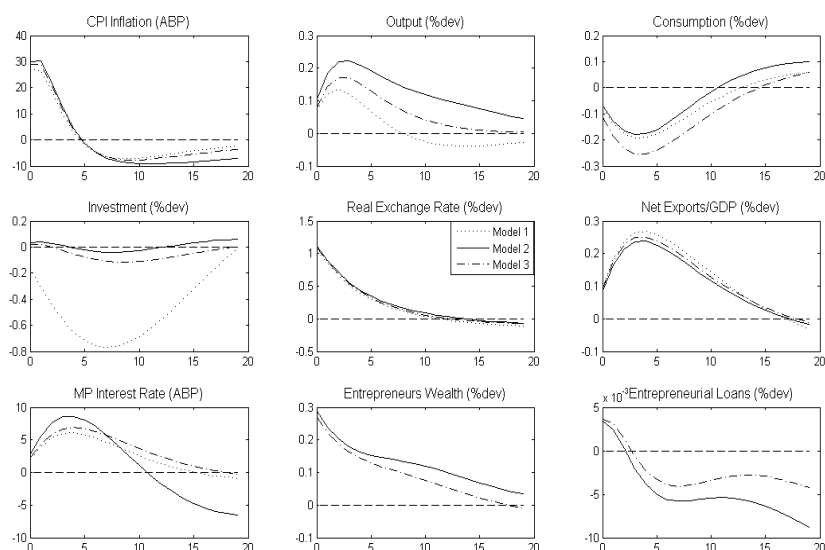
*Source:* Authors' estimations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

Although consumption is stimulated by the inflationary surprise that results from this shock, domestic consumers tend to substitute foreign and domestic assets for private consumption. This inflationary surprise is also useful in explaining the initial increase in entrepreneurs' net wealth due to the reduction in the value of their nominal debt contracts in Models 2 and 3. Although it is fostered by both the increase in entrepreneurs' wealth and the expansion in the real stock of entrepreneurial loans that results from an increase in deposits being held by domestic consumers, real investment practically does not change since the previously mentioned changes are almost negligible and, as mentioned before, the small estimated value for the investment adjustment cost parameter, moderates the responses of investment to demand shocks. This effect contrasts with the initial negative reduction of investment as a result of a foreign interest rate shock found in Model 1.

In Models 2 and 3, the shock produces an expansion in loans, output and inflation, which triggers an increase in the policy rate and the reserve requirement in order to offset the effect of the shock on the domestic economy.

**Figure 15. Foreign Interest Rate Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' estimations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

## 5 Conclusions and Policy Recommendations

Using a dynamic stochastic general equilibrium model with a small open economy structure, price rigidities à la Calvo, financial frictions in the accumulation and management of capital, and a banking sector including deposit and lending units, as well as a monetary policy administration that incorporates not only the interest rate but also legal reserve requirements as instruments of monetary policy, we were able to evaluate the effectiveness to accomplish the inflationary and/or financial stability objectives of the Central Bank of Uruguay. We calibrated some of the parameters of the model using data from Uruguay and estimated the rest of the parameters, 72 in total, using a random walk Metropolis-Hastings chain. Then, we compared the impulse response functions of three different models: i) a baseline model without financial frictions and a monetary rule that sets the level of the monetary policy interest rate as a function of its past value, targeted and actual inflation, and output. In this model reserve requirements are nonexistent; ii) a general model with financial frictions and a monetary rule with two different instruments to conduct the Central Bank monetary policy: interest rate and reserve requirements; and iii) a model with financial frictions and a monetary policy rule where tasks are separated in terms of the monetary policy and the Central Bank's objectives. In this third setting we allow reserve requirements to only respond to



deviations in the stock of entrepreneurial loans, and the monetary policy interest rate can only react to changes in both output and inflation. Both instruments depend on their immediately previous value as well as on four measures of economic activity and inflation: i) the relationship between the current value of the inflation target and its steady state level, ii) the relationship between the value of current inflation and the current value of the inflation target, iii) the relationship between the current level of GDP and its steady state level, and iv) the relationship between the current value of risky entrepreneurial loans and their steady state value.

The key findings from the paper are the following:

1. In the general model, an increase of 100 basis points in the monetary policy interest rate produces a mild reduction in consumer inflation, a rise in both deposit interest rates and lending rates, a decrease in private consumption and investment and as a result a contraction in output. As a reaction to the fall in output and investment, the Central Bank reduces the rate of required reserves, avoiding a bigger interest rate spread. The increase in interest rates attracts funds from the rest of the world and, as a consequence, domestic currency appreciates and both nominal and real exchange rates fall. The negative impact on consumption, investment and output, and the appreciation of the domestic currency induced by the increase in the monetary policy interest rate, is attenuated by the existence of the reserve requirements rule that reacts to changes in inflation, output and entrepreneurial loans in the general model.
2. In the general model, inflation does not react as much as it does in the other two models, the baseline model and the model with role separation in the monetary rule. In fact, the impact of 1 percent increase in the interest rate on inflation is five times greater when reserve requirements only assume the financial stability objective.
3. In the general model, a 25 percent increase in reserve requirements induces an increase in reserve holdings in order to avoid paying the cost for not fulfilling the monetary authority mandate. Since in equilibrium the deposit rate falls, deposits become less attractive and consumers substitute consumption for financial assets, which explains the rise in private consumption spending. This increase in private consumption and the increase in investment produces an increase in output. There is an increase in inflation, caused by this shock, explained in terms of increasing overall production costs that puts upward pressures on the overall price level, and the reduction in the deposit interest rate, which triggers a real depreciation of the domestic currency and an increase in the cost of imported inputs.
4. The qualitative reactions of an increase in the reserve requirement rate, in the general model, are practically the same as those observed in the context of the model with role separation. However, they are quantitatively smaller.

5. A positive temporary technology shock, in the general model, induces a reduction in inflation and an increase in real output for several periods. There is first a contraction and then a longer-lasting increase in consumption. The initial negative response of investment in the general model differs from that observed in the baseline model. The initial reaction of output and consumption to a transitory technological shock in the general model is smaller than in the other two models.
6. Overall, the IRF exercises in the paper suggest that raising the policy interest rate tends to appreciate the currency on impact, while raising RR does the opposite. So, there is scope for combining the two instruments in the control of demand and domestic inflation so as to mitigate large swings in the nominal exchange rate, which can be riskier under liability dollarization.

In terms of policy recommendations, the evidence found in this paper leads to the following suggestion:

1. Having a non-conventional instrument like reserve requirements in the monetary policy rule is important because it can be used to achieve the inflationary objectives of the Central Bank. Reducing the reserve requirements rate will reduce inflation through a decrease in consumption that induce a fall in output. Nevertheless, it also produces a real appreciation of the Uruguayan peso, which is perceived by Uruguayan authorities as perverse.
2. When the Central Bank uses the interest rate as an instrument, the effect of the reserve requirements is to contribute to reducing the negative impact on consumption, investment and output of an eventual increase in this rate. Nevertheless, the quantitative results in terms of inflation reduction are rather poor.
3. The monetary policy rate becomes more effective in inflation when the reserve requirement instrument is solely directed at achieving financial stability and the monetary policy rate used to achieve the inflationary target.
4. Overall, the main policy conclusion of the paper is that having a non-conventional policy instrument, when well targeted, can help effectively control inflation. Moving reserve requirements can also be instrumental in offsetting the impact of monetary policy on the real exchange rate.

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## Appendix A

In this appendix we describe the theoretical framework proposed to evaluate whether the different policy tools used in Uruguay since 2002 have allowed for greater countercyclicality and improved the country's ability to reduce economic volatility. The short-run dynamic of the implemented policies depends crucially on the parameters of the model. The methodology proposed here will allow us to analyze the impact of conventional and non-conventional monetary policies. In what follows, we describe in more detail the functioning of this economy.

### 5.1 The Economy

To evaluate monetary policy we use a small open economy RBC model with sticky prices, financial frictions, and a banking sector that is subject to legal reserve requirements. The model here extends the economic framework developed in Christiano, Trabandt and Walentin (2011) for the case of a small open economy with financial frictions in the accumulation and management of physical capital. We extend this framework by including a more complex structure in the banking sector, which allows us to incorporate legal reserve requirements as an instrument of monetary policy.

### 5.2 Goods Production Side of the Model

The homogeneous domestic good  $Y_t$  is produced by a competitive, representative firm that takes the prices of its output ( $P_t$ ) and its inputs ( $P_{i,t}$ ) as given. The production function is given by:

$$Y_t = \left[ \int_0^1 Y_{i,t}^{\frac{1}{\lambda_d}} di \right]^{\lambda_d}$$

where  $\lambda_d \geq 1$  represents the gross price mark-up.

According to the previous description, this domestic homogeneous good is allocated among alternative uses:

$$Y_t = G_t + C_t^d + I_t^d + \int_0^1 X_t^{i,d} + \text{Monitoring Costs} + \text{Reserves Holding Costs},$$

where,  $C_t^d$  denotes intermediate goods used (together with foreign consumption goods) to produce final household consumption goods;  $I_t^d$  is the amount of intermediate domestic goods used in combination with imported foreign investment goods to produce a homogeneous investment good; and  $\int_0^1 X_t^{i,d}$  denotes domestic resources allocated to exports.

Each intermediate good producer hires labor and capital in order to produce its specialized output according to the following production function:

$$Y_{i,t} = z_t H_{i,t}^{1-\alpha} \epsilon_t K_{i,t}^\alpha - z_t^+ \phi$$

where  $\log(z_t)$  is a technology shock whose first difference has a positive mean.  $\log \epsilon_t$  represents a stationary neutral technology shock, while  $\phi$  denotes a fixed production cost.  $z_t^+$  is defined as

$z_t \Psi_t^{\frac{\alpha}{1-\alpha}}$ , where  $\Psi_t$  is an investment-specific technology shock with positive drift in  $\log(\Psi_t)$ . It is important to notice that the economy has two sources of growth: the positive drifts in  $\log(z_t)$  and  $\log(\Psi_t)$ . The neutral shock to technology has a growth rate given by  $\mu_{z,t}$ :

$$z_t = z_{t-1} \mu_{z,t}$$

while for the investment-specific technology shock we have a growth rate given by  $\mu_{\Psi,t}$ :

$$\Psi_t = \Psi_{t-1} \mu_{\Psi,t}$$

If we define  $z_t^+ = z_t \Psi_t^{\frac{\alpha}{1-\alpha}}$ , using the above relationships it is possible to obtain that:

$$\mu_{z^+,t} = \mu_{z,t} \mu_{\Psi,t}^{\frac{\alpha}{1-\alpha}}$$

These growth rates, as well as appropriate prices, are used to normalize real and nominal variables in order to achieve stationarity in the model.

Each specialized intermediate good producer hires labor services at a unit cost given by  $W_t R_t^f$ , where:

$$R_t^f = \nu^f R_t + 1 - \nu^f$$

In this expression  $\nu^f$  represents the fraction of the wage bill that firms must borrow from lending banks in order to pay for labor services, while  $R_t$  represents the risk-free interest rate that applies on working capital loans.

The normalized real marginal cost of firms is given by:

$$mc_t = \tau^d \frac{1}{(1-\alpha)^{1-\alpha} \alpha^\alpha \epsilon_t} (r_t^k)^\alpha (\bar{w}_t R_t^f)^{1-\alpha}$$

where  $\tau^d$  is a tax-like shock that affects marginal cost.  $r_t^k$  is the rental rate of capital and  $\bar{w}_t$  represents the scaled aggregate wage, both in terms of the domestic homogeneous good.

A second definition of marginal cost is given by a productive efficiency condition, which states that:

$$mc_t = \tau^d \frac{(\mu_{\Psi,t})^\alpha \bar{w}_t R_t^f}{\epsilon_t (1-\alpha) \left( \frac{k_{i,t}}{\mu_{z^+,t} H_{i,t}} \right)^\alpha}$$

Each of the specialized firms is a monopolist in the production of its good so it has absolute price-setting power. Price setting is subject to Calvo frictions, which means that with probability  $\xi_d$  the intermediate good firm cannot reoptimize its price. This condition implies that:

$$P_{i,t} = \tilde{\pi}_{d,t} P_{i,t-1}$$

where:

$$\tilde{\pi}_{d,t} = (\pi_{t-1})^{\kappa_d} (\bar{\pi}_t^c)^{1-\kappa_d-\varkappa_d} (\check{\pi})^{\varkappa_d}$$

where  $\kappa_d, \varkappa_d, \kappa_d + \varkappa_d \in [0, 1]$  are parameters,  $\pi_{t-1}$  is the lagged inflation rate and  $\bar{\pi}_t^c$  is the Central Bank's target inflation rate.  $\check{\pi}$  is a scalar which allows us to capture the case in which non-optimizing firms either do not change price at all ( $\check{\pi} = \varkappa_d = 1$ ) or index only to the steady state inflation rate ( $\check{\pi} = \bar{\pi}, \varkappa_d = 1$ ). It is important to note that we get price dispersion in steady state if  $\varkappa_d > 0$  and if  $\check{\pi}$  is different from the steady state value of  $\pi$ .

Firms reoptimize their prices with probability  $1 - \xi_d$ . This possibility implies maximizing the discounted value of profits:

$$E_t \sum_{j=0}^{\infty} \beta^j v_{t+j} [P_{i,t+j} Y_{i,t+j} - mc_{t+j} P_{t+j} Y_{i,t+j}]$$

subject to the requirement that production equal demand:

$$\left( \frac{P_t}{P_{i,t}} \right)^{\frac{\lambda_d}{\lambda_d-1}} Y_t = Y_{i,t}$$

In this problem  $v_t$  denotes the multiplier on the household's nominal budget constraint and it measures the the marginal value to the household of one unit of profits in terms of currency.

### 5.2.1 Final Consumption Goods

Households purchase final consumption goods  $C_t$ . As previously mentioned, each unit of final consumption good is produced by a representative competitive firm combining both domestic and imported consumption goods in the following production function:

$$C_t = \left[ (1 - \omega_c)^{\frac{1}{\eta_c}} (C_t^d)^{\frac{\eta_c-1}{\eta_c}} + \omega_c^{\frac{1}{\eta_c}} (C_t^m)^{\frac{\eta_c-1}{\eta_c}} \right]^{\frac{\eta_c}{\eta_c-1}}$$

The representative firm takes the price of final consumption goods output ( $P_t^c$ ) as given. It also takes as given the prices of domestic and imported inputs ( $P_t$  and  $P_t^{m,c}$ , respectively). The solution to the profit maximization problem implies the following input demands:

$$\begin{aligned} C_t^d &= (1 - \omega_c) \left( \frac{P_t^c}{P_t} \right)^{\eta_c} C_t \\ C_t^m &= \omega_c \left( \frac{P_t^c}{P_t^{m,c}} \right)^{\eta_c} C_t \end{aligned}$$

The relationship between output and input prices is given by:

$$P_t^c = \left[ (1 - \omega_c) P_t^{1-\eta_c} + \omega_c (P_t^{m,c})^{1-\eta_c} \right]^{\frac{1}{1-\eta_c}}$$

while the inflation rate associated with the final consumption good is given by:

$$\pi_t^c = \frac{P_t^c}{P_{t-1}^c} = \pi_t \left[ \frac{(1 - \omega_c) + \omega_c \left( \frac{P_t^{m,c}}{P_t} \right)^{1-\eta_c}}{(1 - \omega_c) + \omega_c \left( \frac{P_{t-1}^{m,c}}{P_{t-1}} \right)^{1-\eta_c}} \right]^{\frac{1}{1-\eta_c}}$$

### 5.2.2 Final Investment Goods

In this model investment is defined to be the sum of investment goods used in the accumulation of physical capital ( $I_t$ ) plus investment goods used for capital maintenance ( $a(u_t)\bar{K}_t$ ). In this way, we have that the investment production function is given by:

$$I_t + a(u_t)\bar{K}_t = \Psi_t \left[ (1 - \omega_i)^{\frac{1}{\eta_i}} (I_t^d)^{\frac{\eta_i-1}{\eta_i}} + \omega_i^{\frac{1}{\eta_i}} (I_t^m)^{\frac{\eta_i-1}{\eta_i}} \right]^{\frac{\eta_i}{\eta_i-1}}$$

where  $u_t$  defines the utilization rate of capital so capital services are defined as  $K_t = u_t \bar{K}_{t-1}$  and:

$$a(u_t) = 0.5\sigma_b\sigma_a u_t^2 + \sigma_b(1 - \sigma_a)u_t + \sigma_b(0.5\sigma_a - 1)$$

where  $\sigma_a$  and  $\sigma_b$  are parameters of this function.

The law of motion of the stock of physical capital is given by:

$$\bar{K}_{t+1} = (1 - \delta)\bar{K}_t + \Upsilon_t \left[ 1 - \tilde{S} \left( \frac{I_t}{I_{t-1}} \right) \right] I_t$$

where  $\Upsilon_t$  is a shock that affects the way in which investment is transformed into capital. Additionally,  $\tilde{S}(x)$  is an investment adjustment cost function determined by:

$$\tilde{S}(x) = 0.5 \left\{ \exp \left[ \sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] + \exp \left[ -\sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] - 2 \right\}$$

where  $\tilde{S}''$  is the parameter of the cost function.

To accommodate the possibility that the price of investment goods relative to the price of consumption goods declines over time, it is assumed that the investment-specific technology shock  $\Psi_t$  is a unit root process with a potentially positive drift.

The representative investment goods producer takes all relevant prices as given. The solution to his profit maximization problem is given by:

$$\begin{aligned} I_t^d &= \frac{1}{\Psi_t} \left( \frac{P_t^i \Psi_t}{P_t} \right)^{\eta_i} [I_t + a(u_t)\bar{K}_t] (1 - \omega_i) \\ I_t^m &= \frac{1}{\Psi_t} \left( \frac{P_t^i \Psi_t}{P_t^{m,i}} \right)^{\eta_i} [I_t + a(u_t)\bar{K}_t] \omega_i \end{aligned}$$

Finally, the relationship between the price of  $I_t$  and the price of its inputs is given by:

$$P_t^i = \left[ (1 - \omega_i) P_t^{1-\eta_i} + \omega_i (P_t^{m,i})^{1-\eta_i} \right]^{\frac{1}{1-\eta_i}}$$

while its inflation rate is:

$$\pi_t^i = \frac{P_t^i}{P_{t-1}^i} = \frac{\pi_t}{\mu_{\Psi,t}} \left[ \frac{(1 - \omega_i) + \omega_i \left( \frac{P_t^{m,i}}{P_t} \right)^{1-\eta_i}}{(1 - \omega_i) + \omega_i \left( \frac{P_{t-1}^{m,i}}{P_{t-1}} \right)^{1-\eta_i}} \right]^{\frac{1}{1-\eta_i}}$$

### 5.2.3 Exports

Exports involve a continuum of exporters, each of which is a monopolist who produces a specialized export good ( $X_{i,t}$ ). Each monopolist produces the export good using a homogeneous domestically produced good ( $X_t^d$ ) and a homogeneous good derived from imports ( $X_t^m$ ). The specialized export goods are sold to foreign competitive retailers that create a homogeneous good ( $X_t$ ) that is sold to foreign citizens.

There is a total demand by foreigners for domestic exports which is given by:

$$X_t = \left( \frac{P_t^x}{P_t^*} \right)^{-\eta_f} Y_t^*$$

where  $Y_t^*$  represents foreign GDP,  $P_t^*$  is the foreign currency price of foreign homogeneous goods, and  $P_t^x$  is an index of export prices. The export good  $X_t$  is manufactured by a representative competitive foreign retailer firm that combines specialized inputs as follows:

$$X_t = \left[ \int_0^1 X_{i,t}^{\frac{1}{\lambda_x}} \right]^{\lambda_x}$$

The retailer that produces  $X_t$  takes its output price  $P_t^x$  and its input prices  $P_{i,t}^x$  as given. The optimal demand for each specialized input is:

$$X_{i,t} = \left( \frac{P_{i,t}^x}{P_t^x} \right)^{\frac{-\lambda_x}{\lambda_x - 1}} X_t$$

On the other hand, the  $i^{th}$  specialized export is produced by a monopolist using the following technology:

$$X_{i,t} = \left[ \omega_x^{\frac{1}{\eta_x}} (X_t^{i,m})^{\frac{\eta_x - 1}{\eta_x}} + (1 - \omega_x)^{\frac{1}{\eta_x}} (X_t^{i,d})^{\frac{\eta_x - 1}{\eta_x}} \right]^{\frac{\eta_x}{\eta_x - 1}}$$



where  $X_t^{i,m}$  and  $X_t^{i,d}$  are the  $i^{th}$ 's exporter's use of the imported and domestically produced export goods, respectively. The cost minimization problem each specialized exporter faces consists of minimizing the input payments  $\tau_x \left( P_t^{m,x} R_t^x X_t^{i,m} + P_t R_t^x X_t^{i,d} \right)$  subject to the production function presented above. Here  $\tau_x$  is a tax-like shock and  $P_t^{m,x} R_t^x$  is the unit cost of an imported export input.  $R_t^x$  is defined as:

$$R_t^x = \nu^x R_t + 1 - \nu^x$$

where  $\nu^x$  represents the fraction of the resources an specialized exporter needs to finance in advance as a working capital loan. They obtain these loans from lending banks.

The marginal cost (in terms of stationary variables) associated with the above minimization problem is:

$$mC_t^x = \frac{\tau^x R_t^x P_t}{S_t P_t^x} \left[ \omega_x \left( \frac{P_t^{m,x}}{P_t} \right)^{1-\eta_x} + 1 - \omega_x \right]^{\frac{1}{1-\eta_x}}$$

where  $S_t$  is the nominal exchange rate. The optimal demand for domestic input for export production is given by:

$$X_t^{i,d} = \left( \frac{\lambda}{\tau^x R_t^x P_t} \right)^{\eta_x} X_{i,t} (1 - \omega_x)$$

where  $\lambda$  is the Lagrange multiplier from the minimization cost problem. Then, we have that the quantity of domestic homogeneous good used by specialized exporters is  $X_t^d = \int_0^1 X_t^{i,d}$ . It is possible to rewrite this as:

$$X_t^d = \left( \frac{\ddot{P}_t^x}{P_t^x} \right)^{\frac{-\lambda_x}{\lambda_x - 1}} \left[ \omega_x \left( \frac{P_t^{m,x}}{P_t} \right)^{1-\eta_x} + 1 - \omega_x \right]^{\frac{1}{1-\eta_x}} (1 - \omega_x) \left( \frac{P_t^x}{P_t^*} \right)^{-\eta_f} Y_t^*$$

where  $\ddot{P}_t^x$  is a measure of price dispersion given by:

$$\ddot{P}_t^x = \left[ \int_0^1 (P_{i,t}^x)^{\frac{-\lambda_x}{\lambda_x - 1}} di \right]^{\frac{\lambda_x - 1}{-\lambda_x}}$$

For the case of imported inputs for export production we have a similar expression:

$$X_t^m = \omega_x \left( \frac{\ddot{P}_t^x}{P_t^x} \right)^{\frac{-\lambda_x}{\lambda_x - 1}} \left( \frac{\left[ \omega_x \left( \frac{P_t^{m,x}}{P_t} \right)^{1-\eta_x} + 1 - \omega_x \right]^{\frac{1}{1-\eta_x}}}{\frac{P_t^{m,x}}{P_t}} \right)^{\eta_x} \left( \frac{P_t^x}{P_t^*} \right)^{-\eta_f} Y_t^*$$

Export prices are set in the currency of the buyer. Export activities are subject to Calvo price-setting frictions. Christiano, Trabandt and Walentin (2011) remark that pricing frictions in the case of exports help the model to produce a hump-shaped response of output to a monetary shock.

With probability  $\xi_x$  the  $i^{th}$  export good firm cannot reoptimize its price, in which case it updates its price as follows:

$$P_{i,t}^x = \tilde{\pi}_t^x P_{i,t-1}^x$$

where:

$$\tilde{\pi}_t^x = (\pi_{t-1}^x)^{\kappa_x} (\pi^x)^{1-\kappa_x-\varkappa_x} (\bar{\pi})^{\varkappa_x}$$

where  $\kappa_x, \varkappa_x, \kappa_x + \varkappa_x \in [0, 1]$  are parameters. Firms reoptimize their prices with probability  $1 - \xi_x$ . This possibility implies maximizing the discounted value of profits, which is an analogous problem to the one developed for intermediate domestic goods producers.

#### 5.2.4 Imports

Specialized domestic importers purchase a homogeneous foreign good, which they turn into a specialized input and sell it to domestic retailers. Importers supply that input monopolistically to domestic retailers and are subject to Calvo price-setting frictions. There are three types of importing firms.

##### **Consumption-Importing Firm**

This firm produces goods used to produce an intermediate good for the production of consumption. In particular, the production function of the domestic retailer of imported consumption goods is given by:

$$C_t^m = \left[ \int_0^1 (C_{i,t}^m)^{\frac{1}{\lambda_{m,c}}} di \right]^{\lambda_{m,c}}$$

where  $C_{i,t}^m$  is the output of the  $i^{th}$  specialized producer and  $C_t^m$  is an intermediate good used in the production of final consumption goods. Since the domestic retailer is competitive, he takes the prices of both output and inputs ( $P_{i,t}^{m,c}$  and  $P_t^{m,c}$ , respectively) as given. The solution to the domestic retailer's profit maximization problem is given by the following demand curve for specialized inputs:

$$C_{i,t}^m = C_t^m \left( \frac{P_t^{m,c}}{P_{i,t}^{m,c}} \right)^{\frac{\lambda_{m,c}}{\lambda_{m,c}-1}}$$

The producer of  $C_{i,t}^{m,c}$  buys a homogeneous foreign good and converts it one-for-one into the domestic differentiated good  $C_{i,t}^{m,c}$ . His marginal cost is given by:

$$\tau^{m,c} S_t P_t^* R_t^{\nu,*}$$

where:

$$R_t^{\nu,*} = \nu^* R_t^* + 1 - \nu^*$$

which means that the intermediate good firm must pay the inputs with foreign currency and because it does not have not enough resources at the beginning of the period, it must borrow a fraction  $\nu^*$  of them. Since the financing need is in the foreign currency, the loan is taken in that currency and can be thought as a credit extended by the foreign seller. In this context,  $R_t^*$  represents the foreign nominal rate of interest, while  $\tau^{m,c}$  is a tax-like shock.

### Investment-Importing Firm

This firm produces goods used to produce an intermediate good for the production of investment. The production function of the domestic retailer of imported investment goods is given by:

$$I_t^m = \left[ \int_0^1 (I_{i,t}^m)^{\frac{1}{\lambda_{m,i}}} di \right]^{\lambda_{m,i}}$$

where  $I_{i,t}^m$  is the output of the  $i^{th}$  specialized producer and  $I_t^m$  is an intermediate good used in the production of final investment goods. Again, since the domestic retailer is competitive he takes the prices of both output and inputs ( $P_{i,t}^{m,i}$  and  $P_t^{m,i}$ , respectively) as given. The solution to the domestic retailer's profit maximization problem is given by the following demand curve for specialized inputs:

$$I_{i,t}^m = I_t^m \left( \frac{P_t^{m,i}}{P_{i,t}^{m,i}} \right)^{\frac{\lambda_{m,i}}{\lambda_{m,i}-1}}$$

The producer of  $I_{i,t}^{m,i}$  buys a homogeneous foreign good and also converts it one-for-one into the domestic differentiated good  $I_{i,t}^{m,i}$ . His marginal cost is given by:

$$\tau^{m,i} S_t P_t^* R_t^{\nu,*}$$

which means that the intermediate investment good firm must also ask for a working capital loan. As before,  $\tau^{m,i}$  represents a tax-like shock.

### Export-Importing Firm

This firm produces goods used to produce an intermediate good for the production of exports. The production function of the domestic retailer of imported goods used in the production of an input for the production of export goods is:

$$X_t^m = \left[ \int_0^1 (X_{i,t}^m)^{\frac{1}{\lambda_{m,x}}} di \right]^{\lambda_{m,x}}$$

where  $X_{i,t}^m$  is the output of the  $i^{th}$  specialized producer. Once more, since the domestic retailer is competitive he takes the prices of both output and inputs ( $P_{i,t}^{m,x}$  and  $P_t^{m,x}$ , respectively) as given.

The producer of  $X_{i,t}^{m,x}$  buys a homogeneous foreign good and converts it one-for-one into the domestic differentiated good  $X_{i,t}^{m,x}$ . His marginal cost is given by:

$$\tau^{m,x} S_t P_t^* R_t^{\nu,*}$$

which means that the intermediate export input good firm must also ask for a working capital loan. Once more,  $\tau^{m,x}$  represents a tax-like shock.

### Imported Goods Price Frictions

Each of the three types of intermediate goods firm is subject to Calvo price-setting frictions. For  $j = c, i, x$ , with probability  $1 - \xi_{m,j}$  the  $j^{th}$  type of firm can reoptimize its price and with probability  $\xi_{m,j}$  it sets price according to the following relationship:

$$P_{i,t}^{m,j} = \tilde{\pi}_t^{m,j} P_{i,t-1}^{m,j}$$

where:

$$\tilde{\pi}_t^{m,j} = (\pi_{t-1}^{m,j})^{\kappa_j} (\bar{p}_t^c)^{1-\kappa_{m,j}-\varkappa_{m,j}} \bar{\pi}_{m,j}^{\varkappa_{m,j}}$$

where  $\kappa_j, \varkappa_j, \kappa_j + \varkappa_j \in [0, 1]$  are parameters.

### 5.3 Households

Household  $j^{th}$  preferences are given by:

$$E_0^j \sum_{t=0}^{\infty} \beta^t \left[ \zeta_t^c \log (C_t - bC_{t-1}) - \zeta_t^h A_L \frac{(h_{j,t})^{1+\sigma_L}}{1 + \sigma_L} \right]$$

where  $\zeta_t^c$  and  $\zeta_t^h$  represent shocks to marginal utility of consumption and leisure, respectively,  $b$  is the consumption habit parameter and  $\sigma_L$  is the inverse Frisch elasticity.

The first order condition for consumption is given by:

$$0 = \frac{\zeta_t^c}{C_t - bC_{t-1}} - v_t P_t^c (1 + \tau_c) - b\beta E_t^j \frac{\zeta_{t+1}^c}{C_{t+1} - bC_t}$$

where  $v_t$  represents the multiplier on the household's period  $t$  budget constraint.

Households are also responsible for the economy's saving. In particular, they have to choose the stock of domestic and foreign financial assets, as well as their rates of accumulation.

The domestic asset consists of deposits that households make in deposit banks. A fraction of these deposits is required by lending banks to finance both the working capital requirements of firms and entrepreneurial loans. For their deposits, households receive a nominally non-state contingent return  $R_t^d$  from  $t$  to  $t + 1$ . The first order condition associated with the choice of deposits is given by:

$$v_t P_t z_t^+ = \beta E_t \frac{v_{t+1} P_{t+1} z_{t+1}^+}{\mu_{z^+, t+1}} \left[ \frac{R_t^d - \tau^b (R_t^d - \pi_{t+1})}{\pi_{t+1}} \right]$$

where  $\tau^b$  is a tax rate on this financial income.

The foreign financial asset is represented by a bond denominated in foreign currency. The date  $t$  first order condition associated with the choice of this asset  $A_{t+1}^*$  is:

$$v_t S_t = \beta E_t v_{t+1} \left[ S_{t+1} R_t^* \Phi_t - \tau_b \left( S_{t+1} R_t^* \Phi_t - \frac{S_t}{P_t} P_{t+1} \right) \right]$$

The left-hand side of this expression states the cost of acquiring a unit of foreign assets. The term in square brackets is the after-tax payoff of the foreign bond measured in domestic currency units. The first term is the period  $t + 1$  pre-tax interest payoff on  $A_{t+1}^*$ ;  $R_t^*$  is the risk-free foreign nominal interest rate (denominated in foreign currency units), while  $\Phi_t$  represents a relative risk adjustment of the foreign asset return, so that a unit of the foreign asset acquired in  $t$  pays off  $R_t^* \Phi_t$  of foreign currency in  $t + 1$ .

The risk adjustment term is given by:

$$\Phi_t = \Phi \left( a_t, R_t^* - R_t^d, \tilde{\phi}_t \right) = \exp \left\{ -\tilde{\phi}_a (a_t - \bar{a}) - \tilde{\phi}_s [R_t^* - R_t^d - (R^* - R^d)] + \tilde{\phi}_t \right\}$$

where:

$$a_t = \frac{S_t A_{t+1}^*}{P_t z_t^+}$$

and  $\tilde{\phi}_t$  is a mean zero shock and  $\tilde{\phi}_a$  and  $\tilde{\phi}_s$  are positive parameters. As usual in this kind of DSGE models for open economies, the dependence of  $\Phi_t$  on  $a_t$  ensures the existence of a unique steady state of  $a_t$  independent of the initial net foreign assets and the capital stock of the economy. The dependence of  $\Phi_t$  on the relative level of the interest rate  $R_t^* - R_t^d$  is designed to allow the model to reproduce the hump-shaped response of output to a monetary policy shock.

Finally, the term in parenthesis in the previous first order condition states the impact of taxation on the return on foreign assets. In particular, the term after the minus sign is designed to ensure that the principal is deducted from taxes. The principal is expressed in nominal terms and

is set so that the real value at  $t + 1$  coincides with the real value of the currency used to purchase the asset in period  $t$ . Since  $S_t$  measures the period  $t$  domestic currency cost of a unit of foreign assets, the period  $t$  real cost of the asset is  $\frac{S_t}{P_t}$ . The domestic currency value in period  $t + 1$  of this real quantity is  $\frac{P_{t+1}S_t}{P_t}$ .

### 5.3.1 Wage Setting

In this model the homogeneous labor services are supplied to the competitive labor market by labor contractors. They combine specialized labor services supplied by households into a homogeneous labor service using the following technology:

$$H_t = \left[ \int_0^1 (h_{j,t})^{\frac{1}{\lambda_w}} dj \right]^{\lambda_w}$$

where  $h_j$  is the supply of labor services made by household  $j^{th}$  and  $\lambda_w \geq 1$  represents the wage markup.

Households are subject to Calvo wage-setting frictions. With probability  $1 - \xi_w$  the  $j^{th}$  household is able to reoptimize its wage whereas with probability  $\xi_w$  it sets its wage in accordance with:

$$W_{j,t+1} = \tilde{\pi}_{w,t+1} W_{j,t}$$

where:

$$\tilde{\pi}_{w,t+1} = (\pi_t^c)^{\kappa_w} (\bar{\pi}_{t+1}^c)^{1-\kappa_w-\varkappa_w} (\bar{\pi})^{\varkappa_w} (\mu_{z+})^{\vartheta_w}$$

where  $\kappa_w, \varkappa_w, \kappa_w + \varkappa_w, \vartheta_w \in [0, 1]$  and  $\vartheta_w$  is the wage indexation to real growth trend.

Considering the situation of a household that has the opportunity to reoptimize its wage at time  $t$ , we have that in choosing the new wage  $\tilde{W}_t$  the household considers the discounted utility of future histories when it cannot reoptimize:

$$E_t^j = \sum_{i=0}^{\infty} (\beta \xi_w)^i \left[ -\zeta_t^h A_L \frac{(h_{j,t})^{1+\sigma_L}}{1+\sigma_L} + v_{t+i} W_{j,t+i} h_{j,t+i} \left( \frac{1-\tau^y}{1+\tau^w} \right) \right]$$

where  $\tau^y$  is a tax on labor income and  $\tau^w$  is a payroll tax.

The demand for household  $j^{th}$ 's labor services, conditional on it having optimized in period  $t$  and not again since is:

$$h_{j,t+i} = \left( \frac{\tilde{W}_t \tilde{\pi}_{w,t+1} \dots \tilde{\pi}_{w,t+i}}{W_{t+i}} \right)^{\frac{\lambda_w}{1-\lambda_w}} H_{t+i}$$

where  $\tilde{\pi}_{w,t+1} \dots \tilde{\pi}_{w,t+i} = 1$  when  $i = 0$ .

## 5.4 Capital Market Side of the Model

### 5.4.1 The Banking Sector

Banks attract funding from households and lend to entrepreneurs. Instead of using only one banking unit doing both the funding and lending, we analyze these tasks separately, following Glocker and Towbin (2012). Therefore, the banking sector includes deposit units and lending units. Deposit units operate in perfectly competitive input and output markets. They collect deposits from households and lend a fraction of them to lending units at the interbank market rate, while keeping the rest of the deposits as reserves in the Central Bank.

The profit maximization problem of a deposit bank is:

$$\max_{\{\zeta_t(j), D_t(j)\}} Div_t^S(j)$$

s.t.

$$G_t^\zeta(j) = \psi_1 (\zeta_t(j) - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t(j) - \zeta_t^{MP})^2$$

where:

$$Div_t^S(j) = \left[ (1 - \zeta_t(j)) i_t^{IB} + \zeta_t(j) i_t^R - i_t(j)^D - G_t^\zeta(j) \right] D_t(j)$$

where  $\zeta_t(j)$  represents the fraction of deposits that Deposit unit  $j$  puts into an account in the Central Bank and  $\zeta_t^{MP}$  is the legal required reserve ratio.  $G_t^\zeta(j)$  represents a convex function that determines the cost of holding reserves. The linear term is associated with the Central Bank imposing a penalty for not fulfilling the reserve requirement (parameter  $\psi_1 < 0$ ). The quadratic term is associated with the Central Bank punishing large deviations from its reserve requirement target (parameter  $\psi_2 > 0$ ). Deposit units benefits come from i) the proportion of deposits they can lend,  $(1 - \zeta_t(j)) D_t(j)$ , which are remunerated at the interbank market rate  $i_t^{IB}$ , and ii) the fraction of deposits they deposit in Central Bank accounts as reserves,  $\zeta_t(j) D_t(j)$ , which are remunerated at the reserve rate  $i_t^R$ . The costs are represented by interest paid to deposits  $i_t(j)^D D_t(j)$ , and the cost function described above.

Lending units do not interact with households. They are not subject to reserve requirements and finance themselves through the interbank market, which means that they do not hold any deposits from households. Like deposit units, lending units operate in perfectly competitive input and output markets. They obtain funds from deposit units at the cost of the interbank rate and supply loans to entrepreneurs at the lending rate. Lending units also fulfill the financial needs of domestic intermediate goods producers in terms of the working capital they need to pay either for a fraction of the wage bill or for the resources they need to produce export goods, charging them

the interbank rate. The amount of interbank lending always equals the stock of loans supplied to both risky entrepreneurs and non-risky domestic intermediate goods producers.

The equilibrium condition in the financial market requires the following equality to hold at each date  $t$ :

$$(1 - \zeta_t) Dep_t = \underbrace{\nu^f W_t H_t + \nu^x (P_t^{m,x} X_t^m + P_t X_t^d)}_{Working\ Capital\ Loans} + \underbrace{P_t P_{k',t} \bar{K}_{t+1} - \bar{N}_{t+1}}_{Entrepreneurial\ Loans}$$

#### 5.4.2 Financial Frictions

The interaction between lending units and entrepreneurs is modelled by means of the financial contract as in Bernanke et al. (1999). At the end of period  $t$ , each entrepreneur has a level of net worth  $N_{t+1}$ , which constitutes his state at this time.  $N_{t+1}$  completely describes the entrepreneur's history so it is the only relevant information. An entrepreneur willing to purchase a quantity  $\bar{K}_{t+1}$  of newly installed physical capital from capital producers will require a loan from a lending unit defined by:

$$B_{t+1} = P_t P_{k',t} \bar{K}_{t+1} - N_{t+1}$$

where  $P_t P_{k',t}$  is the domestic currency price of a unit of physical capital which operates in period  $t+1$ . After purchasing capital, every entrepreneur experiences an idiosyncratic productivity shock that converts the purchased capital into the quantity  $\omega \bar{K}_{t+1}$ , where  $\omega$  is a lognormally and independently distributed (across entrepreneurs) random variable with unit mean and variance  $\sigma_t^2$ .  $F(\omega, \sigma)$  denotes the cumulative distribution function of  $\omega$ .

Once the period  $t+1$  shocks are observed, entrepreneurs sets the utilization rate of capital  $u_{t+1}$ , and rents its capital in competitive markets at a nominal rental rate of  $P_{t+1} r_{t+1}^k$ , where  $P_t$  represents the price of the homogeneous domestic good. Operating one unit of physical capital at rate  $u_{t+1}$  requires  $a(u_{t+1})$  of domestically produced investment goods for maintenance expenditures.

Once the undepreciated capital returned to the entrepreneur, he sells it to capital producers at a price  $P_{t+1} P_{k',t+1}$ . The entrepreneur also faces a tax rate on capital utilization ( $\tau_k$ ) that excludes from its tax base the maintenance expenditures associated to the operation of capital. Furthermore, physical depreciation is also considered deductible at historical cost. In this way, the rate of return on a period  $t$  investment in a unit of physical capital is given by:

$$R_{t+1}^k = \frac{(1 - \tau^k) \left[ u_{t+1} \Psi_t r_t^k - \frac{P_{t+1}^i}{P_{t+1}} a(u_{t+1}) \right] P_{t+1} + (1 - \delta) P_{t+1} P_{k',t+1} + \tau^k \delta P_t P_{k',t}}{P_t P_{k',t}}$$



where  $\Psi_t$  represents an investment-specific technology shock and  $P_t^i$  is the price of final investment goods. At this point, the resources available to an entrepreneur who has purchased  $\bar{K}_{t+1}$  units of physical capital in period  $t$  and who experiences an idiosyncratic productivity shock  $\omega$  are given by:

$$P_t P_{k',t} R_{t+1}^k \omega \bar{K}_{t+1}$$

Since each entrepreneur faces a nominal gross interest rate  $Z_{t+1}$  for each unit of loan, it is possible to think that there exists a cut-off value of  $\omega$ ,  $\bar{\omega}_{t+1}$ , such that the entrepreneur has just enough resources to pay back to the lending unit:

$$P_t P_{k',t} R_{t+1}^k \bar{\omega}_{t+1} \bar{K}_{t+1} = Z_{t+1} B_{t+1}$$

Those entrepreneurs for which it happens that  $\omega_{t+1} < \bar{\omega}_{t+1}$  are bankrupt and turn over all their resources to the lending bank. Since there exist monitoring costs, banks only receive a fraction  $(1 - \mu)$  of those resources. On the other hand, for loans in the amount  $B_{t+1}$  the bank receives  $Z_{t+1} B_{t+1}$  from the  $1 - F(\bar{\omega}_{t+1}, \sigma_t)$  entrepreneurs who are not bankrupt. As a consequence, the state-by-state zero profit condition for the competitive lending units is given by:

$$[1 - F(\bar{\omega}_{t+1}, \sigma_t)] Z_{t+1} B_{t+1} + (1 - \mu) \int_0^{\bar{\omega}_{t+1}} \omega dF(\omega, \sigma_t) R_{t+1}^k P_t P_{k',t} \bar{K}_{t+1} = R_t B_{t+1}$$

Since  $P_t P_{k',t} R_{t+1}^k \bar{\omega}_{t+1} \bar{K}_{t+1} = Z_{t+1} B_{t+1}$ , we can rewrite the previous expression as:

$$[1 - F(\bar{\omega}_{t+1}, \sigma_t)] P_t P_{k',t} R_{t+1}^k \bar{\omega}_{t+1} \bar{K}_{t+1} + (1 - \mu) \int_0^{\bar{\omega}_{t+1}} \omega dF(\omega, \sigma_t) R_{t+1}^k P_t P_{k',t} \bar{K}_{t+1} = R_t B_{t+1}$$

Defining:

$$\begin{aligned} G(\bar{\omega}_{t+1}, \sigma_t) &= \int_0^{\bar{\omega}_{t+1}} \omega dF(\omega, \sigma_t) \\ \Gamma(\bar{\omega}_{t+1}, \sigma_t) &= \bar{\omega}_{t+1} [1 - F(\bar{\omega}_{t+1}, \sigma_t)] + G(\bar{\omega}_{t+1}, \sigma_t) \end{aligned}$$

we have that the former expression can be rewritten as:

$$\frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} \frac{R_{t+1}^k}{R_t} [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] = \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} - 1$$

where the term  $[\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)]$  defines the share of revenues earned by entrepreneurs that borrow  $B_{t+1}$  which goes to banks. Since both  $\Gamma(\bar{\omega}_{t+1}, \sigma_t)$  and  $G(\bar{\omega}_{t+1}, \sigma_t)$  are increasing in  $\bar{\omega}$ , the share of entrepreneurial revenues accruing to banks is non-monotonic with respect to  $\bar{\omega}_{t+1}$ .

Lending units offer a loan contract to each entrepreneur, which can be defined through a specific loan amount and an individual interest rate. These contract variables are the solution to

a particular optimization problem. In fact, the equilibrium contract is one that maximizes entrepreneurial welfare subject to the zero profit condition on lending banks. On this basis, we assume that entrepreneurial welfare corresponds to entrepreneurs' expected wealth at the end of the contract. It is convenient to express welfare as a ratio to the amount the entrepreneur could receive by depositing his net worth in a bank:

$$\begin{aligned} \frac{E_t \int_{\bar{\omega}_{t+1}}^{\infty} [R_{t+1}^k P_t P_{k',t} \omega \bar{K}_{t+1} - Z_{t+1} B_{t+1}] dF(\omega, \sigma_t)}{R_t N_{t+1}} &= \frac{E_t \int_{\bar{\omega}_{t+1}}^{\infty} [\omega - \bar{\omega}_{t+1}] dF(\omega, \sigma_t) R_{t+1}^k P_t P_{k',t} \bar{K}_{t+1}}{R_t N_{t+1}} \\ &= E_t \left\{ [1 - \Gamma(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \right\} \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} \end{aligned}$$

In this way, the date- $t$  debt contract specifies a level of debt  $B_{t+1}$  and a state -  $t + 1$  contingent rate of interest  $Z_{t+1}$ . However, it is possible to equivalently characterize the contract by a state -  $t + 1$  contingent set of values for  $\bar{\omega}_{t+1}$  and a value of  $\frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}}$ . The equilibrium contract results then from the following optimization problem:

$$\left\{ \bar{\omega}_{t+1}, \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} \right\} \max E_t \left\{ [1 - \Gamma(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} + \lambda_{t+1} \left( [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} - \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} + 1 \right) \right\}$$

where  $\lambda_{t+1}$  is the Lagrange multiplier which is defined for each period  $t + 1$  state of nature. The first order conditions are given by:

$$\begin{aligned} 0 &= E_t \left\{ [1 - \Gamma(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} + \lambda_{t+1} \left( [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} - 1 \right) \right\} \\ 0 &= -\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t) \frac{R_{t+1}^k}{R_t} + \lambda_{t+1} [\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t) - \mu G_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \\ 0 &= [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} - \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} + 1 \end{aligned}$$

From where we get:

$$\begin{aligned} 0 &= E_t \left\{ [1 - \Gamma(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} + \frac{\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)}{\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t) - \mu G_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)} \left( [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \right) \right\} \\ 0 &= [\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t)] \frac{R_{t+1}^k}{R_t} \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} - \frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} + 1 \end{aligned}$$

The result for  $\frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}}$  implies that:

$$\frac{P_t P_{k',t} \bar{K}_{t+1}}{N_{t+1}} - 1 = \frac{B_{t+1}}{N_{t+1}}$$

which means that an entrepreneur's loan amount is proportional to his net worth. Furthermore, the law of motion for the net worth of an individual entrepreneur is given by:

$$V_t = R_t^k P_{t-1} P_{k',t-1} K_t - \Gamma(\bar{\omega}_t, \sigma_{t-1}) R_t^k P_{t-1} P_{k',t-1} K_t$$

Each entrepreneur faces an identical and independent probability  $1 - \gamma$  of being selected to exit the economy. Because selection is random, the net worth of the entrepreneurs who survive is  $\gamma V_t$ . A fraction  $1 - \gamma$  of new entrepreneurs arrive. Entrepreneurs who arrive or survive receive a transfer  $W_t^e$ , which ensures that all entrepreneurs have sufficient funds to obtain at least some amount of loans. The average net worth across all entrepreneurs after  $W_t^e$  transfers have been made is:

$$\bar{N}_{t+1} = \gamma \bar{V}_t + W_t^e$$

or

$$\bar{N}_{t+1} = \gamma \left\{ R_t^k P_{t-1} P_{k',t-1} \bar{K}_t - \left[ R_{t-1} + \frac{\mu \int_0^{\bar{\omega}_t} dF(\omega, \sigma_{t-1}) R_t^k P_{t-1} P_{k',t-1} \bar{K}_t}{P_{t-1} P_{k',t-1} \bar{K}_t - \bar{N}_t} \right] (P_{t-1} P_{k',t-1} \bar{K}_t - \bar{N}_t) \right\} + W_t^e$$

where an upper bar over a letter denotes its aggregate average value.

### 5.4.3 Capital Producers

Capital goods producers build the capital stock that is sold to entrepreneurs. At the beginning of period  $t$ , capital producers buy the undepreciated physical capital units (used by intermediate domestic goods producers) from entrepreneurs. At the end of the same period, capital producers sell newly-installed physical capital units to entrepreneurs at a price  $P_t P_{k',t}$ . As Christiano, Trabandt and Walentin (2011) states, the profit maximization problem of the representative competitive capital producer can also be interpreted as the first order condition for the investment decision of a household that builds and sells physical capital:

$$0 = -v_t P_t^i + v_t P_t P_{k',t} \Upsilon_t \left[ 1 - \tilde{S} \left( \frac{I_t}{I_{t-1}} \right) - \tilde{S}' \left( \frac{I_t}{I_{t-1}} \right) \left( \frac{I_t}{I_{t-1}} \right) \right] + \beta E_t v_{t+1} P_{t+1} P_{k',t+1} \Upsilon_{t+1} \tilde{S}' \left( \frac{I_{t+1}}{I_t} \right) \left( \frac{I_{t+1}}{I_t} \right)^2$$

## 5.5 The Government Sector

In this model government consumption expenditures are modelled as:

$$G_t = g_t z_t^+$$

where  $g_t$  is an exogenous stochastic process orthogonal to the different shocks of the model:

$$\log g_t = (1 - \rho_g) \log g + \rho_g \log g_{t-1} + \varepsilon_t^g$$

where  $g = \eta_g Y$  is the steady state level of government expenditures.

In terms of tax revenues, the model has five tax rates ( $\tau_k, \tau_b, \tau_y, \tau_c, \tau_w$ ) which are assumed constant throughout time.

The monetary policy is conducted by the Central Bank in accordance with a Taylor rule approach. The Central Bank has two instruments of monetary policy. On the one hand, this institution can modify the risk-free interest rate  $R_t$ . On the other hand, it can also make use of reserve requirements, changing in this way the amount of available credit in the economy. We assume that both instruments depend on their immediately previous value. They also depend on four measures of economic activity and inflation: i) the relationship between the current value of the inflation target and its steady state level, ii) the relationship between the value of current inflation and the current value of the inflation target, iii) the relationship between the current level of GDP and its steady state level, and iv) the relationship between the current value of risky entrepreneurial loans and their steady state value:

$$\begin{aligned} \log \left( \frac{R_t}{R} \right) &= \\ \rho_R \log \left( \frac{R_{t-1}}{R} \right) + (1 - \rho_R) &\left[ \log \left( \frac{\bar{\pi}_t^c}{\bar{\pi}^c} \right) + r_\pi \log \left( \frac{\pi_t^c}{\bar{\pi}_t^c} \right) + r_y \log \left( \frac{gdp_t}{gdp} \right) + r_L \log \left( \frac{B_{t+1}}{B} \right) \right] + \varepsilon_t^R \\ \log \left( \frac{\zeta_t^{MP}}{\zeta^{MP}} \right) &= \\ \rho_\zeta \log \left( \frac{\zeta_{t-1}^{MP}}{\zeta^{MP}} \right) + (1 - \rho_\zeta) &\left[ \log \left( \frac{\bar{\pi}_t^c}{\bar{\pi}^c} \right) + \zeta_\pi \log \left( \frac{\pi_t^c}{\bar{\pi}_t^c} \right) + \zeta_y \log \left( \frac{gdp_t}{gdp} \right) + \zeta_L \log \left( \frac{B_{t+1}}{B} \right) \right] + \varepsilon_t^\zeta \end{aligned}$$

where  $\varepsilon_t^R$  and  $\varepsilon_t^\zeta$  are monetary policy shocks and the parameters are taken as unknowns to be estimated. In these policy rules,  $gdp$  denotes measured GDP in the data, which might differ from the output measure of the model because of the costs functions that characterize the behavior of capital accumulation, monitoring and reserves holding. In the previously stated policy rules,  $\bar{\pi}_t^c$  is an exogenous process that characterizes the Central Bank's consumer price index inflation target and its steady state value corresponds to the steady state of actual inflation.

Finally, the Central Bank also has to set the interest rate paid to the reserves deposit banks hold. In our model we will assume the following interest rate relationship:

$$R_t^R = R_t - \Theta + \varepsilon_{\Theta,t}$$

where  $\Theta$  is a parameter that reflects the steady state interest rate spread between the reserves rate and the monetary policy rate. Additionally,  $\varepsilon_{\Theta,t}$  is a monetary policy shock to the mentioned spread.

## 5.6 The External Sector

The foreign variables of the model are driven by a stochastic process that incorporates the idea that foreign output ( $Y_t^*$ ) is affected by disturbances to  $z_t^+$  in the same way domestic variables are. In particular we have:

$$Y_t^* = z_t^+ y_t^* = z_t \Psi_t^{\frac{\alpha}{1-\alpha}} y_t^*$$

where  $\log y_t^*$  is assumed to be a stationary process. The stochastic process is given by:

$$X_t^* = AX_{t-1}^* + C\varepsilon_t$$

where:

$$X_t^* = \begin{pmatrix} \log\left(\frac{y_t^*}{y^*}\right) \\ \pi_t^* - \pi^* \\ R_t^* - R^* \\ \log\left(\frac{\mu_{z,t}}{\mu_z}\right) \\ \log\left(\frac{\mu_{\Psi,t}}{\mu_{\Psi}}\right) \end{pmatrix}; A = \begin{bmatrix} a_{11} & a_{12} & a_{13} & 0 & 0 \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{24}\frac{\alpha}{1-\alpha} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{34}\frac{\alpha}{1-\alpha} \\ 0 & 0 & 0 & \rho_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \rho_{\mu_{\Psi}} \end{bmatrix}$$

$$C = \begin{bmatrix} \sigma_{y^*} & 0 & 0 & 0 & 0 \\ c_{21} & \sigma_{\pi^*} & 0 & c_{24} & c_{24}\frac{\alpha}{1-\alpha} \\ c_{31} & c_{32} & \sigma_{R^*} & c_{34} & c_{34}\frac{\alpha}{1-\alpha} \\ 0 & 0 & 0 & \sigma_{\mu_z} & 0 \\ 0 & 0 & 0 & 0 & \sigma_{\mu_{\Psi}} \end{bmatrix}; \varepsilon_t = \begin{pmatrix} \varepsilon_{y^*,t} \\ \varepsilon_{\pi^*,t} \\ \varepsilon_{R^*,t} \\ \varepsilon_{\mu_z,t} \\ \varepsilon_{\mu_{\Psi},t} \end{pmatrix}$$

The previous VAR specification assumes that the shock  $\varepsilon_{y^*,t}$  affects the first three variables in  $X_t^*$ , while  $\varepsilon_{\pi^*,t}$  only affects the second two and  $\varepsilon_{R^*,t}$  only affects the third variable. The assumption about  $\varepsilon_{R^*,t}$  corresponds to one strategy for identifying a monetary policy shock, in which it is assumed that inflation and output are predetermined relative to the monetary policy shock. Under this interpretation of  $\varepsilon_{R^*,t}$ , the treatment Christiano, Trabandt and Walentin (2011) make of the foreign monetary policy shock and the domestic one is inconsistent because in this model domestic prices are not predetermined in the period of a monetary policy shock.

The zeros in the last two columns of the first row of  $A$  and  $C$  reflects the assumption that the impact of technology shocks on  $Y_t^*$  is completely taken into account by  $z_t^+$ , while all other shocks to  $Y_t^*$  are orthogonal to  $z_t^+$  and affect  $Y_t^*$  via  $y_t^*$ . Additionally, both  $A$  and  $C$  capture the idea that technological innovations affect foreign inflation and the interest rate via their impact on  $z_t^+$ . Finally, the assumptions on  $A$  and  $C$  imply that  $\log\left(\frac{\mu_{z,t}}{\mu_z}\right)$  and  $\log\left(\frac{\mu_{\Psi,t}}{\mu_{\Psi}}\right)$  are univariate first order autoregressive processes driven by  $\varepsilon_{\mu_z,t}$  and  $\varepsilon_{\mu_{\Psi},t}$ .

## 5.7 Resource Constraint and Current Account

On the one hand it is possible to express the aggregate output of the economy simply as the un-weighted average of intermediate goods:

$$\begin{aligned}
Y_t^{sum} &= \int_0^1 Y_{i,t} di \\
&= \int_0^1 [(z_t H_{i,t})^{1-\alpha} \epsilon_t K_{i,t}^\alpha - z_t^+ \phi] di \\
&= \int_0^1 \left[ z_t^{1-\alpha} \epsilon_t \left( \frac{K_{i,t}}{H_{i,t}} \right)^\alpha H_{i,t} - z_t^+ \phi \right] di \\
&= z_t^{1-\alpha} \epsilon_t \left( \frac{K_t}{H_t} \right)^\alpha \int_0^1 H_{i,t} di - z_t^+ \phi \\
&= z_t^{1-\alpha} \epsilon_t K_t^\alpha H_t^{1-\alpha} - z_t^+ \phi
\end{aligned}$$

where  $K_t$  and  $H_t$  are the economy-wide average stock of capital services and homogeneous labor, respectively. Since all intermediate good firms face the same factor prices, all of them adopt the same  $\frac{K_{i,t}}{H_{i,t}}$  ratio.

Since the demand for  $Y_{i,t}$  is given by:

$$Y_{i,t} = \left( \frac{P_t}{P_{i,t}} \right)^{\frac{\lambda_d}{\lambda_d-1}} Y_t$$

so we have:

$$Y_t^{sum} = \int_0^1 Y_{i,t} di = \int_0^1 \left( \frac{P_t}{P_{i,t}} \right)^{\frac{\lambda_d}{\lambda_d-1}} Y_t di = Y_t P_t^{\frac{\lambda_d}{\lambda_d-1}} \int_0^1 P_{i,t}^{\frac{\lambda_d}{1-\lambda_d}}$$

if we name:

$$\ddot{P}_t = \left[ \int_0^1 P_{i,t}^{\frac{\lambda_d}{1-\lambda_d}} di \right]^{\frac{1-\lambda_d}{\lambda_d}}$$

Then we have:

$$Y_t^{sum} = Y_t P_t^{\frac{\lambda_d}{\lambda_d-1}} \left( \ddot{P}_t \right)^{\frac{\lambda_d}{1-\lambda_d}}$$

Dividing both sides by  $P_t$  we finally have:

$$Y_t = (\ddot{p}_t)^{\frac{\lambda_d}{\lambda_d-1}} Y_t^{sum} = (\ddot{p}_t)^{\frac{\lambda_d}{\lambda_d-1}} [z_t^{1-\alpha} \epsilon_t K_t^\alpha H_t^{1-\alpha} - z_t^+ \phi]$$

where there is the noteworthy possibility of having price dispersion in the steady state of the model.

On the other hand, we can define the resource constraint for domestic homogeneous output in terms of expenditures. According to the previously developed relationships we have:

$$\begin{aligned}
Y_t &= G_t + C_t^d + I_t^d + \int_0^1 X_t^{i,d} + \text{MonitoringCosts} + \text{ReservesHoldingCosts} \\
&= G_t + (1 - \omega_c) \left( \frac{P_t^c}{P_t} \right)^{\eta_c} C_t + \frac{1}{\Psi_t} \left( \frac{P_t^i \Psi_t}{P_t} \right)^{\eta_i} [I_t + a(u_t) \bar{K}_t] (1 - \omega_i) + \\
&+ \left( \frac{\ddot{P}_t^x}{P_t^x} \right)^{\frac{-\lambda_x}{\lambda_x - 1}} \left[ \omega_x \left( \frac{P_t^{m,x}}{P_t} \right)^{1 - \eta_x} + 1 - \omega_x \right]^{\frac{1}{1 - \eta_x}} (1 - \omega_x) \left( \frac{P_t^x}{P_t^*} \right)^{-\eta_f} Y_t^* + \\
&+ \mu G(\bar{\omega}_t, \sigma_{t-1}) R_t^k P_t P_{k',t} \bar{K}_{t+1} + \text{Dep}_t \left[ \psi_1 (\zeta_t - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t - \zeta_t^{MP})^2 \right]
\end{aligned}$$

### Current Account

The current account of the economy states:

$$S_t A_{t+1}^* + S_t P_t^* R_t^{\nu,*} \left[ C_t^m (\ddot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1 - \lambda_{m,c}}} + I_t^m (\ddot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1 - \lambda_{m,i}}} + X_t^m (\ddot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1 - \lambda_{m,x}}} \right] = S_t P_t^x X_t + R_{t-1}^* \Phi_{t-1} S_t A_t^*$$

where the left-hand side summarizes the cost of new purchases of net foreign assets and expenses on imports, whereas the right-hand side represents the income the economy receives due to export sales and previous purchased net foreign assets.  $\ddot{p}_t^{m,c}$ ,  $\ddot{p}_t^{m,i}$  and  $\ddot{p}_t^{m,x}$  represent price distortion terms.

### 5.8 Estimation Strategy

We estimate the model presented here using Bayesian techniques. Following Mancini Griffoli (2011) our model can be written like any other DSGE model in the form  $\mathbb{E}_t = \{f(y_{t+1}, y_t, y_{t-1}, u_t)\} = 0$ ,  $y_t = g(y_{t-1}, u_t)$  being its particular system of solution equations. This solution can be rewritten as:

$$\begin{aligned}
y_t^* &= M \bar{y}(\theta) + M \hat{y}_t + N(\theta) x_t + \eta_t \\
\hat{y}_t &= g_y(\theta) \hat{y}_{t-1} + g_u(\theta) u_t \\
E(\eta_t \eta_t') &= V(\theta) \\
E(u_t u_t') &= Q(\theta)
\end{aligned}$$

where  $\hat{y}_t$  is a vector of steady state deviations,  $\bar{y}$  is a vector of steady state values and  $\theta$  is the vector of deep (or structural) parameters to be estimated. These equations express a relationship among endogenous variables that are not directly observed. Only  $y_t^*$  is observable, and it is related to true variables with an error  $\eta_t$ . A possible trend is captured with  $N(\theta)x_t$ , which allows for the most general case in which the trend depends on the structural parameters. The first and second equations above make up a system of measurement and transition or state equations, respectively, as is typical for a Kalman filter.

The next step is to estimate the likelihood of the DSGE solution system previously mentioned. Since the equations are linear in the endogenous and exogenous variables, the likelihood function may be evaluated with a linear prediction error algorithm like the Kalman filter. From the Kalman filter recursion, it is possible to derive the log-likelihood  $\log \mathcal{L}(\theta|Y_T^*)$  where the vector  $\theta$  contains the parameters we have to estimate:  $\theta$ ,  $V(\theta)$  and  $Q(\theta)$ , where  $Y_T^*$  expresses the set of observable endogenous variables  $y_t^*$  found in the measurement equation.

Up to this point we can calculate the log posterior kernel, which can be expressed as:

$$\log \mathcal{K}(\theta|Y_T^*) = \log \mathcal{L}(\theta|Y_T^*) + \log p(\theta)$$

where  $p(\theta)$  are the priors of the deep parameters. Since all these elements are known, we can maximize the log posterior kernel with respect to  $\theta$ , which allows us to find the mode of the posterior distribution. A posteriori, we can find the posterior distribution of the parameters in  $\theta$ . The distribution will be given by the kernel equation above, but it is necessary to resort to sampling-like methods such as Metropolis-Hastings, which allows us to build the posterior distribution function in a recursive manner. In fact, the algorithm generates a Markov chain with a stationary distribution which gives the posterior distribution we are interested in.

### 5.8.1 Calibration

Calibrated parameters are presented in Table 4. The sample average real interest rate for deposits in Uruguay is negative (using a measure of domestic inflation (GDP deflator) instead of CPI inflation due to the normalization proposed in our model and described in Appendix B) which forced us to set the value of the discount factor  $\beta$  as high as possible. We calibrate the capital share parameter  $\alpha$  in order to match the average income share of labor income for the sample used here.

Several parameters are calibrated based on sample averages. First, we set the composite of technology growth  $\mu_{z+}$  in order to equal the average growth rate of GDP. Using relative investment prices to separate investment-specific technology from neutral technology, we get the reported value of  $\mu_{\Psi}$ . Second, we set the depreciation rate  $\delta$  in order to match the sample average investment to output ratio (0.200). Third, we set the steady state real exchange rate  $\tilde{\varphi}$  to match the export share of GDP (0.305). Fourth, we set the disutility of labor scaling parameter  $A_L$  to match the fraction of time that individuals spend working on average (0.2305).



For the input shares  $\omega_c$ ,  $\omega_i$  and  $\omega_x$  we assumed a value of 40 percent. For  $\eta_g$  we used the sample average of the government consumption share of GDP, which excludes government investment since in our model only private agents can invest. Tax rates were calibrated according to information provided by the official Uruguayan tax agency (DGI); since tax rates were constant during the sample period, we also assumed them to be constant in our model. The steady state inflation rate was set in accordance to current inflation target in Uruguay (5 percent), which implies the quarterly value reported in the table.

With respect to steady state price mark-ups, we set all of them to be equal to 1.2, which means a 20 percent mark-up over the marginal cost. The indexation parameters  $\varkappa^j$  are set so that there is no indexation to the potentially time-varying inflation target, which implies that as in Christiano, Trabandt and Walentin (2011) we do not allow for partial indexation in this estimation (this would result in steady state price and wage dispersion).  $\tilde{\pi}$  is set equal to the steady state inflation of the model. The wage indexation to real growth trend is set to allow for full indexation of wages to the steady state real growth. The wage rigidity parameter  $\xi_w$  is set equal to 0.9.

We calibrate  $\tilde{\phi}_a$  in order to achieve stationarity for the open economy model. The working capital fractions are set equal to 0.5 in order to allow possible influence of interest rates on labor demand.

Finally, we set the financial parameter  $\gamma$  and the transfers to entrepreneurs  $\frac{We}{y}$  in order to achieve a net worth to assets ratio of 0.5, which is a standard value in the literature. We assume a bankruptcy rate of 1 percent and calibrate  $F(\bar{\omega})$  to this end. We also calibrate the bank's monitoring cost parameter  $\mu$  in order to achieve a reasonable spread between deposit and lending interest rates. In order to assess the dependence of the results on this parameter we also present impulse response functions to shocks in monetary policy instruments for different values of  $\mu$ , representing different degrees of financial frictions.

## 5.9 *Estimated Parameters*

Using Bayesian techniques we estimate a subset of 72 model parameters that includes 19 shock standard deviations, 16 VAR parameters for the foreign economy, 29 structural parameters and 8 AR(1) coefficients for the exogenous processes.

### 5.9.1 *Prior Distributions*

In order to estimate this subset of parameters, we use the prior distributions employed by Christiano, Trabandt and Walentin (2011). For the case of the new parameters, we use the following prior distributions: i) for parameter  $\rho_\zeta$  we choose a beta distribution with mean and variance equal to 0.85 and 0.1, respectively; ii) for parameter  $r_L$  we choose a normal distribution with mean and variance equal to 1.0 and 0.15, respectively; iii) for parameter  $\zeta_\pi$  we choose a normal distribution with mean and variance equal to 1.7 and 0.15, respectively; iv) for parameter  $\zeta_y$  we choose a nor-

**Table 4. Calibrated Parameters**

Parameter	Description	Value
$\beta$	Discount factor	0.9999
$\alpha$	Capital share in production	0.30
$\omega_j$	Import share in investment, consumption and export goods $j = i, c, x$	0.40
$\eta_g$	Government consumption share on GDP	0.1098
$\tau^k$	Capital tax rate	0.25
$\tau^y$	Labor income tax rate	0.10
$\tau^c$	Consumption tax rate	0.22
$\tau^w$	Payroll tax rate	0.3375
$\tau^b$	Bonds tax rate	0
$\mu_z$	Steady state growth rate of neutral technology	1.0098
$\mu_\Psi$	Steady state growth rate of investment technology	1.0060
$\bar{\pi}$	Steady state gross inflation target	1.0125
$\lambda_j$	Price mark ups $j = d; x; m, c; m, i; m, x$	1.2
$\lambda_w$	Wage mark up	1.5
$\tilde{\phi}_a$	Risk function parameter	0.01
$\tilde{\phi}_s$	Risk adjustment function parameter	0.25
$A_L$	Disutility of labor scaling parameter	35893
$\tilde{\varphi}$	Steady state value of real exchange rate	2.2056
$\vartheta_w$	Wage indexation to real growth trend	1
$\varkappa_j$	Indexation to inflation target $j = d; x; m, c; m, i; m, x; w$	$1 - \kappa_j$
$\tilde{\pi}$	Indexing base	1.0125
$\delta$	Depreciation rate	0.0296
$F(\bar{\omega})$	Steady state bankruptcy rate	0.1
$\mu$	Monitoring costs parameter	0.15
$\frac{W_e}{y}$	Transfers to entrepreneurs	0.01

Source: Authors elaboration.

mal distribution with mean and variance equal to 0.125 and 0.05, respectively; v) for parameter  $\zeta_L$  we choose a normal distribution with mean and variance equal to 0.5 and 0.05, respectively; vi) for parameter  $\psi_1$  we choose a normal distribution with mean and variance equal to  $-0.001$  and  $0.0005$ , respectively; and vii) for parameter  $\psi_2$  we choose an inverted Gamma distribution with mean equal to  $10,000$  and infinite variance. These prior distributions are similar to those used by Christiano, Trabandt and Walentin (2011) for parameters that are analogous to ours. The complete description of prior distributions as well as the results of the posterior mode search can be found in Tables 5 and 6. Notice that for all estimated parameters the prior distribution is not equal to the posterior, suggesting that they are identified parameters in the model.

**Table 5. Estimated Parameters: prior distributions' choices**

Parameter	Prior Mean	Mode	Std.Dev	t-stat	Prior Dist	Prior Std.Dev
$\xi_d$	0.750	0.7276	0.0038	193.4193	beta	0.0750
$\xi_x$	0.750	0.6623	0.0089	74.2285	beta	0.0750
$\xi_{m,c}$	0.750	0.7245	0.0079	91.1992	beta	0.0750
$\xi_{m,i}$	0.750	0.8617	0.0116	73.9961	beta	0.0750
$\xi_{m,x}$	0.660	0.4576	0.0070	65.0855	beta	0.1000
$\kappa_d$	0.500	0.3910	0.0120	32.6932	beta	0.1500
$\kappa_x$	0.500	0.5092	0.0162	31.5163	beta	0.1500
$\kappa_{m,c}$	0.500	0.4053	0.0188	21.5674	beta	0.1500
$\kappa_{m,i}$	0.500	0.6649	0.0094	70.5245	beta	0.1500
$\kappa_{m,x}$	0.500	0.4696	0.0088	53.5329	beta	0.1500
$\kappa_w$	0.500	0.3725	0.0232	16.0273	beta	0.1500
$\nu^j$	0.500	0.0694	0.0345	2.0093	beta	0.2500
$\sigma_L/10$	0.750	0.6915	0.0147	46.9525	gamm	0.1500
$b$	0.650	0.4557	0.0117	38.9045	beta	0.1500
$S''$	5.000	5.7460	0.1030	55.9031	gamm	0.1500
$\sigma_a$	0.800	0.7289	0.0077	94.2672	gamm	0.0750
$\rho_R$	0.850	0.9498	0.0074	120.0051	beta	0.1000
$r_\pi$	1.700	1.6635	0.0121	137.1230	norm	0.1500
$r_y$	0.125	0.1046	0.0035	30.0668	norm	0.0500
$r_L$	1.000	0.8297	0.0172	48.1382	norm	0.1500
$\rho_\zeta$	0.850	0.9390	0.0060	157.3207	beta	0.1000
$\zeta_\pi$	1.700	1.6957	0.0146	116.1179	norm	0.1500
$\zeta_y$	0.125	0.0973	0.0098	9.9594	norm	0.0500
$\zeta_L$	0.500	0.5025	0.0032	155.9522	norm	0.0500
$\psi_1$	-0.001	-0.0014	0.0000	31.8284	norm	0.0005
$\psi_2$	10000.000	10000.7031	0.2045	48907.3356	invG	Inf
$\eta_x$	1.500	1.5449	0.0195	79.2277	gamm	0.2500
$\eta_i$	1.500	1.3526	0.0266	50.7796	gamm	0.2500
$\eta_f$	1.500	1.3934	0.0210	66.2521	gamm	0.2500
$\rho_{\mu_z}$	0.500	0.5734	0.0087	65.7853	beta	0.0750
$\rho_\epsilon$	0.850	0.7713	0.0097	79.8210	beta	0.0750
$\rho_\Upsilon$	0.850	0.9132	0.0060	151.0020	beta	0.0750
$\rho_{\zeta^c}$	0.850	0.8980	0.0105	85.9142	beta	0.0750
$\rho_{\zeta^h}$	0.850	0.8038	0.0061	132.5122	beta	0.0750
$\rho_{\bar{\phi}}$	0.850	0.9367	0.0051	185.1079	beta	0.0750
$\rho_g$	0.850	0.7993	0.0053	151.4638	beta	0.0750
$\rho_\gamma$	0.850	0.8766	0.0058	151.4990	beta	0.0750

Source: Authors elaboration.

### Shocks

The linearized version of the model consists of 23 equations with 23 associated shocks. The shocks have the following structure:

**Table 6. Estimated Parameters: prior distributions' choices (cont)**

Parameter	Prior Mean	Mode	Std.Dev	t-stat	Prior Dist	Prior Std.Dev
$a_{11}$	0.500	0.7672	0.0480	15.9733	norm	0.5000
$a_{22}$	0.000	0.1469	0.0351	4.1837	norm	0.5000
$a_{33}$	0.500	1.0258	0.0179	57.4367	norm	0.5000
$a_{12}$	0.000	-0.2956	0.0294	10.0596	norm	0.5000
$a_{13}$	0.000	0.5460	0.0437	12.5042	norm	0.5000
$a_{21}$	0.000	0.1622	0.0354	4.5819	norm	0.5000
$a_{23}$	0.000	-0.3017	0.0360	8.3794	norm	0.5000
$a_{24}$	0.000	-0.0089	0.0272	0.3260	norm	0.5000
$a_{31}$	0.000	-0.0312	0.0156	1.9930	norm	0.5000
$a_{32}$	0.000	0.0087	0.0414	0.2107	norm	0.5000
$a_{34}$	0.000	0.0984	0.0257	3.8274	norm	0.5000
$c_{21}$	0.000	0.1077	0.0544	1.9798	norm	0.5000
$c_{31}$	0.000	-0.0347	0.0236	1.4704	norm	0.5000
$c_{32}$	0.000	-0.0260	0.0393	0.6632	norm	0.5000
$c_{24}$	0.000	0.0970	0.0435	2.2275	norm	0.5000
$c_{34}$	0.000	0.0107	0.0276	0.3895	norm	0.5000
$100\sigma_{\mu_z}$	0.150	1.0843	0.1579	6.8651	invg	Inf
$100\sigma_{\epsilon}$	0.500	0.9073	0.1915	4.7371	invg	Inf
$10\sigma_{\Upsilon}$	0.150	0.1698	0.0983	1.7283	invg	Inf
$10\sigma_{\zeta^c}$	0.150	0.6064	0.1700	3.5676	invg	Inf
$10\sigma_{\zeta^h}$	0.150	0.0700	0.0774	0.9037	invg	Inf
$100\sigma_{\phi}$	0.150	0.0795	0.1103	0.7208	invg	Inf
$100\sigma_{\epsilon_R}$	0.150	0.2734	0.0680	4.0171	invg	Inf
$100\sigma_{\epsilon_\zeta}$	0.150	23.8527	0.6912	34.5078	invg	Inf
$100\sigma_g$	0.500	1.3142	0.3820	3.4403	invg	Inf
$10\sigma_{\tau^d}$	0.500	2.7044	0.3266	8.2795	invg	Inf
$10\sigma_{\tau^x}$	0.500	3.6526	0.1828	19.9794	invg	Inf
$10\sigma_{\tau^m,c}$	0.500	7.2701	0.2808	25.8945	invg	Inf
$10\sigma_{\tau^m,i}$	0.500	0.2295	0.1234	1.8596	invg	Inf
$10\sigma_{\tau^m,x}$	0.500	7.2851	0.3194	22.8081	invg	Inf
$100\sigma_\gamma$	0.500	1.8047	0.6325	2.8534	invg	Inf
$100\sigma_y^*$	0.500	1.6742	0.2116	7.9133	invg	Inf
$100\sigma_{\pi^*}$	0.500	0.3375	0.0923	3.6589	invg	Inf
$1000\sigma_{R^*}$	1.500	1.0054	0.1816	5.5368	invg	Inf
$100\sigma_{\Theta}$	0.150	0.0363	0.0051	7.1610	invg	Inf

Source: Authors elaboration.

- 10 AR(1) processes:  $\epsilon, \Upsilon, \bar{\pi}^c, \zeta^c, \zeta^h, \tilde{\phi}, \sigma, \gamma, g, \tau^y$ .
- 8 i.i.d. processes:  $\tau^d, \tau^x, \tau^{m,c}, \tau^{m,x}, \tau^{m,i}, \varepsilon_R, \varepsilon_\zeta, \varepsilon_\Theta$ .
- 5 VAR(1) processes:  $y^*, \pi^*, R^*, \mu_z, \mu_\Psi$ .

which are employed to generate the impulse response functions discussed in the main text.

### 5.10 Estimation Results

The estimated parameters were obtained using a random walk Metropolis-Hastings chain with 10,000 draws after burning the first third of them. The scale used for the jumping distribution in the Metropolis-Hastings algorithm is set equal to 0.30, which allows us to obtain an acceptance rate of 0.28. The posteriors means of estimated parameters are used to generate impulse response functions to several real and financial shocks. According to what can be seen in Appendix E graphs, the data seem to be informative about several but not all estimated parameters, which may be due to the short length of data series and the selection of data variables made to perform the estimations.

Posterior means and their respective confidence intervals are presented in Table 7 and Table 8, while their corresponding graphs are included in Appendix E. Almost all parameters estimated values obtained are statistically significant, with the exception of some parameters in the Foreign VAR structure.

All Calvo price rigidity parameters estimations are in the interval 0.40 – 0.85, which is a common result in this literature. The indexation to lagged inflation is important for the Uruguayan data, ranging from 0.30 to 0.65. The estimated value for the working capital parameter is equal to 0.07, a significantly lower value than the one reported by Christiano, Trabandt and Walentin (2011) for the Swedish economy (0.46). For the case of the Frisch elasticity, the estimated value is equal to 0.15 ( $1/\sigma_L$ ). The estimated value of the consumption habit parameter  $b$  is equal to 0.43, which reveals the relative importance of past consumption in the utility function. The capacity utilization parameter  $\sigma_a$  is equal to 0.73 which allows for important variation in utilization. Finally, the investment adjustment cost parameter is estimated to be 0.53, a moderate value that reflects the importance of the financial friction mechanism in inducing gradual responses as a substitute mechanism for the investment adjustment cost function.

Finally, we focus on the financial side and the parameters of the Taylor rules. The significance of the estimation of parameters  $\Psi_1$  and  $\Psi_2$  makes explicit the importance of this cost function for the dynamics of the model. For both Taylor Rules, all parameter estimations were statistically significant. For the case of the interest rate rule, the posterior means of estimated parameters imply a strong dependence of the interest rate to its past value and a weak response to deviations of output from its steady state level. Parameter  $r_L$  is positive and reflects a considerable importance of risky

loans in the determination of this monetary policy instrument. The value found for  $r_\pi$  turns to be similar to commonly obtained values in the literature. For the case of the reserves requirement rule, the posterior means of estimated parameters also imply a strong dependence of the reserve requirement to its past value and a weak response to deviations of output from their steady state level. The parameter  $\zeta_L$  is also positive. The value found for  $\zeta_\pi$  turns out to be similar to the value found for  $r_\pi$ .

**Table 7. Estimated Parameters: posterior means and confidence intervals**

Parameter	Prior Mean	Posterior Mean	Lower CI bound	Upper CI bound
$\xi_d$	0.750	0.7310	0.7143	0.7438
$\xi_x$	0.750	0.6614	0.6491	0.6745
$\xi_{m,c}$	0.750	0.7209	0.7061	0.7333
$\xi_{m,i}$	0.750	0.8677	0.8536	0.8819
$\xi_{m,x}$	0.660	0.4380	0.4222	0.4607
$\kappa_d$	0.500	0.3584	0.3128	0.4121
$\kappa_x$	0.500	0.5201	0.4962	0.5465
$\kappa_{m,c}$	0.500	0.4342	0.3828	0.4793
$\kappa_{m,i}$	0.500	0.6420	0.6236	0.6568
$\kappa_{m,x}$	0.500	0.4558	0.4289	0.4879
$\kappa_w$	0.500	0.3292	0.2999	0.3631
$\nu^j$	0.500	0.0744	0.0075	0.1360
$\sigma_L/10$	0.750	0.6462	0.6088	0.6838
$b$	0.650	0.4375	0.3740	0.5081
$S''$	5.000	5.3460	0.5119	0.5612
$\sigma_a$	0.800	0.7254	0.7109	0.7463
$\rho_R$	0.850	0.9585	0.9340	0.9755
$r_\pi$	1.700	1.6674	1.6371	1.7051
$r_y$	0.125	0.0865	0.0760	0.0973
$r_L$	1.000	0.8188	0.7920	0.8516
$\rho_\zeta$	0.850	0.9389	0.9222	0.9561
$\zeta_\pi$	1.700	1.7256	1.6924	1.7708
$\zeta_y$	0.125	0.1073	0.0909	0.1231
$\zeta_L$	0.500	0.5129	0.5034	0.5220
$\psi_1$	-0.001	-0.0015	-0.0015	-0.0014
$\psi_2$	10000.000	9999.6643	9999.2374	10000.1460
$\eta_x$	1.500	1.5641	1.5032	1.6245
$\eta_i$	1.500	1.2296	1.1598	1.3057
$\eta_f$	1.500	1.2848	1.2159	1.3457
$\rho_{\mu_z}$	0.500	0.6087	0.5950	0.6205
$\rho_\epsilon$	0.850	0.7709	0.7512	0.7919
$\rho_\Upsilon$	0.850	0.9147	0.9037	0.9261
$\rho_{\zeta^c}$	0.850	0.8917	0.8734	0.9074
$\rho_{\zeta^h}$	0.850	0.7869	0.7724	0.8015
$\rho_{\bar{\phi}}$	0.850	0.9292	0.9135	0.9441
$\rho_g$	0.850	0.7669	0.7555	0.7836
$\rho_\gamma$	0.850	0.8639	0.8502	0.8784

Source: Authors elaboration.

## Appendix B

This appendix presents the way in which the variables of the model are scaled in order to induce stationarity. In particular we have that:

**Table 8. Estimated Parameters: posterior means and confidence intervals (cont)**

Parameter	Prior Mean	Posterior Mean	Lower CI bound	Upper CI bound
$a_{11}$	0.500	0.8046	0.7504	0.8615
$a_{22}$	0.000	0.2387	0.1783	0.3028
$a_{33}$	0.500	0.9997	0.9564	1.0607
$a_{12}$	0.000	-0.3621	-0.4459	-0.2931
$a_{13}$	0.000	0.4673	0.3631	0.5936
$a_{21}$	0.000	0.1382	0.0893	0.1746
$a_{23}$	0.000	-0.3092	-0.4400	0.1607
$a_{24}$	0.000	0.0376	-0.0400	0.1125
$a_{31}$	0.000	-0.0275	-0.0547	-0.0018
$a_{32}$	0.000	-0.0485	-0.0907	0.0084
$a_{34}$	0.000	0.1551	0.0816	0.2388
$c_{21}$	0.000	0.0846	-0.0223	0.1783
$c_{31}$	0.000	-0.0568	-0.1008	-0.0144
$c_{32}$	0.000	-0.0564	-0.1419	0.0235
$c_{24}$	0.000	0.1537	0.0182	0.2983
$c_{34}$	0.000	0.0244	-0.0627	0.1091
$100\sigma_{\mu_z}$	0.150	0.9551	0.6114	1.3334
$100\sigma_{\epsilon}$	0.500	0.9400	0.7209	1.1949
$10\sigma_{\Upsilon}$	0.150	0.1602	0.0784	0.2391
$10\sigma_{\zeta^c}$	0.150	0.6212	0.4532	0.8086
$10\sigma_{\zeta^h}$	0.150	0.0909	0.0382	0.1439
$100\sigma_{\phi}$	0.150	0.1410	0.0442	0.2553
$100\sigma_{\epsilon_R}$	0.150	0.2658	0.1997	0.3260
$100\sigma_{\epsilon_\zeta}$	0.150	24.6227	23.3347	26.0654
$100\sigma_g$	0.500	1.3711	0.9119	1.7951
$10\sigma_{\tau^d}$	0.500	2.6966	2.0849	3.3438
$10\sigma_{\tau^x}$	0.500	4.0285	3.6188	4.4600
$10\sigma_{\tau^{m,c}}$	0.500	8.0674	7.2849	9.0015
$10\sigma_{\tau^{m,i}}$	0.500	0.4398	0.1963	0.6889
$10\sigma_{\tau^{m,x}}$	0.500	7.8934	7.2226	8.4458
$100\sigma_{\gamma}$	0.500	1.6211	0.9642	2.3140
$100\sigma_{y^*}$	0.500	1.4844	1.1636	1.8417
$100\sigma_{\pi^*}$	0.500	0.3881	0.2831	0.4889
$1000\sigma_{R^*}$	1.500	1.4020	1.0597	1.8657
$100\sigma_{\Theta}$	0.150	0.0394	0.0316	0.0484

Source: Authors elaboration.

**Table B.1. Variables Scaling**

Scale factor	Variables
$z_t^+ \Psi_t$	$K_{t+1}, \bar{K}_{t+1}, I_t,$
$z_t^+$	$I_t^d, I_t^m, C_t^d, C_t^m, C_t, G_t, Y_t, X_t^m, X_t, Y_t^*$
$P_t z_t^+$	$W_t, W_t^e, \bar{N}_{t+1}$
$P_t$	$P_t^{m,x}, P_t^{m,c}, P_t^{m,i}, P_t^c, \Psi_t P_t^i,$
$P_t^*$	$P_t^*$

Lower-case letters represents the scaled value of these variables, so for the equations presented in the appendix that follows we have:

$$j = \frac{J}{ScaleFactor}$$

for any variable  $J$  in the model.

We also define the scaled value of the price of new installed physical capital and the real rental rate of capital as follows:

$$p_{k',t} = \Psi_t P_{k',t}$$

$$\bar{r}_t^k = \Psi_t r_t^k$$

Finally, we define the following inflation rates:

$$\pi_t = \frac{P_t}{P_{t-1}} \quad \pi_t^c = \frac{P_t^c}{P_{t-1}^c} \quad \pi_t^i = \frac{P_t^i}{P_{t-1}^i} \quad \pi_t^x = \frac{P_t^x}{P_{t-1}^x}$$

$$\pi_t^{m,c} = \frac{P_t^{m,c}}{P_{t-1}^{m,c}} \quad \pi_t^{m,i} = \frac{P_t^{m,i}}{P_{t-1}^{m,i}} \quad \pi_t^{m,x} = \frac{P_t^{m,x}}{P_{t-1}^{m,x}} \quad \pi_t^* = \frac{P_t^*}{P_{t-1}^*}$$

and the growth rate of nominal exchange rate:

$$s_t = \frac{S_t}{S_{t-1}}$$

## Appendix C

The following equations were employed to solve the model using an appropriately modified version of the original code provided by Christiano, Trabandt and Walentin (2011).



## Model Equations

Domestic homogeneous good marginal cost definitions:

$$mc_t = \tau^d \left( \frac{1}{1-\alpha} \right)^{1-\alpha} \left( \frac{1}{\alpha} \right)^\alpha (\bar{r}_t^k)^\alpha (\bar{w}_t R_t^f)^{1-\alpha} \frac{1}{\epsilon_t}$$

$$mc_t = \tau^d \frac{\mu_{\Psi,t}^\alpha \bar{w}_t R_t^f}{\epsilon_t (1-\alpha) \left( \frac{k_t}{\mu_{z^+,t}} / H_t \right)^\alpha}$$

Non-linear pricing equations for domestic intermediate goods producers:

$$E_t \left[ \psi_{z^+,t} y_t + \left( \frac{\tilde{\pi}_{d,t+1}}{\pi_{t+1}} \right)^{\frac{1}{1-\lambda_d}} \beta \xi_d F_{t+1}^d - F_t^d \right] = 0$$

$$E_t \left[ \lambda_d \psi_{z^+,t} y_t mc_t + \left( \frac{\tilde{\pi}_{d,t+1}}{\pi_{t+1}} \right)^{\frac{\lambda_d}{1-\lambda_d}} \beta \xi_d K_{t+1}^d - K_t^d \right] = 0$$

$$\ddot{p}_t = \left[ (1 - \xi_d) \left( \frac{1 - \xi_d \left( \frac{\tilde{\pi}_{d,t}}{\pi_t} \right)^{\frac{1}{1-\lambda_d}}}{1 - \xi_d} \right)^{\lambda_d} + \xi_d \left( \ddot{p}_{t-1} \frac{\tilde{\pi}_{d,t}}{\pi_t} \right)^{\frac{\lambda_d}{1-\lambda_d}} \right]^{\frac{1-\lambda_d}{\lambda_d}}$$

$$\frac{K_t^d}{F_t^d} = \left[ \frac{1 - \xi_d \left( \frac{\tilde{\pi}_{d,t}}{\pi_t} \right)^{\frac{1}{1-\lambda_d}}}{1 - \xi_d} \right]^{1-\lambda_d}$$

$$\tilde{\pi}_{d,t} = (\pi_{t-1})^{\kappa_d} (\bar{\pi}_t^c)^{1-\kappa_d-\varkappa_d} (\bar{\pi})^{\varkappa_d}$$

Non-linear pricing equations for export goods producers:

$$E_t \left[ \psi_{z^+,t} q_t p_t^c p_t^x x_t + \left( \frac{\tilde{\pi}_{t+1}^x}{\pi_{t+1}^x} \right)^{\frac{1}{1-\lambda_x}} \beta \xi_x F_{t+1}^x - F_t^x \right] = 0$$

$$E_t \left[ \lambda_x \psi_{z^+,t} q_t p_t^c p_t^x x_m c_t^x + \left( \frac{\tilde{\pi}_{t+1}^x}{\pi_{t+1}^x} \right)^{\frac{\lambda_x}{1-\lambda_x}} \beta \xi_x K_{t+1}^x - K_t^x \right] = 0$$

$$\ddot{p}_t^x = \left[ (1 - \xi_x) \left( \frac{1 - \xi_x \left( \frac{\tilde{\pi}_t^x}{\pi_t^x} \right)^{\frac{1}{1-\lambda_x}}}{1 - \xi_x} \right)^{\lambda_x} + \xi_x \left( \ddot{p}_{t-1}^x \frac{\tilde{\pi}_t^x}{\pi_t^x} \right)^{\frac{\lambda_x}{1-\lambda_x}} \right]^{\frac{1-\lambda_x}{\lambda_x}}$$

$$\frac{K_t^x}{F_t^x} = \left[ \frac{1 - \xi_x \left( \frac{\tilde{\pi}_t^x}{\pi_t^x} \right)^{\frac{1}{1-\lambda_x}}}{1 - \xi_x} \right]^{1-\lambda_x}$$

$$\tilde{\pi}_t^x = (\pi_{t-1}^x)^{\kappa_x} (\pi_t^x)^{1-\kappa_x-\lambda_x} (\bar{\pi})^{\lambda_x}$$

Non-linear pricing equations for consumption importer:

$$E_t \left[ \psi_{z^+,t} p_t^{m,c} c_t^m + \left( \frac{\tilde{\pi}_{t+1}^{m,c}}{\pi_{t+1}^{m,c}} \right)^{\frac{1}{1-\lambda_{m,c}}} \beta \xi_{m,c} F_{t+1}^{m,c} - F_t^{m,c} \right] = 0$$

$$E_t \left[ \lambda_{m,c} \psi_{z^+,t} p_t^{m,c} c_t^m m c_t^{m,c} + \left( \frac{\tilde{\pi}_{t+1}^{m,c}}{\pi_{t+1}^{m,c}} \right)^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} \beta \xi_{m,c} K_{t+1}^{m,c} - K_t^{m,c} \right] = 0$$

$$\ddot{p}_t^{m,c} = \left[ (1 - \xi_{m,c}) \left( \frac{1 - \xi_{m,c} \left( \frac{\tilde{\pi}_t^{m,c}}{\pi_t^{m,c}} \right)^{\frac{1}{1-\lambda_{m,c}}}}{1 - \xi_{m,c}} \right)^{\lambda_{m,c}} + \xi_{m,c} \left( \ddot{p}_{t-1}^{m,c} \frac{\tilde{\pi}_t^{m,c}}{\pi_t^{m,c}} \right)^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} \right]^{\frac{1-\lambda_{m,c}}{\lambda_{m,c}}}$$

$$\frac{K_t^{m,c}}{F_t^{m,c}} = \left[ \frac{1 - \xi_{m,c} \left( \frac{\tilde{\pi}_t^{m,c}}{\pi_t^{m,c}} \right)^{\frac{1}{1-\lambda_{m,c}}}}{1 - \xi_{m,c}} \right]^{1-\lambda_{m,c}}$$

$$\tilde{\pi}_t^{m,c} = (\pi_{t-1}^{m,c})^{\kappa_{m,c}} (\pi_t^{m,c})^{1-\kappa_{m,c}-\lambda_{m,c}} (\bar{\pi})^{\lambda_{m,c}}$$

Non-linear pricing equations for export input importer:

$$E_t \left[ \psi_{z^+,t} p_t^{m,x} x_t^m + \left( \frac{\tilde{\pi}_{t+1}^{m,x}}{\pi_{t+1}^{m,x}} \right)^{\frac{1}{1-\lambda_{m,x}}} \beta \xi_{m,x} F_{t+1}^{m,x} - F_t^{m,x} \right] = 0$$

$$E_t \left[ \lambda_{m,x} \psi_{z^+,t} p_t^{m,x} x_t^m m c_t^{m,x} + \left( \frac{\tilde{\pi}_{t+1}^{m,x}}{\pi_{t+1}^{m,x}} \right)^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \beta \xi_{m,x} K_{t+1}^{m,x} - K_t^{m,x} \right] = 0$$

$$\ddot{p}_t^{m,x} = \left[ (1 - \xi_{m,x}) \left( \frac{1 - \xi_{m,x} \left( \frac{\tilde{\pi}_t^{m,x}}{\pi_t^{m,x}} \right)^{\frac{1}{1-\lambda_{m,x}}}}{1 - \xi_{m,x}} \right)^{\lambda_{m,x}} + \xi_{m,x} \left( \ddot{p}_{t-1}^{m,x} \frac{\tilde{\pi}_t^{m,x}}{\pi_t^{m,x}} \right)^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \right]^{\frac{1-\lambda_{m,x}}{\lambda_{m,x}}}$$

$$\frac{K_t^{m,x}}{F_t^{m,x}} = \left[ \frac{1 - \xi_{m,x} \left( \frac{\tilde{\pi}_t^{m,x}}{\pi_t^{m,x}} \right)^{\frac{1}{1-\lambda_{m,x}}}}{1 - \xi_{m,x}} \right]^{1-\lambda_{m,x}}$$

$$\tilde{\pi}_t^{m,x} = (\pi_{t-1}^{m,x})^{\kappa_{m,x}} (\bar{\pi}_t)^{1-\kappa_{m,x}-\chi_{m,x}} (\check{\pi})^{\chi_{m,x}}$$

Non-linear pricing equations for investment importer:

$$E_t \left[ \psi_{z+,t} p_t^{m,i} i_t^m + \left( \frac{\tilde{\pi}_{t+1}^{m,i}}{\pi_{t+1}^{m,i}} \right)^{\frac{1}{1-\lambda_{m,i}}} \beta \xi_{m,i} F_{t+1}^{m,i} - F_t^{m,i} \right] = 0$$

$$E_t \left[ \lambda_{m,i} \psi_{z+,t} p_t^{m,i} i_t^m m c_t^{m,i} + \left( \frac{\tilde{\pi}_{t+1}^{m,i}}{\pi_{t+1}^{m,i}} \right)^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} \beta \xi_{m,i} K_{t+1}^{m,i} - K_t^{m,i} \right] = 0$$

$$\dot{p}_t^{m,i} = \left[ (1 - \xi_{m,i}) \left( \frac{1 - \xi_{m,i} \left( \frac{\tilde{\pi}_t^{m,i}}{\pi_t^{m,i}} \right)^{\frac{1}{1-\lambda_{m,i}}}}{1 - \xi_{m,i}} \right)^{\lambda_{m,i}} + \xi_{m,i} \left( \dot{p}_{t-1}^{m,i} \frac{\tilde{\pi}_t^{m,i}}{\pi_t^{m,i}} \right)^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} \right]^{\frac{1-\lambda_{m,i}}{\lambda_{m,i}}}$$

$$\frac{K_t^{m,i}}{F_t^{m,i}} = \left[ \frac{1 - \xi_{m,i} \left( \frac{\tilde{\pi}_t^{m,i}}{\pi_t^{m,i}} \right)^{\frac{1}{1-\lambda_{m,i}}}}{1 - \xi_{m,i}} \right]^{1-\lambda_{m,i}}$$

$$\tilde{\pi}_t^{m,i} = (\pi_{t-1}^{m,i})^{\kappa_{m,i}} (\bar{\pi}_t)^{1-\kappa_{m,i}-\chi_{m,i}} (\check{\pi})^{\chi_{m,i}}$$

Domestic consumption inflation:

$$\pi_t^c = \pi_t \left[ \frac{(1 - \omega_c) + \omega_c (p_t^{m,c})^{1-\eta_c}}{(1 - \omega_c) + \omega_c (p_{t-1}^{m,c})^{1-\eta_c}} \right]^{\frac{1}{1-\eta_c}}$$

Domestic investment inflation:

$$\pi_t^i = \frac{\pi_t}{\mu_{\Psi,t}} \left[ \frac{(1 - \omega_i) + \omega_i (p_t^{m,i})^{1-\eta_i}}{(1 - \omega_i) + \omega_i (p_{t-1}^{m,i})^{1-\eta_i}} \right]^{\frac{1}{1-\eta_i}}$$

Law of motion of physical capital:

$$\bar{k}_{t+1} = \frac{1 - \delta}{\mu_{z^+,t}\mu_{\Psi,t}} \bar{k}_t + \Upsilon_t \left[ 1 - \tilde{S} \left( \frac{\mu_{z^+,t}\mu_{\Psi,t} \dot{i}_t}{\dot{i}_{t-1}} \right) \right] \dot{i}_t$$

Law of motion of net worth:

$$n_{t+1} = \frac{\gamma_t}{\pi_t \mu_{z^+,t}} \left[ R_t^k p_{k',t-1} \bar{k}_t - R_{t-1} (p_{k',t-1} \bar{k}_t - n_t) - \mu G(\bar{\omega}_t, \sigma_{t-1}) R_t^k p_{k',t-1} \bar{k}_t \right] + w^e$$

First order condition associated with financial contract:

$$E_t \left\{ \left[ 1 - \Gamma(\bar{\omega}_{t+1}, \sigma_t) \right] \frac{R_{t+1}^k}{R_t} + \frac{\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)}{\Gamma_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t) - \mu G_{\bar{\omega}}(\bar{\omega}_{t+1}, \sigma_t)} \left[ \Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t) \right] \frac{R_{t+1}^k}{R_t} - 1 \right\} = 0$$

Lending banks zero profit condition:

$$\Gamma(\bar{\omega}_{t+1}, \sigma_t) - \mu G(\bar{\omega}_{t+1}, \sigma_t) = \frac{R_t}{R_{t+1}^k} \left( 1 - \frac{n_{t+1}}{p_{k',t} \bar{k}_{t+1}} \right)$$

Deposit banks first order conditions:

$$- [R_t - R_t^R - \psi_1] = \psi_2 (\zeta_t^R - \zeta_t^{MP})$$

$$R_t^d = (1 - \zeta_t^R) R_t + \zeta_t^R R_t^R - \left[ \psi_1 (\zeta_t^R - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t^R - \zeta_t^{MP})^2 \right]$$

Household consumption first order condition:

$$\frac{\zeta_t^c}{c_t - b \frac{c_{t-1}}{\mu_{z^+,t}}} - \beta b E_t \left( \frac{\zeta_{t+1}^c}{c_{t+1} \mu_{z^+,t+1} - b c_t} \right) - \psi_{z^+,t} p_t^c (1 - \tau^c) = 0$$

Household foreign bonds first order condition:

$$\psi_{z^+,t} = \beta E_t \frac{\psi_{z^+,t+1}}{\pi_{t+1} \mu_{z^+,t+1}} [s_{t+1} R_t^* \Phi_t - \tau_b (s_{t+1} R_t^* \Phi_t - \pi_{t+1})]$$

where:

$$\Phi_t = \exp \left[ -\tilde{\phi}_a (a_t - \bar{a}) - \tilde{\phi}_s (R_t^* - R_t^d - (R^* - R^d)) + \tilde{\phi}_t \right]$$

Household domestic assets first order condition:

$$\psi_{z^+,t} = \beta \frac{\psi_{z^+,t+1}}{\mu_{z^+,t+1}} \left[ \frac{R_t^d - \tau^b (R_t^d - \pi_{t+1})}{\pi_{t+1}} \right]$$

Capital goods producers' investment decision:

$$\begin{aligned} -\psi_{z^+,t} p_t^i + \psi_{z^+,t} p_{k',t} \Upsilon_t \left[ 1 - \tilde{S} \left( \frac{\mu_{z^+,t} \mu_{\Psi,t} \dot{i}_t}{\dot{i}_{t-1}} \right) - \tilde{S}' \left( \frac{\mu_{z^+,t} \mu_{\Psi,t} \dot{i}_t}{\dot{i}_{t-1}} \right) \frac{\mu_{z^+,t} \mu_{\Psi,t} \dot{i}_t}{\dot{i}_{t-1}} \right] + \\ + \beta \psi_{z^+,t+1} p_{k',t+1} \Upsilon_{t+1} \tilde{S}' \left( \frac{\mu_{z^+,t+1} \mu_{\Psi,t+1} \dot{i}_{t+1}}{\dot{i}_t} \right) \left( \frac{\dot{i}_{t+1}}{\dot{i}_t} \right)^2 \mu_{z^+,t+1} \mu_{\Psi,t+1} = 0 \end{aligned}$$

Entrepreneurs' capital utilization:

$$\bar{r}_t^k = p_t^i [\sigma_b \sigma_a u_t + \sigma_b (1 - \sigma_a)]$$

Non-linear pricing equations for wage setting:

$$F_t^w = \frac{\psi_{z^+,t}}{\lambda_w} (\ddot{w}_t)^{-\frac{\lambda_w}{1-\lambda_w}} h_t \left( \frac{1 - \tau^y}{1 + \tau^w} \right) + \beta \xi_w E_t \left[ \left( \frac{\bar{w}_{t+1}}{\bar{w}_t} \right) \left( \frac{\tilde{\pi}_{t+1}^w}{\pi_{t+1}^w} \right)^{\frac{1}{1-\lambda_w}} F_{t+1}^w \right]$$

$$K_t^w = \zeta_t^h \left( \ddot{w}_t^{-\frac{\lambda_w}{1-\lambda_w}} h_t \right)^{1+\sigma_L} + \beta \xi_w E_t \left[ \left( \frac{\tilde{\pi}_{t+1}^w}{\pi_{t+1}^w} \right)^{\frac{(1+\sigma_L)\lambda_w}{1-\lambda_w}} K_{t+1}^w \right]$$

$$\frac{K_t^w}{F_t^w} = \left[ \frac{1 - \xi_w \left( \frac{\tilde{\pi}_t^w}{\pi_t^w} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right]^{(1-\lambda_w)(1+\sigma_L)}$$

$$\ddot{w}_t = \left[ (1 - \xi_w) \left( \frac{1 - \xi_w \left( \frac{\tilde{\pi}_t^w}{\pi_t^w} \right)^{\frac{1}{1-\lambda_w}}}{1 - \xi_w} \right)^{\lambda_w} + \xi_w \left( \frac{\tilde{\pi}_t^w}{\pi_t^w} \ddot{w}_{t-1} \right)^{\frac{\lambda_w}{1-\lambda_w}} \right]^{\frac{1-\lambda_w}{\lambda_w}}$$

$$\tilde{\pi}_t^w = \pi_t^w (\pi_{t-1}^c)^{\kappa_w} (\bar{\pi}_t^c)^{1-\kappa_w-\varkappa_w} (\bar{\pi})^{\varkappa_w} \mu_{z^+,t}$$

Taylor rules:

$$\log \left( \frac{R_t}{R} \right) = \rho_R \log \left( \frac{R_{t-1}}{R} \right) + (1 - \rho_R) \left[ \log \left( \frac{\bar{\pi}_t^c}{\bar{\pi}^c} \right) + r_\pi \log \left( \frac{\pi_t^c}{\bar{\pi}^c} \right) + r_y \log \left( \frac{gdp_t}{gdp} \right) + r_L \log \left( \frac{B_{t+1}}{B} \right) \right] + \varepsilon_{R,t}$$

$$\log \left( \frac{\zeta_t^{MP}}{\zeta_t^{MP}} \right) = \rho_\zeta \log \left( \frac{\zeta_{t-1}^{MP}}{\zeta_t^{MP}} \right) + (1 - \rho_\zeta) \left[ \log \left( \frac{\bar{\pi}_t^c}{\bar{\pi}_t^c} \right) + \zeta_\pi \log \left( \frac{\pi_t^c}{\bar{\pi}_t^c} \right) + \zeta_y \log \left( \frac{gdp_t}{gdp} \right) + \zeta_L \log \left( \frac{B_{t+1}}{B} \right) \right] + \varepsilon_{\zeta,t}$$

Reserves rate and monetary policy rate relationship:

$$R_t^R = R_t - \Theta_t + \varepsilon_{\Theta,t}$$

Adjusted resource constraint:

$$\begin{aligned} y_t = & \frac{\mu G(\bar{\omega}_t, \sigma_{t-1}) R_t^k p_{k',t-1} \bar{k}_t}{\pi_t \mu_{z+,t}} + dep_t \left[ \psi_1 (\zeta_t^R - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t^R - \zeta_t^{MP})^2 \right] + \\ & + g_t + (1 - \omega_c) (p_t^c)^{\eta_c} c_t + (1 - \omega_i) (p_t^i)^{\eta_i} \left[ i_t + a(u_t) \frac{\bar{k}_t}{\mu_{z+,t} \mu_{\Psi,t}} \right] + \\ & + (1 - \omega_x) (\dot{p}_t^x)^{-\frac{\lambda_x}{\lambda_x-1}} (p_t^x)^{-\eta_f} y_t^* \left[ \omega_x (p_t^{m,x})^{1-\eta_x} + (1 - \omega_x) \right]^{\frac{\eta_x}{1-\eta_x}} \end{aligned}$$

Current account:

$$a_t + q_t p_t^c R_t^{\nu,*} \left[ c_t^m (\dot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} + i_t^m (\dot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} + x_t^m (\dot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \right] = q_t p_t^c p_t^x x_t + R_{t-1}^* \Phi_{t-1} s_t \frac{a_{t-1}}{\pi_t \mu_{z+,t}}$$

Financial market equilibrium:

$$(1 - \zeta_t^R) dep_t = \nu_t^f \bar{w}_t H_t + \nu_t^x (\dot{p}_t^x)^{-\frac{\lambda_x}{\lambda_x-1}} (p_t^x)^{-\eta_f} y_t^* \left[ \omega_x (p_t^{m,x})^{1-\eta_x} + (1 - \omega_x) \right]^{\frac{1}{1-\eta_x}} + p_{k',t} \bar{k}_{t+1} - n_{t+1}$$

Marginal cost of final export goods:

$$mc_t^x = \frac{\tau^x R_t^x}{q_t p_t^c p_t^x} \left[ \omega_x (p_t^{m,x})^{1-\eta_x} + (1 - \omega_x) \right]^{\frac{1}{1-\eta_x}}$$

Marginal cost of consumption importers:

$$mc_t^{m,c} = \tau^{m,c} \frac{q_t p_t^c}{p_t^{m,c}} R_t^{\nu,*}$$

Marginal cost of investment importers:

$$mc_t^{m,i} = \tau^{m,i} \frac{q_t p_t^c}{p_t^{m,i}} R_t^{\nu,*}$$

Marginal cost of export importers:

$$mc_t^{m,x} = \tau^{m,x} \frac{q_t p_t^c}{p_t^{m,x}} R_t^{\nu,*}$$

Real GDP defined from the production side:

$$y_t = (\ddot{p}_t)^{\frac{\lambda_d}{\lambda_d-1}} \left[ \epsilon_t \left( \frac{k_t}{\mu_{\Psi,t} \mu_{z^+,t}} \right)^\alpha H_t^{1-\alpha} - \phi \right]$$

Investment adjustment costs:

$$a(u_t) = 0.5\sigma_b\sigma_a u_t^2 + \sigma_b(1-\sigma_a)u_t + \sigma_b \left[ \frac{\sigma_a}{2} - 1 \right]$$

Definition of  $R^f$  :

$$R_t^f = \nu^f R_t + 1 - \nu^f$$

Definition of  $R^x$  :

$$R_t^x = \nu^x R_t + 1 - \nu^x$$

Definition of  $R^{\nu,*}$  :

$$R_t^{\nu,*} = \nu^* R_t^* + 1 - \nu^*$$

Total foreign export demand:

$$x_t = (p_t^x)^{-\eta_f} y_t^*$$

Relative price of final consumption good:

$$p_t^c = \left[ (1 - \omega_c) + \omega_c (p_t^{m,c})^{1-\eta_c} \right]^{\frac{1}{1-\eta_c}}$$

Relative price of final investment good:

$$p_t^i = \left[ (1 - \omega_i) + \omega_i (p_t^{m,i})^{1-\eta_i} \right]^{\frac{1}{1-\eta_i}}$$

Definition of capital utilization:

$$k_t = u_t \bar{k}_t$$

Dynamics of  $p^{m,x}$  :

$$\frac{p_t^{m,x}}{p_{t-1}^{m,x}} = \frac{\pi_t^{m,x}}{\pi_t}$$

Dynamics of  $p^{m,c}$  :

$$\frac{p_t^{m,c}}{p_{t-1}^{m,c}} = \frac{\pi_t^{m,c}}{\pi_t}$$

Dynamics of  $p^{m,i}$  :

$$\frac{p_t^{m,i}}{p_{t-1}^{m,i}} = \frac{\pi_t^{m,i}}{\pi_t}$$

Dynamics of  $p^x$  :

$$\frac{p_t^x}{p_{t-1}^x} = \frac{\pi_t^x}{\pi_t^*}$$

Dynamics of real exchange rate  $q$  :

$$\frac{q_t}{q_{t-1}} = \frac{s_t \pi_t^*}{\pi_t^c}$$

Investment cost function and its derivative:

$$\tilde{S}(x) = \frac{1}{2} \left\{ \exp \left[ \sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] + \exp \left[ -\sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] - 2 \right\}$$

$$\tilde{S}'(x) = \frac{1}{2} \sqrt{\tilde{S}''} \left\{ \exp \left[ \sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] - \exp \left[ -\sqrt{\tilde{S}''} (x - \mu_z + \mu_\Psi) \right] \right\}$$

Rate of return on capital:

$$R_{t+1}^k = \frac{\pi_{t+1}}{\mu_{\Psi,t}} \left\{ \frac{(1 - \tau^k) [u_{t+1} \bar{r}_{t+1}^k - p_{t+1}^i a(u_{t+1})] + (1 - \delta) p_{k',t+1} + \tau^k \delta \frac{\mu_{\Psi,t+1}}{\pi_{t+1}} p_{k',t}}{p_{k',t}} \right\}$$

Relationship between  $h$  and  $H$  :

$$h_t = (\ddot{w}_t)^{\frac{\lambda_w}{1-\lambda_w}} H_t$$

Imported consumption:



$$c_t^m = \omega_c \left( \frac{p_t^c}{p_t^{m,c}} \right)^{\eta_c} c_t$$

Imported investment:

$$i_t^m = \omega_i \left( \frac{p_t^i}{p_t^{m,i}} \right)^{\eta_i} \left[ i_t + a(u_t) \frac{\bar{k}_t}{\mu_{\Psi,t} \mu_{z^+,t}} \right]$$

Imported export inputs:

$$x_t^m = \omega_x \left[ \frac{\left[ (1 - \omega_x) + \omega_x (p_t^{m,x})^{1-\eta_x} \right]^{\frac{1}{1-\eta_x}}}{p_t^{m,x}} \right]^{\eta_x} (\ddot{p}_t^x)^{-\frac{\lambda_x}{\lambda_x-1}} (p_t^x)^{-\eta_f} y_t^*$$

Wage inflation:

$$\pi_{t+1}^w = \frac{\bar{w}_{t+1} \mu_{z^+,t+1} \pi_{t+1}}{\bar{w}_t}$$

### ***Law of Motion for Exogenous Processes***

Composite technology growth:

$$\mu_{z^+,t} = \mu_{\Psi,t}^{\frac{\alpha}{1-\alpha}} \mu_{z,t}$$

Tax-like shocks:

$$\log \tau_t^d - \log \tau^d = \rho_{\tau^d} (\log \tau_{t-1}^d - \log \tau^d) + \varepsilon_{\tau^d,t}$$

$$\log \tau_t^x - \log \tau^x = \rho_{\tau^x} (\log \tau_{t-1}^x - \log \tau^x) + \varepsilon_{\tau^x,t}$$

$$\log \tau_t^{m,c} - \log \tau^{m,c} = \rho_{\tau^{m,c}} (\log \tau_{t-1}^{m,c} - \log \tau^{m,c}) + \varepsilon_{\tau^{m,c},t}$$

$$\log \tau_t^{m,i} - \log \tau^{m,i} = \rho_{\tau^{m,i}} (\log \tau_{t-1}^{m,i} - \log \tau^{m,i}) + \varepsilon_{\tau^{m,i},t}$$

$$\log \tau_t^{m,x} - \log \tau^{m,x} = \rho_{\tau^{m,x}} (\log \tau_{t-1}^{m,x} - \log \tau^{m,x}) + \varepsilon_{\tau^{m,x},t}$$

Stationary neutral technology shock:

$$\log \epsilon_t = (1 - \rho_\epsilon) \log \epsilon + \rho_\epsilon \log \epsilon_{t-1} + \varepsilon_{\epsilon,t}$$

Marginal efficiency of investment shock:

$$\log \Upsilon_t = (1 - \rho_\Upsilon) \log \Upsilon + \rho_\Upsilon \log \Upsilon_{t-1} + \varepsilon_{\Upsilon,t}$$

Preferences shocks:

$$\log \zeta_t^c = (1 - \rho_{\zeta^c}) \log \zeta^c + \rho_{\zeta^c} \log \zeta_{t-1}^c + \varepsilon_{\zeta^c,t}$$

$$\log \zeta_t^h = (1 - \rho_{\zeta^h}) \log \zeta^h + \rho_{\zeta^h} \log \zeta_{t-1}^h + \varepsilon_{\zeta^h,t}$$

Unit root technology shocks:

$$\log \mu_{\Psi,t} = (1 - \rho_{\mu_\Psi}) \log \mu_\Psi + \rho_{\mu_\Psi} \log \mu_{\Psi,t-1} + \varepsilon_{\mu_\Psi,t}$$

$$\log \mu_{z,t} = (1 - \rho_{\mu_z}) \log \mu_z + \rho_{\mu_z} \log \mu_{z,t-1} + \varepsilon_{\mu_z,t}$$

Fiscal shocks:

$$\log \tau_t^y = (1 - \rho_{\tau^y}) \log \tau^y + \rho_{\tau^y} \log \tau_{t-1}^y + \varepsilon_{\tau^y,t}$$

$$\log g_t = (1 - \rho_g) \log (\eta_g y) + \rho_g \log g_{t-1} + \varepsilon_{g,t}$$

Risk shock:

$$\tilde{\phi}_t = (1 - \rho_{\tilde{\phi}}) \tilde{\phi} + \rho_{\tilde{\phi}} \tilde{\phi}_{t-1} + \varepsilon_{\tilde{\phi},t}$$

Inflation target shock:

$$\log \bar{\pi}_t^c = (1 - \rho_\pi) \log \bar{\pi}^c + \rho_\pi \log \bar{\pi}_{t-1}^c + \varepsilon_{\bar{\pi}^c,t}$$

Financial frictions shocks:

$$\log \sigma_t = (1 - \rho_\sigma) \log \sigma + \rho_\sigma \log \sigma_{t-1} + \varepsilon_{\sigma,t}$$

$$\log \gamma_t = (1 - \rho_\gamma) \log \gamma + \rho_\gamma \log \gamma_{t-1} + \varepsilon_{\gamma,t}$$

Foreign VAR:

$$\log y_t^* - \log y^* = a_{11} (\log y_{t-1}^* - \log y^*) + a_{12} (\pi_{t-1}^* - \pi^*) + a_{13} (R_{t-1}^* - R^*) + \sigma_{y^*} \varepsilon_{y^*,t}$$

$$\begin{aligned} \pi_t^* - \pi^* &= a_{21} (\log y_{t-1}^* - \log y^*) + a_{22} (\pi_{t-1}^* - \pi^*) + a_{23} (R_{t-1}^* - R^*) + \\ &+ a_{24} \frac{\alpha}{1-\alpha} (\log \mu_{\Psi,t-1} - \log \mu_{\Psi}) + c_{21} \varepsilon_{y^*,t} + \sigma_{\pi^*} \varepsilon_{\pi^*,t} + c_{24} \varepsilon_{\mu_{z,t}} + c_{24} \frac{\alpha}{1-\alpha} \varepsilon_{\mu_{\Psi},t} \end{aligned}$$

$$\begin{aligned} R_t^* - R^* &= a_{31} (\log y_{t-1}^* - \log y^*) + a_{32} (\pi_{t-1}^* - \pi^*) + a_{33} (R_{t-1}^* - R^*) + \\ &+ a_{34} \frac{\alpha}{1-\alpha} (\log \mu_{\Psi,t-1} - \log \mu_{\Psi}) + c_{31} \varepsilon_{y^*,t} + c_{32} \varepsilon_{\pi^*,t} + \sigma_{R^*} \varepsilon_{R^*,t} + c_{34} \varepsilon_{\mu_{z,t}} + c_{34} \frac{\alpha}{1-\alpha} \varepsilon_{\mu_{\Psi},t} \end{aligned}$$

### ***Measurement Equations Linking Data and Model Variables***

$$\pi_t^{d,data} = 400 \log \pi_t + \varepsilon_{\pi,t}^{me}$$

$$\pi_t^{i,data} = 400 \log \pi_t^i + \varepsilon_{\pi^i,t}^{me}$$

$$\pi_t^{c,data} = 400 \log \pi_t^c + \varepsilon_{\pi^c,t}^{me}$$

$$R_t^{data} = 400 \log (R_t - 1)$$

$$R_t^{d,data} = 400 \log (R_t^d - 1)$$

$$R_t^{R,data} = 400 \log (R_t^R - 1)$$

$$\pi_t^{*,data} = 400 \log \pi_t^*$$

$$R_t^{*,data} = 400 \log (R_t^* - 1)$$

$$\Delta \log Y_t^{*,data} = 100 (\log \mu_{z^+,t} + \Delta \log y_t^*) - 100 \log \mu_{z^+}$$

$$\Delta \log H_t^{data} = 100 \log \left( \frac{h_t}{h_{t-1}} \right) + \varepsilon_{H,t}^{me}$$

$$\Delta \log q_t^{data} = 100 \Delta \log q_t + \varepsilon_{q,t}^{me}$$

$$\Delta \log C_t^{data} = 100 (\log \mu_{z^+,t} + \Delta \log c_t) - 100 \log \mu_{z^+}$$

$$\Delta \log Y_t^{data} = 100 [\log \mu_{z^+,t} + \Delta \log gdp_t] - 100 \log \mu_{z^+} + \varepsilon_{y,t}^{me}$$

$$\Delta \log I_t^{data} = 100 (\log \mu_{z^+,t} + \log \mu_{\Psi,t} + \log i_t - \log i_{t-1}) - 100 (\log \mu_{z^+} + \log \mu_{\Psi}) + \varepsilon_{i,t}^{me}$$

$$\Delta \log W_t^{data} = 100 (\log \mu_{z^+,t} + \Delta \log \bar{w}_t) - 100 \log \mu_{z^+} + \varepsilon_{w,t}^{me}$$

$$\Delta \log X_t^{data} = 100 (\log \mu_{z^+,t} + \Delta \log x_t) - 100 \log \mu_{z^+} + \varepsilon_{x,t}^{me}$$

$$\Delta \log M_t^{data} = 100 \left\{ \log \mu_{z^+,t} + \log \left[ \frac{c_t^m (\dot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} + i_t^m (\dot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} + x_t^m (\dot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}}}{c_{t-1}^m (\dot{p}_{t-1}^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} + i_{t-1}^m (\dot{p}_{t-1}^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} + x_{t-1}^m (\dot{p}_{t-1}^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}}} \right] \right\} - 100 \log \mu_{z^+} + \varepsilon_{m,t}^{me}$$

$$\Delta \log N_t^{data} = 100 (\log \mu_{z^+,t} + \Delta \log n_t) - 100 \log \mu_{z^+} + \varepsilon_{N,t}^{me}$$

$$\Delta \log Spread_t^{data} = 100 \Delta \log Spread_t + \varepsilon_{spread,t}^{me}$$

$$Spread_t^{data} = 400 spread_t + \varepsilon_{spread,t}^{me}$$

$$spread_t = \frac{\bar{\omega}_{t+1} R_{t+1}^k}{1 - \frac{n_{t+1}}{p_{k',t} k_{t+1}}} - R_t^d$$

$$\Delta \log G_t^{data} = 100 (\log \mu_{z^+,t} + \Delta \log g_t) - 100 \log \mu_{z^+} + \varepsilon_{g,t}^{me}$$

$$\hat{H}_t^{data} = 100 \left( \frac{h_t - h}{h} \right) + \varepsilon_{\hat{H},t}^{me}$$

$$bankruptcyrate_t = F(\bar{\omega}_{t+1}, \sigma_t)$$

$$s_t = \frac{Slev_t}{Slev_{t-1}}$$

$$\begin{aligned} gdp_t &= y_t - \frac{\mu G(\bar{\omega}_t, \sigma_{t-1}) R_t^k p_{k',t-1} \bar{k}_t}{\pi_t \mu_{z^+,t}} - dept \left[ \psi_1 (\zeta_t^R - \zeta_t^{MP}) + \frac{\psi_2}{2} (\zeta_t^R - \zeta_t^{MP})^2 \right] - \\ &- (1 - \omega_i) (p_t^i)^{\eta_i} a(u_t) \frac{\bar{k}_t}{\mu_{\Psi,t} \mu_{z^+,t}} \end{aligned}$$

$$\left( \frac{nx}{y} \right)_t = \frac{1}{y_t} \left\{ q_t p_t^c p_t^x x_t - \left[ q_t p_t^c R_t^{\nu,*} \left( c_t^m (\dot{p}_t^{m,c})^{\frac{\lambda_{m,c}}{1-\lambda_{m,c}}} + i_t^m (\dot{p}_t^{m,i})^{\frac{\lambda_{m,i}}{1-\lambda_{m,i}}} + x_t^m (\dot{p}_t^{m,x})^{\frac{\lambda_{m,x}}{1-\lambda_{m,x}}} \right) \right] \right\}$$

$$\begin{aligned} \Delta gdp_t^{12q} &= 1200 \log \mu_{z^+,t} + \Delta \log Y_t^{data} + \Delta \log Y_{t-1}^{data} + \Delta \log Y_{t-2}^{data} + \Delta \log Y_{t-3}^{data} + \Delta \log Y_{t-4}^{data} + \\ &+ \Delta \log Y_{t-5}^{data} + \Delta \log Y_{t-6}^{data} + \Delta \log Y_{t-7}^{data} + \Delta \log Y_{t-8}^{data} + \Delta \log Y_{t-9}^{data} + \Delta \log Y_{t-10}^{data} + \\ &+ \Delta \log Y_{t-11}^{data} \end{aligned}$$

$$\Delta gdp_t^{4q} = 1200 \log \mu_{z^+,t} + \Delta \log Y_t^{data} + \Delta \log Y_{t-1}^{data} + \Delta \log Y_{t-2}^{data} + \Delta \log Y_{t-3}^{data}$$

$$\pi_t^{c,4q} = \frac{\pi_t^{c,data} + \pi_{t-1}^{c,data} + \pi_{t-2}^{c,data} + \pi_{t-3}^{c,data}}{4}$$

## Appendix D

Our model estimates its structural parameters using (among others) four foreign sector-related variables: real effective exchange rate and foreign output, inflation and interest rate. Since the Uruguayan economy exhibits a high level of dependence on the rest of the world and the external sector plays an important role in our model, we explain the construction of these variables with more detail.

In order to build the real effective exchange rate, foreign output and foreign inflation series, we use a weighted average approach that takes into account data from the nine most relevant Uruguayan commercial partners, according to the information available at the Central Bank of Uruguay's website. The countries included in this calculations are (sorted in order of relevance): Brazil, Argentina, United States, China, Germany, Mexico, Spain, Italy and the United Kingdom. To compute these series we employ a moving weights system that allows us to take into account changes in relative importance of commercial partners over time. Unless particularly specified, all data series were obtained from the International Financial Statistics dataset (International Monetary Fund).

### *Real Exchange Rate*

We compute the real effective exchange rate index for the Uruguayan economy using the following expression:

$$REER_t = \sum_{i=1}^9 \omega_{i,t} BRRER_{i,t}$$

where  $BRRER_{i,t}$  is the bilateral real exchange rate between Uruguay and country  $i$  at time  $t$ , and  $\omega_{i,t}$  represents the normalized (taking into account the nine commercial partners mentioned above) share of total commerce between Uruguay and country  $i$  at time  $t$ :

$$\omega_{i,t} = \frac{X_{i,t} + M_{i,t}}{\sum_{i=1}^9 [X_{i,t} + M_{i,t}]}$$

where  $X_{i,t}$  and  $M_{i,t}$  represent exports from Uruguay to country  $i$  and imports from country  $i$ , respectively.

The bilateral real exchange rate between Uruguay and country  $i$  is computed following standard practices:

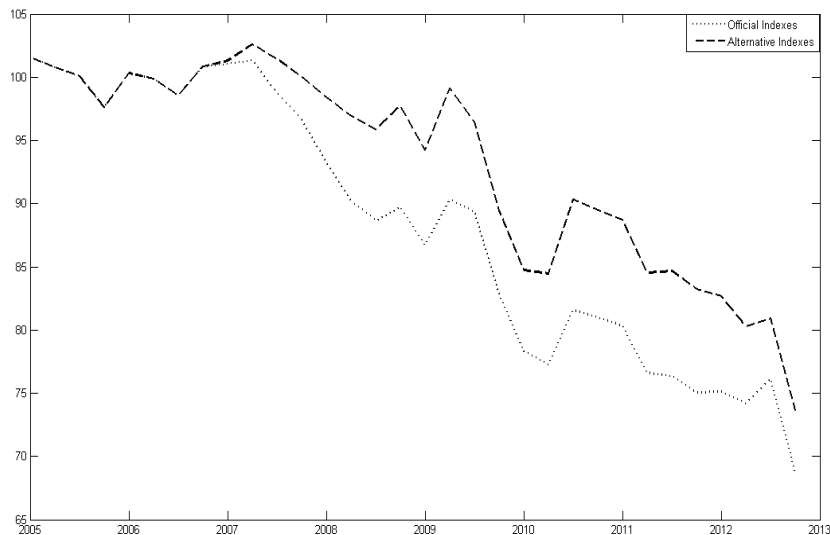
$$BRRER_{i,t} = \left( \frac{NERI_{U,t}}{NERI_{i,t}} \right) \left( \frac{CPI_{i,t}}{CPI_{U,t}} \right)$$

where  $NERI_{U,t}$  is the nominal exchange rate index for Uruguay at time  $t$ ,  $NERI_{i,t}$  is the nominal exchange rate index for country  $i$  at time  $t$ ,  $CPI_{i,t}$  is the consumer price index for country  $i$  at time

$t$  and  $CPI_{U,t}$  is the consumer price index for Uruguay at time  $t$ . All nominal exchange rate indexes are expressed on a 2005 basis and each of them represents the evolution of country  $i$ 's currency with respect to the US dollar (number of country  $i$ 's currency units needed to buy one dollar).

The bilateral real exchange rate index between Uruguay and Argentina deserves particular attention. The Central Bank of Uruguay computes this index using Argentina's official consumer price index and nominal exchange rate. However, researchers and public authorities in Argentina have cast doubts on the accuracy of these series since January of 2007 and January of 2011, respectively. In order to overcome this problem, we choose to employ a different series for the CPI and the nominal exchange rate between the Argentinian peso and the US dollar. The Argentinian CPI index, based on the authors' calculations, and is available upon request. The nominal exchange rate index relies on data provided by the website *www.dolarblue.net*, which reports the value of a dollar in terms of Argentinian pesos for those who cannot buy the foreign currency on the official circuit due to the strict legal restrictions imposed by the Argentinian government. The impact of these changes on the real effective exchange rate index for Uruguay can be seen in the following figure:

**Figure 16. Real Effective Exchange Rate**



Source: Authors' calculations.

Although both series reflects an important appreciation of the Uruguayan currency, the latter is less intense when using the alternative indexes suggested in the previous paragraph for the Argentinian economy.

### *Foreign Inflation*

This series represents the weighted average of inflation rates recorded in the nine countries referred before. Once again, for Argentina we use an alternative index for CPI inflation. As previously described, weights are computed taking into account the relative importance of each country in terms of trade and its changes across time. Thus, annualized foreign inflation is computed according to the following formula:

$$\Pi_t^* = \sum_{i=1}^9 \omega_{i,t} \Pi_{i,t}$$

where  $\Pi_{i,t} = 400 * \log \frac{CPI_{i,t}}{CPI_{i,t-1}}$ .

### *Foreign Output*

This series is obtained through the sum of the GDP of the nine countries mentioned above. As a result, foreign output is computed according to the following formula:

$$Y_t^* = \sum_{i=1}^9 Y_{i,t}$$

where  $Y_{i,t}$  represents country  $i$ 's GDP in constant 2005 dollars.

### *Foreign Interest Rate*

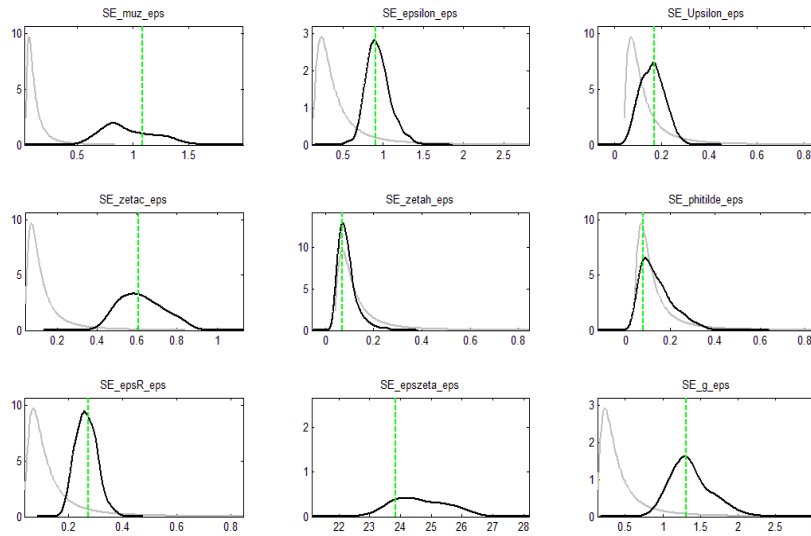
The foreign interest rate in our model represents a risk-free rate that is subject to a shock. Since we are talking about a risk-free interest rate and our time unit is a quarter, the data for the foreign interest rate correspond to the three-month US dollar LIBOR rate, obtained from the British Banking Association website.



# Appendix E

## Priors and Posteriors Distributions

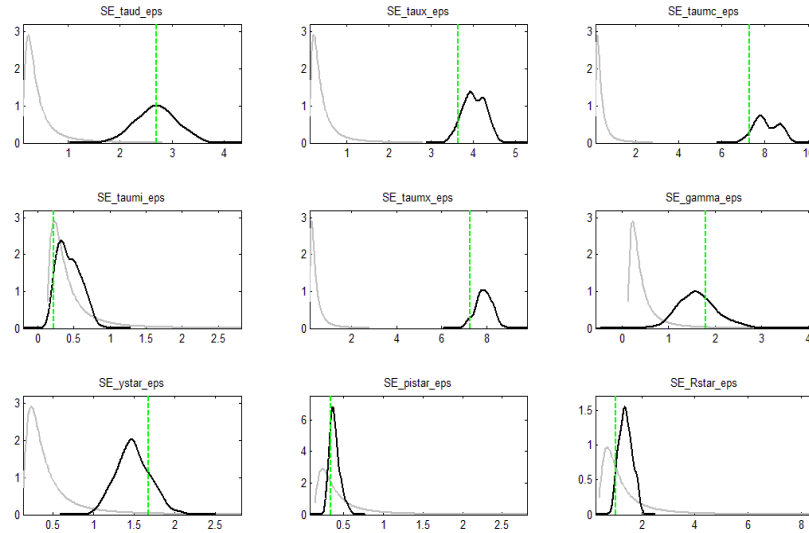
Figure 17. Posteriors Distributions of the Estimated Parameters



Source: Authors' calculations.

Note: SE stands for standard errors of the shock standard deviations. The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

**Figure 18. Posteriors Distributions of the Estimated Parameters**



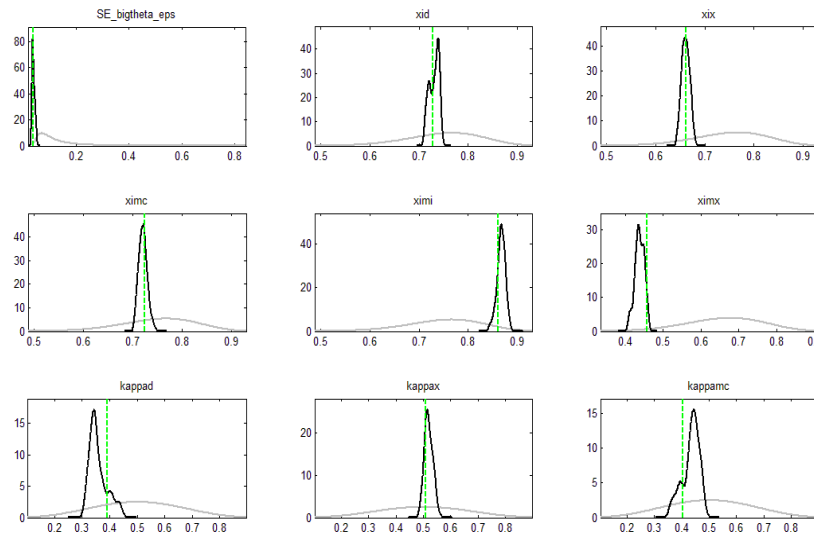
*Source:* Authors' calculations.

*Note:* SE stands for standard errors of the shock standard deviations. The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

## Appendix F

### *Impulse Response Functions*

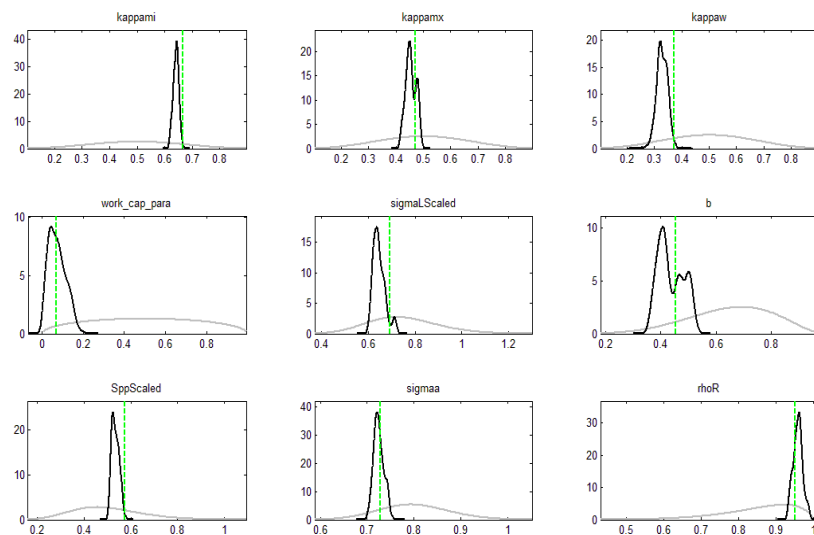
**Figure 19. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* SE stands for standard errors of the shock standard deviations. The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

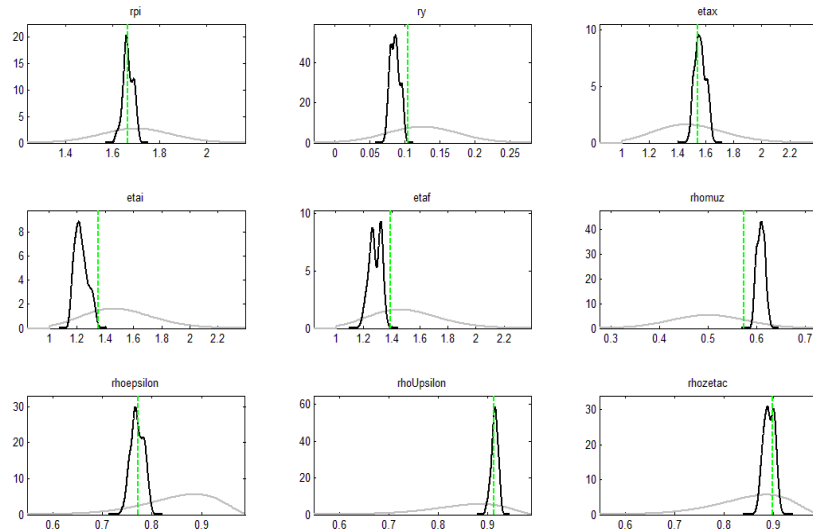
**Figure 20. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

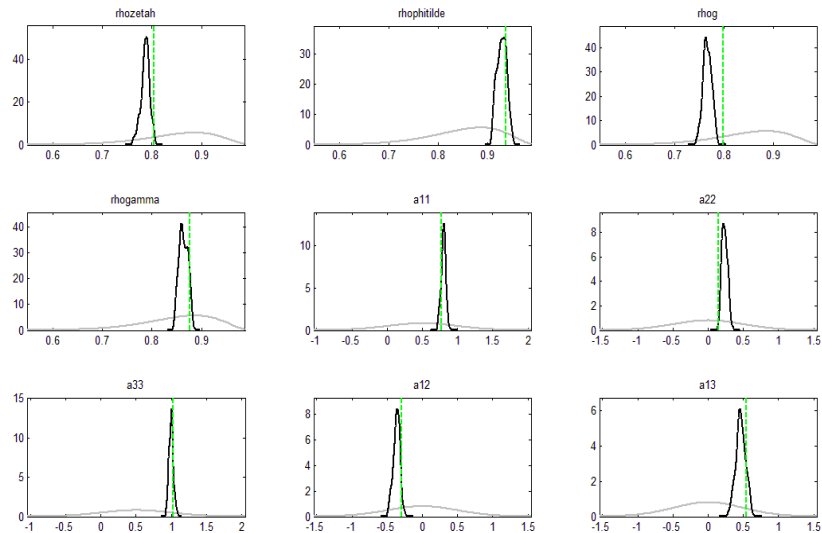
**Figure 21. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

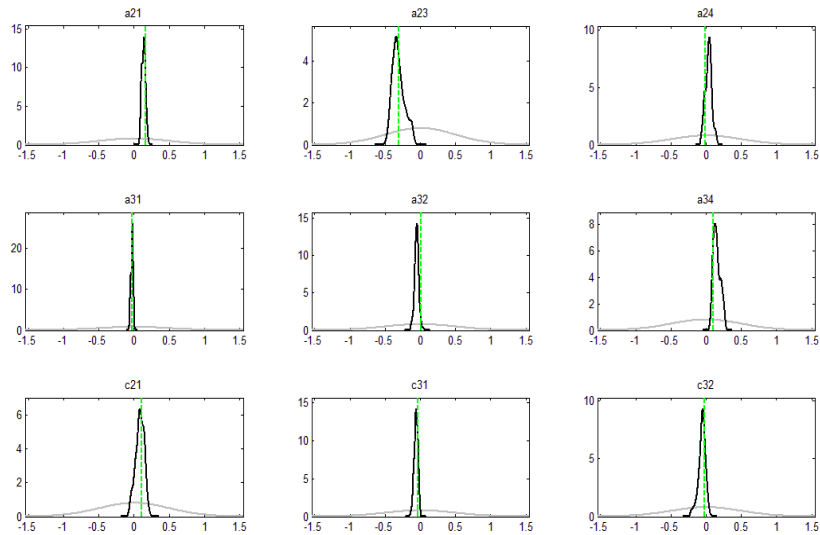
**Figure 22. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

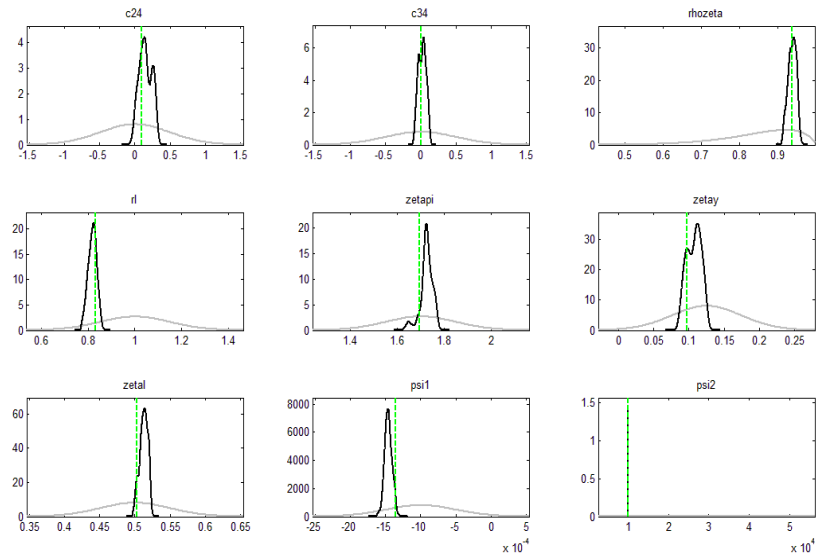
**Figure 23. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

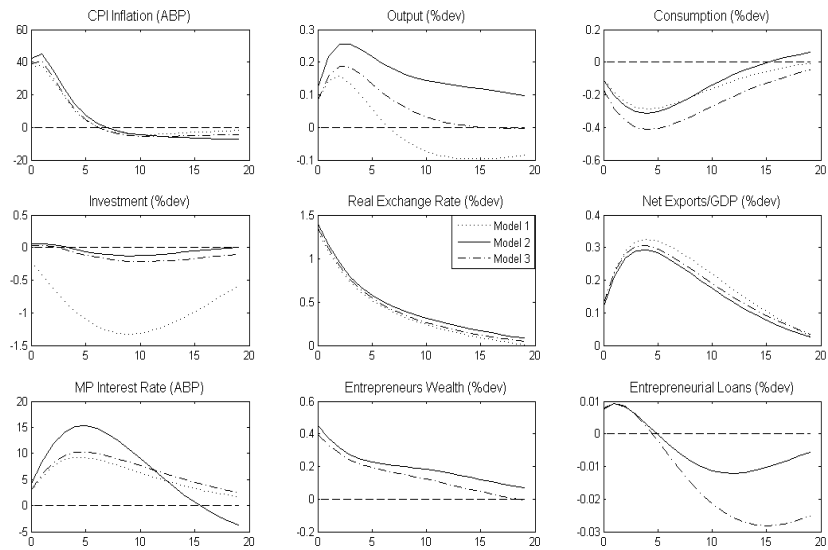
**Figure 24. Posteriors Distributions of the Estimated Parameters**



*Source:* Authors' calculations.

*Note:* The gray line represents the prior distribution and the black line shows the posterior distribution. The green line is the posterior mean.

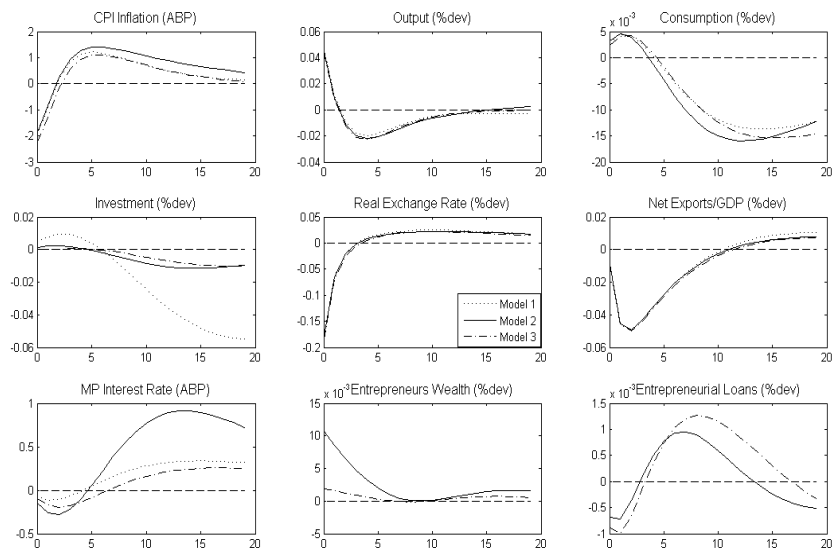
**Figure 25. Risk Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

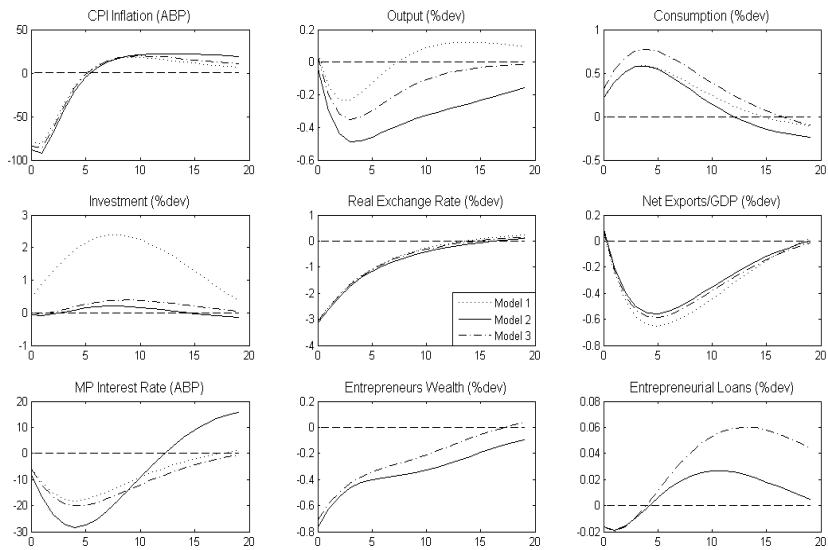
**Figure 26. Foreign Inflation Rate Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

**Figure 27. Foreign Output Shock  
IRF for Models 1, 2 and 3**

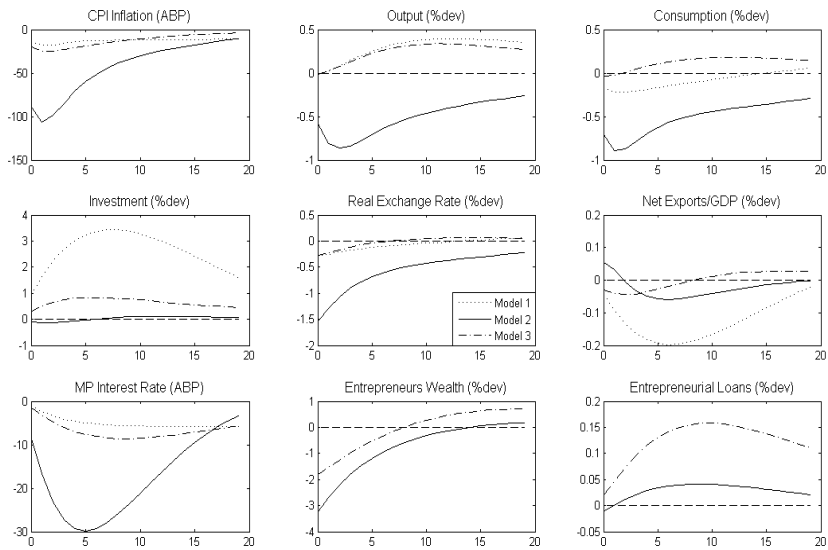


*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).



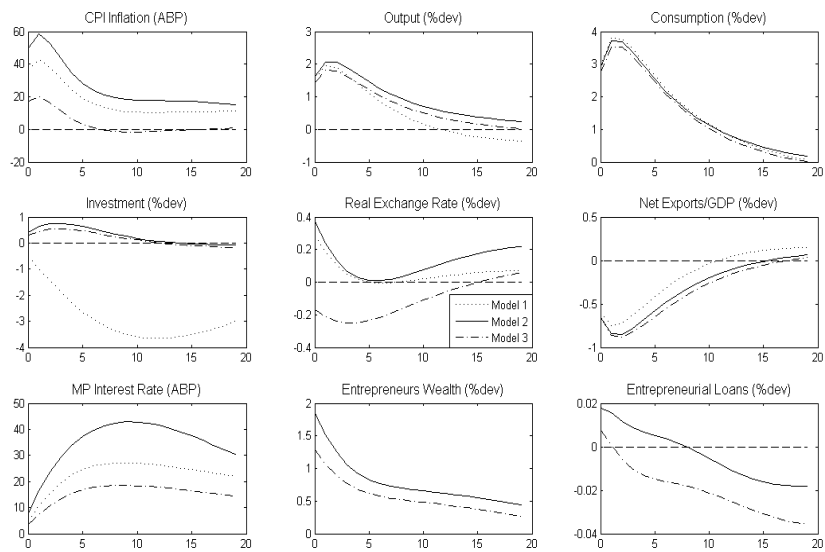
**Figure 28. Investment Specific Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

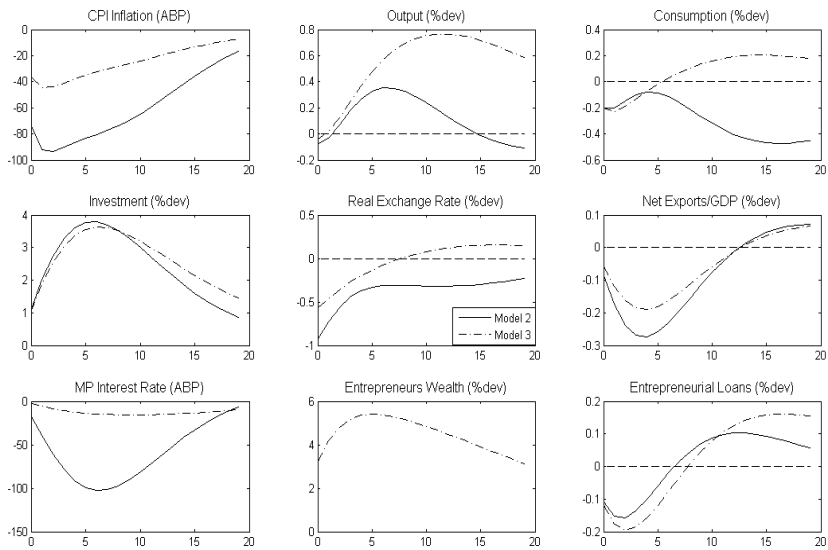
**Figure 29. Consumption Preference Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

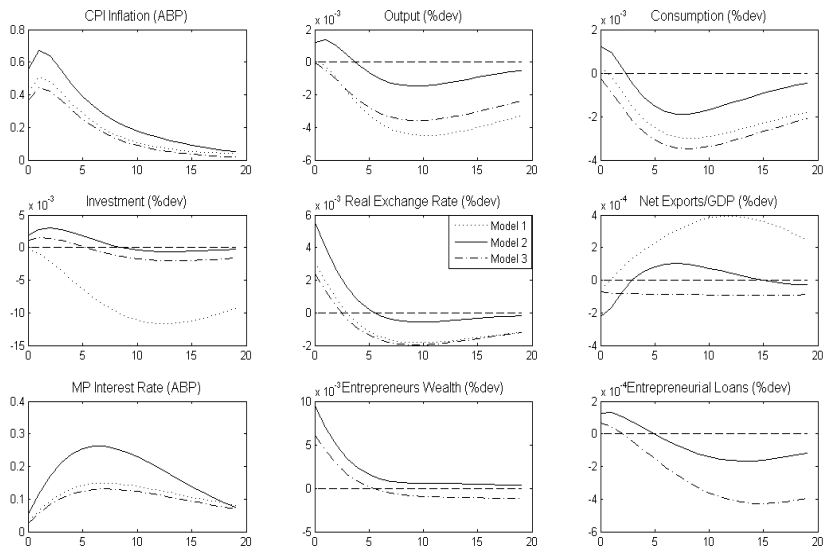
**Figure 30. Survival Rate of Entrepreneurs Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).

**Figure 31. Labor Preference Shock  
IRF for Models 1, 2 and 3**



*Source:* Authors' calculations.

*Note:* The units on the y-axis are either in terms of percentage deviation (% dev.) from steady state, or annualized basis points (ABP).